MURRAY-DARLING BASIN COMMISSION

Project M305: Task 6

Land Use Mapping Requirements for Natural Resource Management in the Murray-Darling Basin

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EXECUTIVE SUMMARY

Ecologically sustainable development requires the management of natural resources from an informed position. Information on the nature, extent, trends and effects of land-use is essential for rational planning and management of natural resources by contributing to the development of sustainable land-use systems, better deployment of resources to support key activities or selection of alternate land-uses better suited to various types of land.

Planning and management have numerous other considerations such as economic sustainability and the social consequences of land-use or land-use change. However, there first is a requirement to establish the baseline information on the state of the natural resources.

With Natural Resources Management Strategy support the BASINCARE project is assembling a digital vegetation data set at a Basin-wide resolution of 1:100 000. This report investigates the mapping requirements for producing complementary information on land-use.

The basic approach of the investigation is to define the land-use mapping needs of a broad range of natural resource managers throughout the Basin. This information is fundamental to the needs of other groups, *eg.* planners, community, and local governments, for their further development.

Key natural resource managers from each state were assembled at a series of workshops where each of their major planning and management programs was examined, and information requirements assessed. The common factor that emerged was the necessity for information on land-use management regimes rather than merely the end product of land-use, *ie.* information on the *How* of land-use; the nature of cultivation practices, logging techniques, fertiliser application, etc., rather than simply the type and amounts of commodity produced. It is at this level of management that changes in, or modification of, land-use practices can be effected.

The approach to land-use mapping developed was based on the concept of 'Level of Intervention', with land-use classes being structured in terms of their degree of modification and potential impact on a putative 'natural state' (defined as essentially unmodified native vegetation cover).

A review of existing land-use classification schemas indicated their inappropriateness to the 'level of intervention' approach and so a new classification schema was developed and is presented in Chapter 5.

This classification schema was developed in accordance with user needs and without reference to any particular mapping methodology. Chapter 6 develops the practicalities of mapping the Basin in accordance with the classes expressed in the classification schema. Given the enormity of the undertaking from a spatial and logistic perspective combined with the limitations of the currently available technologies a mapping methodology based on the visual interpretation of Landsat TM was found to be most appropriate. While adequate in terms of spatial resolution, at the proposed mapping scale of 1:1 00 000, and discrimination of the

broader land-use types, TM imagery alone does not have the capacity to define all of the classes of the classification schema. Visual interpretation and labelling by local managers is the key.

Techniques for direct examination of digital satellite data and supporting GIS based information, in the field or regional office, have been developed and costs compared to more conventional techniques.

Using a combination of satellite remote sensing techniques and visual interpretation, completion of a Land-use data set for the Murray-Darling Basin to a level of detail equivalent to at least the secondary class level presented in this report is estimated to cost in the order of $1.5 million to $2.0 million.

RECOMMENDATIONS:

1. That the proposed Land-use classification, principles and structure (pending review) be adopted as the standard framework for collection and assembly of Land-use information in the Murray-Darling Basin.

2. That the Commission endorse in principle and subject to a detailed project specification, a program of Land-use mapping for the Murray-Darling Basin based on the visual interpretation of 1995 Landsat TM data, supplemented where necessary by higher resolution data types or derived attribute data.

3. That one or more pilot projects be instigated to test the relative accuracies of the mapping methods proposed and to more tightly define the project costs and methods. In particular, the practicality of field based computer mapping techniques based on TerraScan and ArcView style software packages should be assessed.

4. That Woody/Non-woody vegetation cover mapping projected for 1996 be combined with the land-use mapping program.

5. That an inventory of relevant GIS boundary data be compiled.

6. That an Inter-agency Reference Group be established to facilitate the use and further development of the land use classification.

7. The proposed schema be forwarded to ANZLIC for review before finalisation of its Draft National Land Use Codes.

LAND-USE MAPPING REQUIREMENTS FOR NATURAL RESOURCE MANAGEMENT IN THE MURRAY-DARLING BASIN

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Many thanks are also due to the participants of the workshops held in each state for their attendance, discussion and contributions to the content and structure of the resulting Land-use classification. It was particularly gratifying to witness the high level of co-operation between agencies, which often have competing management information needs, in the development of a rather different approach to Land-use mapping.

Finally, we extend our gratitude to the numerous reviewers of various draft versions of this report. We appreciate your considerable commitment of time to these reviews and value your comments, which we have attempted to incorporate. Many comments have been incorporated *en toto*; some have been modified; and some, we have taken the liberty of passing over because we disagreed with them. However, it is these latter comments that have provided the basis on which the proposed classification could be tested at this stage of its development -- these comments are no less important as the other comments.

CHAPTER ONE

OVERVIEW

1.1 THE MURRAY-DARLING BASIN

The Murray-Darling Basin covers one seventh of the area of Australia. It hosts a range of significant natural resources, the economic value of which accounts for about one third of the national output from rural industries. It is vital to Australia's balance of trade and to the existence of almost 3 million people who depend directly on its natural resources.

For decades, attention has focussed on the River Murray and its salinity problems. It is now obvious that major problems extend throughout the basin, including degradation of the land, the natural environment and the human cultural environment. In 1987, it was estimated that losses to agriculture alone amounted to $260 million per year, and costs due to river salinity $35 million per year (Murray-Darling Basin Ministerial Council 1990).

There is now widespread recognition of the need for land-use planning and natural resource management to address land degradation issues on a 'process' basis by developing and implementing management programs with due regard to the process of land degradation, rather than just dealing with the consequences. The formation of the Murray-Darling Basin Ministerial Council (bringing together the key natural resource management Ministers from the contracting governments) and the Murray-Darling Basin Commission (bringing together the heads of the key natural resource management agencies from each of the contracting governments) represents recognition that many of the resource management problems cross state boundaries and that rational resource management requires co-ordinated action by two or more states.

1.2 ROLE OF THE MURRAY-DARLING BASIN COMMISSION

The Murray-Darling Basin Ministerial Council was established in 1985 to provide a strategic focus for planning and management for the ecologically sustainable use of the Basin's natural resources. The Council is concerned with policy issues requiring common action by member Governments - Commonwealth, New South Wales, Victoria and South Australia, and more recently, Queensland.

The charter of the Council is:

> *to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the land, water and environmental resources of the Murray-Darling Basin.*

The Murray-Darling Basin Commission is composed of the heads of natural resource management agencies of each of the contracting governments. It was established to provide a focus for the consideration of cooperative planning and management strategies for the sustainable use and management of the basin's resources. The objectives of the Commission's natural resource management programs are:

> *to develop a detailed understanding of the long-term impact of changes in land and water use in the Basin, and the processes involved;*
>
> *to provide timely, relevant and expert advice to the Ministerial Council and contracting governments on the short, medium and long-term options for sustainable management of the land and water resources of the Basin;*
>
> *to provide full community consultation and participation in both the development and implementation of the Strategy.*

1.3 THE NATURAL RESOURCES MANAGEMENT STRATEGY

In 1987, the Ministerial Council published a major study that detailed the status of the environmental resources of the Basin. This Environmental Resources Study became the base document for the Natural Resources Management Strategy (Murray-Darling Basin Ministerial Council 1990).

This Strategy provides a framework for coordinated effort across the Basin to halt degradation and to better manage the resources of the Basin.

Problems identified:

Some of the most serious Community concerns noted in the Environmental Resources study relate to:

- rising salinity level in soils and streams;
- deteriorating quality of water supplies;
- land degradation (*eg.* soil erosion and acidification);
- decline and loss of native vegetation;
- loss of natural habitats;
- over commitment of, and competing demands for, water supplies (*eg.* irrigation, industrial and recreational);
- cultural losses (*eg.* Aboriginal heritage sites).

Strategic Aims:

The aims of the Strategy are to:

- prevent further degradation of natural resources;
- restore degraded resources;

- promote sustainable land use practices;
- ensure appropriate resource use planning and management;
- ensure a long term viable economic future for Basin dependants;
- minimise adverse effects of resource use;
- ensure self-maintaining populations of native species;
- preserve cultural heritage;
- conserve recreation values;
- ensure Community and Government cooperation.

The Strategy recognises that information is essential to rational planning and resource management, and makes provision for the funding of knowledge-based activities as well as actual works. One of the priorities identified was the assembly of land-use and condition information for manipulation and use by the Commission and contracting governments.

1.4 THE NEED FOR A LAND-USE DATASET

Ecologically Sustainable Development requires the management our natural resources from an informed position. Knowledge contributes to improvements in management of the resources of the basin through improvements in the development of sustainable land use systems, better deployment of resources to support key activities, or simply the selection of management practices which are appropriate for the various types of land.

There is confusion between the terms land-use and land-cover. Land-use is defined as the economic and cultural activities at a specified place. Land-use is cultural. Land-cover is the material environment. The confusion arises because certain land-uses seem to have characteristic land-covers. Nevertheless, Land-cover does not equal land-use.

Graetz, Fisher and Wilson (1992) make a strong case for understanding of the physical nature, extent and trend of 'Land-cover' as a central component of improved 'Land-use' or management of the continent. Their thesis is:

- Land-cover supports all terrestrial life by providing food and shelter

- Land-cover is the surface that mediates the exchanges of energy and matter between the Earth's crust, the lithosphere, and the overlying atmosphere, including the Sun. In this interface, there is the biosphere – the thin layer of living organisms of which the land-cover is the terrestrial component. The components of this surface, of land-cover, are most commonly vegetation and soil, and much less commonly, the water of wetlands.

- Land-cover, because it is living influences the exchanges of energy and matter between the lithosphere and the atmosphere. These exchanges of energy and mass are more familiarly known as the Hydrologic Cycle, the Carbon Cycle, and the Nitrogen Cycle. Together this flow of energy to and from space and the cycling of elements comprises the Climate System and the Biogeochemical Cycles.

- **any change in Land-cover will have consequences for living organisms. These consequences can be either benign or detrimental and be influential in the short or long term** *(emphasis added)*.

Modern approaches to resource management now take a strongly integrated approach by examining the processes involved in the deliberate or inadvertent modification of the environment, and designing management to minimise or obviate adverse impacts or to maximise productive aspects within a framework of ecological sustainability. Ignoring the processes risks ineffective application of resources and degradation of the land and water resource.

Most human land-use activities have implications for Land-cover, either by harvesting it directly to support human needs (food, fibre or fuel), by its removal to support other activities (*eg.* removal of forest for pasture development; inundation by dams), or its inadvertent removal or debilitation (recreational pressure). Informed management of land and water resources demands consideration of the impacts of such activities on the whole system – of Integrated Catchment Management. Land-use information provides much of the *Why?* of changes in land-cover.

Clearly, knowledge of the nature, distribution, extent and trends in land-use and management is integral to adopting a systems approach to environmental planning and resource management in the Murray-Darling Basin.

However, land-use is only one part of the information needs in developing and implementing natural resource management programs. Information on the nature and capabilities of the land and on the condition (including trend in condition) is also required. This has been recognised in the Natural Resource Management Strategy, which through the Murray-Darling Basin Commission, is supporting the assembly of a vegetation dataset (Project M305 Basincare) for the whole of the Basin. The output of the project is a digital data set of land cover types. While closely allied to land-use, this is not land-use information. It is only when the two data sets are drawn together that comprehensive statements may be made regarding the causation of changes to land cover. These datasets are complementary in determining which land-uses are sustainable for the many land cover types across the Basin.

CHAPTER TWO

PROJECT M305: BASINCARE

2.1 VEGETATION AND LAND USE MAPPING -- BASINCARE

NRMS project M305 BASINCARE aims to co-ordinate and integrate the future activities that map and collect vegetation and land use data in the Murray-Darling Basin as well as the existing data.

Data will be derived through the interpretation of satellite imagery (Landsat Thematic Mapper, or Landsat TM) and will be processed and stored in a digital format suitable for use in computerised geographic information systems (GIS). This data will provide an effective basis from which to monitor change, model future impacts and evaluate the effectiveness of policies and actions in the management of the basins natural resources.

The use of satellite imagery will provide accurate spatial information on the boundaries of vegetation and land cover types whilst detailed site information yields the most accurate descriptive information. The enormity of the undertaking from a spatial and logistic perspective necessitates that the mapping methodology be simple, robust, pragmatic and most importantly able to produce a data set to satisfy the diverse range of user needs.

The full BASINCARE project (Ritman 1994) comprises a series of tasks that together will help develop an integrated natural resource dataset. These tasks are:

Task 1 Production of a digital vegetation dataset (structural vegetation) at a basin-wide level of resolution (1:100 000 nominal scale) derived from interpretation of Landsat TM imagery supported by air photo interpretation and on-ground verification.

Task 2 Inventory of existing map data suitable for addressing land degradation issues at the regional level of resolution (1:100 000 presentation scale).

Task 3 Inventory of existing floristic site data to support regional datasets and 'local scale' issues.

Task 4 The assessment and digital combination of existing site and mapped vegetation data.

Task 5 Collection of a Basin-wide digital site and map based floristic data set.

Task 6 Investigation and planning of Land-use data requirements. This would form the basis for the compilation of a Land-use dataset at a Basin-wide level of resolution (1:100 000), derived from the interpretation of Landsat TM imagery supported by ground

verification. Land cover data collected as part of Task 1 will provide a provisional template for some land-use boundaries.

2.2 LAND-USE DATA REQUIREMENTS -- TASK 6

This report represents the initial investigation into land-use data requirements. The aims of the report are:

1. To determine the land use information and mapping requirements for natural resource mapping at the Basin-wide scale. What features or aspects of land-use need to be mapped?

2. To review previous land-use mapping programs and classifications to determine their possible applicability to the Basin land-use mapping needs.

3. To develop a consistent framework or land-use classification schema for application Basin-wide.

4. To advise on an efficient, consistent mapping methodology for land-use mapping which utilises the data sources, and is complementary to, the structural vegetation mapping of Task 1.

5. To provide realistic cost estimates for the implementation of Basin-wide land-use mapping at the scale of 1:100 000.

2.3 DERIVING THE MAPPING REQUIREMENTS

The management of natural resources within the Murray-Darling Basin is carried out by a large variety of agencies with often competing responsibilities ranging from production through to conservation. Likewise, each of the four States, the ACT, and the Commonwealth, has their own specific land management and land-use planning policies that may to some extent overlap or even conflict. These differing management levels require information that differs in the type of data perceived to be needed, the detail of the data and in the scale of presentation, ranging from strategic overview at the Basin-wide scale to the tactical implementation scale at paddock level.

In order to establish the land-use mapping needs for environmental planning and natural resource management within the Basin, these differing viewpoints need to be considered such that the final mapping program caters for as many of these needs as possible.

In an effort to minimise the potential confusion between these various needs, it was decided to aim initially at the data requirements of upper-middle level of land managers. At this level there is both an understanding of the practical data needs at the paddock scale and of the data needs of the policy level. In addition, each State was approached individually in order to compartmentalise what could otherwise develop into an intractable set of information needs. An exhaustive list of the various data needs has not been

attempted; rather the approach was one of sensing the needs and selecting common threads, as a basis for the development of the proposed classification.

The following procedure was adopted:

1. Through the BASINCARE co-ordinating committee, key natural resource managers were identified for each state. In turn they were requested to identify land management personnel from a range of agencies, each with specific land-use mapping requirements.

2. A draft discussion paper, outlining the need for land-use mapping; a classification philosophy based on the type and level of intervention in the landscape and views on dataset structure, was circulated to these state groups (Appendix B).

3. Workshops were arranged in each state to establish land-use mapping requirements and dataset structure. An example of the workshop agenda is attached (Appendix C) and a list of workshop attendees is attached (Appendix D).

4. After discussion, the general concept of mapping land-use by dominant land-management regime was well accepted and each state workshop derived a list of land use mapping requirements. These were consolidated into a draft Basin-wide land-use mapping classification schema and returned to the state groups for appraisal and comment.

5. After review of existing land-use classifications and state comments, numerous modifications were incorporated and the resulting draft classification schema is proposed in this report.

    - Chapter 3 examines the philosophical basis from which the proposed classification schema was developed.

    - Chapter 4 presents an examination of selected existing land-use classifications.

    - Chapter 5 presents the classification schema in detail and examines the principles and concepts behind the structure.

6. On the basis of an extensive literature review (references and abstracts are available on disk if requested) and mapping experience in a variety of natural resources mapping projects, a number of mapping methodologies were assessed.

    Several approaches to land-use mapping are examined in Chapter 6. A new methodology, using in-field computer-mapping techniques, is costed for comparative purposes.

7. Development of a realistic costing of these different mapping methods, presented for comparison in Chapter 7. These are shown in matrix form as the choice of method or combination of methods may change

from area to area depending on required accuracy, logistics and other cost factors.

CHAPTER THREE

SUSTAINABLE LAND-USE AND LAND-USE INFORMATION

3.1 INTRODUCTION

Ecologically Sustainable Development is not an option -- it is an imperative. The need to develop and implement sustainable land use and management systems, based on an understanding of ecological principles, in the Murray-Darling Basin is clearly recognised in the charter of the Murray-Darling Basin Ministerial Council. This need forms the fundamental philosophy of the Natural Resources Management Strategy.

While the concept of Ecologically Sustainable Development has been variously defined, its relevance to contemporary and future societies is unquestioned. The Commonwealth of Australia (1992) suggested the following definition of Ecologically Sustainable Development in Australia:

> *using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be increased.*

Clearly, there is a close relationship between the economic health of a country and environmental health. This is in contrast to earlier views that development and the environment were essentially in competition - one was always at the expense of the other.

The Natural Resources Management Strategy recognises that many land-use decisions in the past have resulted in unsustainable use of our natural resources. The reasons for these decisions are not the driving issue -- making better decisions in the future is.

Without the goal of ecologically sustainable development, decisions on land-use may be made in an *ad hoc* fashion with limited regard to long term consequences.

3.2 THE ROLE OF LAND-USE INFORMATION IN ECOLOGICALLY SUSTAINABLE DEVELOPMENT

The Working Group on Sustainable Agriculture (Australian Agricultural Council 1991) stressed the need for a systems or integrated approach to the management of agricultural land. It also recognised a specific need for an improved information base to support the movement towards sustainable agriculture:

Appropriate information is crucial to achieving sustainable agriculture. It is important for farmers and landholders, for agricultural professionals and for policy makers, planners and others working at regional State and federal levels. The type and level of detail of information required will vary considerably between these different levels, but specific needs can be categorised as follows:

- *to ensure agricultural production works within the natural capacities of particular ecosystems; and*
- *to monitor progress towards the goal of sustainable agriculture.*

The need for information to support resource management programs is not restricted to agricultural endeavours. All human uses of the natural resource have the potential to affect the resource itself, and informed decisions are required to minimise and/or reverse impacts of use on the landscape in the interests of ecologically sustainable use of the resource.

Information on the nature, extent and distribution of the various land-use systems is important in understanding the causes of various forms of land degradation and in developing and implementing preventative and ameliorative programs. Without an understanding of the causes of production or natural resource losses, it is probable the management programs will concentrate on the symptoms rather than the causes.

The development and implementation of programs to manage salinity provides a salutary lesson. Early attempts to manage land salinisation concentrated on the living with salt approach by planting salt tolerant pasture on salted areas. With the development of some understanding of the mechanics of salinisation, particularly the role of rising groundwater tables, tree-planting on the perimeters of salted areas was undertaken. Further development of the knowledge of the role of regional water tables and the impact of large-scale clearing of native vegetation for pastoral or crop production lead to the development of regional programs where the cause of the problem, and therefore the site for preventative measures was often distant to the appearance of salinity.

Current approaches have taken this approach further, through the researching of land management systems that minimise groundwater accessions through maximising agricultural use of soil moisture. A clear understanding of the nature of human intervention in natural processes and their spatial extent is critical to such an approach.

Land-use information has the potential to be a key element of informed land resource management, provided the right information is assembled. Information of the uses made of the land resources of the Murray-Darling Basin may be used in three broad ways:

a) Description

The information is used to simply describe the various uses made of the land in terms of its outputs or commodities: wheat, sorghum, beef, etc. This information may be presented as a map or as a table of areas devoted to each use, or as production (tonnes of wheat, head of stock, etc.).

While this commodity-based information clearly has some uses in making comparisons of the relative importance of nominated uses in the economy of the basin, it has severe limitations in policy development, particularly for the allocation of resources for land-use planning and the development and application of improved land management systems. The descriptive element requires additional judgements to be made in policy development, particularly about the likely success of any new management system.

b) Monitoring

Changes in land use may sometimes be used as an indicator of land condition. Changes in land condition can be difficult to measure satisfactorily and creditably. Emerging trends could be related to changes in management, as well as natural variation resulting from the variation in the nature of the land, from seasonal changes in moisture regimes, or from phenological changes in vegetation, etc. It is often simpler, and probably equally reliable, to measure changes in land-use or land management practices as a measure of the impact of land management programs on the condition of the land.

If the trend in land-use can reasonably be expected to indicate movement towards or away from ecological sustainability, this can be exceedingly useful information in the overall planning and management of the resources of the Murray-Darling Basin.

c) Modelling

It is in the arena of examination of future trends in land condition, either without intervention or as a result of land management programs, and in the development of ecologically sustainable land management systems, where land-use information has its greatest value -- the ability to evaluate *What if?* scenarios.

By understanding the nature of a particular land-use and its effect on the land and water resources, its spatial extent in the basin and the nature/capabilities of the land that is so used, assessments can be made of the likely long term effects on the land and associated water resources. Appropriate management programs can then be instigated before major land degradation problems surface.

However this does imply a need to **map/describe forms and levels of intervention in the landscape rather than land-use *per se*.** A land-

use such as winter cereal production is not particularly informative if the prevention of wind and water erosion is an objective. The cropping systems used in the production of winter cereals in southern Australia range from continuous cropping through to minimum tillage, each with a quite different set of impacts on the environment. If the type and level of intervention in the environment were mapped/described, then the degree of cultivation, the extent of chemical (fertiliser and herbicide) usage, the length of the rotation and the inclusion of legumes in the rotation are far more important than the end product – wheat or barley – in the management of the land and water resources of the basin.

If the processes leading to loss of productive capacity of the land or of the land itself is not identified and understood, it is unlikely that remedial measures will be satisfactory in the long term. There is the strong risk that the symptoms, rather than the cause, will be treated. The almost inevitable result is a mis-allocation of resources for land management programs, inappropriate land-use planning, mis-utilisation of the land resource, and continuing degradation of the land and water resources.

Obviously, other information is also required for the development and implementation of improved resource management programs. The nature of the land and its capabilities, the condition of the land and its trends with time, the particular requirements of the various form(s) of production and resource protection, land tenure, the economics of the various forms or production, and many other factors are all important in their own ways. The particular mix of information for any one purpose will vary, however the information is fundamental to most federal, state or regional planning programs.

3.3 FORMS OF LAND USE INFORMATION

The forms in which the land uses of the Murray-Darling Basin are described will have a significant bearing on the utility of the dataset. The previous discussion made passing reference to the opportunities for both mapped and tabular information.

Maps provide the spatial context, the distribution and relative abundance of the land uses, and their relationships to special features or values such as rivers. Maps also provide an effective means of exploring relationships between land use and land type or land condition. Modern electronic equipment is more than capable of overlaying two or more thematic maps and presenting a consolidated map, highlighting particular combinations regarded as being important.

Tabular data is useful in comparing numerical aspects of land use information: how much of the basin is committed to a nominated land use in comparison with another; how the area of a particular land use has changed over a particular period, etc.

Fortunately, modern Geographic Information Systems are adept at handling both sets of data, generating tabular data from the mapped information and providing opportunities for modelling of impacts of land use on the land and water environments across the whole or restricted parts of the basin.

The forms of land use mapped should be clearly defined:

- in terms of the type and level of intervention in the landscape,
- in terms relevant to the protection of the land and water resources and their productive potential.
- in terms relevant to the ecologically sustainable management of the land and water resource.

These forms of information will then form the land use dataset. Maps should then be based on these descriptions and area statements prepared.

CHAPTER FOUR

EXISTING LAND-USE CLASSIFICATIONS

4.1 INTRODUCTION

Previous examples of land-use mapping in Australia and beyond have been considered in preparing the proposed classification. Clearly, there is little point developing a new classification if an existing system is relevant and workable. Equally, previous and current land-use mapping may not be immediately relevant to the Commission's needs, and there is no point in perpetuating a classification that does not meet current needs.

There is and has been a range of efforts in land-use mapping in some states that can provide some guidance in the development of a land-use classification for the Murray-Darling Basin. Further, any system adopted by the Murray-Darling Basin Commission should be able to incorporate information from such efforts if possible.

A range of existing or past classification systems have been reviewed in terms of their objectives and their relevance to Commission objectives. This is by no means a comprehensive review as there appear to be almost as many different classification schemas as there have been attempts at land-use mapping. *It should be noted that any apparent criticisms of any of the past or existing programs are not intended as a criticism of that program, but rather a comment on the utility of the approach to the Commission's needs.*

4.2 COMMONWEALTH 1:1 MILLION LAND-USE MAP SERIES

The Commonwealth of Australia published in 1979 a series of maps at a scale of 1:1 000 000 showing land-use, land cover and land tenure for the whole of Australia. The land use maps recognised 16 major land-use zones based primarily on rainfall distribution. Each zone was divided into 8 land-use classes with further detailed classes of land use, organised in a hierarchical fashion (see Box 4.1). The information was derived from Landsat I and II imagery, air photographs, census data and sundry other sources. The map series provided full continental coverage of three key datasets. However the continental scale used (1:1 000 000) severely limits its use by the Commission and the contracting governments.

4.3 VICTORIAN STATE-WIDE LAND-USE/LAND-COVER MAPPING

Victoria has undertaken two related programs of mapping of land-use across the whole state.

The first, undertaken by the (then) Department of Conservation, Forests and Lands, was commissioned by the (then) Department of Water Resources to provide information for its Natural Resources Inventory. This report

assembled a range of information considered to be relevant to the management of the water resources of the state (Department of Water Resources 1989).

BOX 4.1 LAND USE CLASSES OF THE 1:1 000 000 LAND-USE SERIES

LAND-USE ZONES (determined by rainfall) *eg.* HUMID ZONE

- Unused land
- Forestry land
- Grazed land
- Urban land
- Conserved land
- Agricultural land
- Cropped land

A system of 17 classes was adopted (Box 4.2), without any internal structure and with a considerable number of mixed classes. These classes reflected a mixture of land-use and land-cover. All land (public and private) was covered. The information was taken from visual interpretation of Landsat MSS images at a scale of 1:250 000 and presented at a range of scales from 1:550 000 to 1:2 000 000. A state-wide cover at a scale of 1:250 000 was assembled on a basin-by-basin basis in the (then) Rural Water Commission's Geographic Information System.

BOX 4.2 LAND-USE/COVER CLASSES -- NATURAL RESOURCES INVENTORY

- Alpine/Subalpine vegetation
- Coastal dunes/Sand
- Coastal scrubland
- Grazing/Broad acre cropping
- Heathland scrub
- Irrigated land/Intensive cropping
- Low forest (Mixed species)
- Mallee/Saltbush
- Native grassland
- Open cut mines
- Plantations
- Redgum woodlands
- Swamps/Marshes
- Tall forest (Mixed species)
- Urban/Industrial
- Very tall forest (Ash)
- Water

The flat structure of the classification and the overlap of land-cover and land-use components of the information limits its utility for Commission purposes. While it was a ground-breaking exercise in its day and remains the only state-wide land-use cover at a regional scale in the contracting states, it is not recommended for adoption by the Commission.

A revision of these maps was undertaken for the Office of the Commissioner for the Environment (1992) to assist in the development of the Victorian State of the Environment report. This report was interested primarily in the management of private land, and the revision concentrated on this land.

Six classes of agricultural land and three additional classes were recognised, based on the previous work, but with a clearer separation of land-use and land-cover components (Box 4.3). Again a generally flat structure was adopted. The information was taken from visual interpretation of TM imagery at a scale of 1:250 000 and presented at 1:1 000 000. The information has been entered into the Geographic Information System of the Department of Conservation and Natural Resources.

BOX 4.3 LAND-USE/COVER CLASSES -- STATE OF THE ENVIRONMENT REPORT

- Agricultural Land
  - broad-are cropping
  - horticulture
  - grazing
  - grazing on irrigated pasture
  - plantation forestry (freehold land)
  - plantation forestry (on public land)
- Other Land
  - remnant vegetation
  - public land
  - urban land on dryland pasture

This approach is also not recommended for adoption by the Commission because of its flat structure and limited coverage.

4.4 LAND-USE MAPPING IN NEW SOUTH WALES

There are two current programs describing and mapping land use in New South Wales.

The **Western Rangeland Region Monitoring project** has been describing land use on an annual basis since 1986. The classification adopted (Box 4.4) is based on the disturbance of the natural landscape in a semi-arid environment.

BOX 4.4 LAND-USE CLASSIFICATION -- WESTERN RANGELAND REGION MONITORING

- Undeveloped (uncleared)
- Developed (marginal and better cropping land)
  - cropped
    - frequency of cropping
    - form of cultivation (tillage practices)
  - not cropped

The system adopted has relevance to a limited range of land uses in the Basin, although such land-uses may cover much of the Basin. The practical

nature of the system and the hierarchical classification have much to recommend them.

The **Catchment Agricultural Management System**, being trialed in the Bogan Shire, is a paddock based system of recording land-use. Bogan shire is dominantly use for marginal cropping, and the classification adopted (Box 4.5) reflects this.

This is a pilot project to develop procedures for joint landholder/government recording of land use information as a basis for development and implementation of sustainable land use and management. Information is collected from visual interpretation of Landsat TM hardcopy imagery at a scale of 1:100 000 and is stored in ArcView. To enable management of the spatial data at a paddock scale, paddock boundaries were digitised from the TM imagery in lieu of accurate cadastral data.

BOX 4.5 LAND-USE CLASSIFICATION -- CATCHMENT AGRICULTURAL MANAGEMENT SYSTEM, BOGAN SHIRE

- Trees/No Trees
- Land Use
  - cropped
    - summer
    - winter
  - native pasture
  - sown pasture
- Management Layers
  - fallow type
  - tillage practices
  - harvested/not harvested
- Outcomes/outputs
  - crop yield (good/bad)
  - pasture condition
  - weeds
- Flooded/Not Flooded

In addition, the Soil Conservation Service's mapping program includes a land use component (Box 4.6). This classification has much to recommend it in that is based around enterprises and does not become bogged down on fine detail. It does however confuse features of the landscape (water bodies and timber) with land use in the basic classification. Nevertheless, there are valuable lessons here for the development of a Basin-wide land use classification.

Box 4.6 LAND USE CLASSIFICATION -- SOIL CONSERVATION SERVICE

• cropping	continuous or rotation
	strip
	irrigation
	fodder
	turf
	sugar cane
• horticulture	orchard
	vineyard/trellis planting
	vegetable/flower
• grazing or grassland	native pasture
	volunteer or naturalised pasture
	improved pasture
	tussock
	sedge/rush/fern
	irrigated
	bare surface
	weed
• intensive animal production	pigs
	poultry
	cattle
	aquaculture
• mining and quarrying	open cut
	soil dump
	gravel extraction by surface scraping
	shafts/pit heads
	alluvial mining
	restored lands
• water body	natural
	man-made
	swamp
	sea-grass estuarine
	sea-grass marine
	artificial wetland
• timber	native forest
	native forest-logged
	windbreak
	tree or woodlot
	softwood plantation
	softwood plantation - logged
	hardwood plantation
	hardwood plantation - logged
	weed species
• urban	industrial/commercial
	residential
	community facility
	caravan park
	rural residential
• recreation	natural
	semi-natural
	intensive/urban
	tourism development
• utilities and other	(various groupings)

4.5 LAND USE MAPPING IN QUEENSLAND

The Western Arid Region Land Use study covered some 50% of the Murray-Darling Basin in Queensland. While the dominant land use was grazing, no detailed land use mapping was undertaken; rather descriptions of land use appeared in the text of the report. A wide range of information was assembled, including Social Organisation, Transport, Land Tenure, and a wide ranging examination of the Pastoral Industry.

The land use information assembled appeared to be too detailed for the Commissions needs, but the experience will be valuable in the operational phase of a land use mapping program.

4.6 LAND-USE CLASSIFICATION FOR SOIL AND LAND SURVEY -- AUSTRALIA

There has been a concerted effort to develop consistent standards for the description of land and soils across Australia, resulting in the publication of a soil and land survey field handbook (McDonald, Isbell, Speight, Walker and Hopkins 1984). This handbook provides consistent means of describing and recording many features of interest to scientists, planners and land managers.

The handbook however makes limited mention of land use, referring only to a small number of classes, based on the type of disturbance of the site described (Box 4.7). While this may be adequate for the purposes of soil and land surveys, it provides a very limited suite of information for other purposes and is therefore not recommended for adoption by the Commission.

BOX 4.7 LAND USE CLASSES FOR SOIL AND LAND SURVEY

- No disturbance
- No disturbance other than grazing by hoofed animals
- Limited clearing of native vegetation
- Extensive clearing of native vegetation
- Complete clearing of native vegetation
  - pasture, native or improved, never cultivated
  - pasture, native or improved, cultivated at some stage
  - cultivated dryland farming
  - cultivated irrigated pasture or crop
- Highly disturbed

4.7 NATIONAL LAND-USE CODES -- ANZLIC

The Australia and New Zealand Land Information Council (ANZLIC) is developing a National Land Use code (Box 4.8). This code is designed to identify the characteristics of land parcels which relate to the manner and purposes for which the land is used. It is intended to be used with other information such as ownership, location, size, etc. The code has been designed with:

- simplicity and flexibility
- potential for expansion
- generality
- compatibility with other systems

in mind. There is provision for the recording of mixed uses of a given parcel of land.

BOX 4.8 DRAFT NATIONAL LAND-USE CODE (upper levels of structure only)

- Residential and Accommodation
- Manufacturing and Industrial
  - food, textiles and timber
  - chemical and metal
  - transport and machinery
  - other
- Services
  - commercial services -- wholesale
  - commercial services -- retail
  - commercial services -- repair
  - public services -- emergency
  - public services -- government
  - public services -- education
  - public services -- defence
  - public services -- medical, health and community welfare
  - services -- other
- Transportation and Storage
- Utilities and Communication
- Recreation, Entertainment, Cultural and Sport
- Rural Production
- Mining and other Resource Extraction

The draft classification has much to recommend it. Generally it conforms to the principles outlined in Chapter 3. It is hierarchical, and is capable of

expansion without destroying the integrity of existing information. It groups like activities with like activities, and separates most markedly different activities.

However, it is dominantly production oriented and fails to provide a real feeling for the forms and levels of intervention in the rural landscape; for the consequences of the land use. It is strongly parcel-driven, giving relatively equal prominence to vastly differing activities. For example, wheat production, beef cattle/feedlot, national park and post box occupy equivalent levels within the hierarchy.

It is recommended that the Commission not adopt this classification for its purposes. There will however be merit in consultation with ANZLIC before the finalisation of its National Land Use codes to support the incorporation of key features of the proposed land use classification in this report in the National Codes.

4.8 LAND-USE CLASSIFICATION FOR SOIL AND LAND MAPPING -- NEW ZEALAND

The New Zealand Soil Description Handbook (Milne, Clayden, Singleton and Wilson 1991) provides for the recording of land use and land management practices separately. In both cases, there is very limited structure to the information (see Boxes 4.9 and 4.10).

BOX 4.9 LAND USE CLASSES -- NEW ZEALAND

- Berry fruit
- Field crop
- Market garden
- Orchard
- Production forestry
- Protection forestry
- Protected areas
- Recreation
- Vine growing
- Pastoral:
  - farming
  - beef cattle
  - dairy cattle
  - sheep
  - specified livestock

The classes are very general, reflecting the origin of the classification -- the description of soils and land. The prime consideration, quite expectedly, appears to be an understanding of how land use or management may have affected the soil being described. This has some benefits for a systems approach to resource management, however it is limited by the relatively few categories. The broad classes and the limited internal structure of the classification limit its applications.

BOX 4.10 LAND MANAGEMENT CLASSES -- NEW ZEALAND

• Burnt	• Cleared	• Cultivated
• Cutover	• Drainage works	• Erosion works
• Fertilised	• Flood Works	• Grazed
• Irrigated	• Mounded	• Re-contoured
• Subsoiled		

It is recommended that this classification not be adopted by the Commission in its present form.

4.9 LAND-USE CLASSIFICATION FOR SOIL AND LAND MAPPING -- UNITED NATIONS

United Nations-sponsored Guidelines for the use of SOTER, a computer-based soil and terrain database (van Engelen and Ting-tiang 1993), clearly separates land-use from land-cover.

Land-cover and land-use information are kept separate from other soil and terrain data but are mapped onto the soil and terrain units, thereby achieving a simple link between the land use and cover information and the soil and terrain data. The land-use information is also separate from the land-cover information.

Land-use classes are defined in a hierarchical system. At the highest level, classes are sub-divided into subclasses and groups on the basis of type of land use, and the occurrence of inputs and/or outputs (animal products, crops) (see Box 4.11).

It is recognised in the guidelines that other organisations are working on global data-bases for land-use (including FAO) and that revision of the SOTER classes may be required.

This is a well-structured classification that recognises the difference between land-use and management systems, it is hierarchical, and it groups many like activities. It clearly has been designed with a much wider range of activities than occur in the Murray-Darling Basin or even Australia. Given the breadth of activities which it covers, it is not surprising that it lumps together many aspects of land management that could reasonably be expected to be of prime importance in the Basin. For example, irrigation appears only in the land use system sub-classes, and then in various land-use orders and groups. Further, the land-use map is a derivative of the soil/terrain map, and cannot fully reflect the spatial consequences of different management across a single map unit. As the SOTER classification stands, it could meet some of the needs of the Commission and contracting governments. However, it is

recommended that a more locally based classification, based on local land use/management systems to meet local needs, but using many of the features of the SOTER classification, be adopted.

4.10 LAND-USE AND LAND-COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA -- US GEOLOGICAL SURVEY

This system of classification (Anderson, Hardy, Roach and Witmer 1976) is specifically designed for application to data derived from remote sensor sources and recognises some of the constraints imposed in terms of data spatial resolution and interpretation. The differences between Land Cover and Land Use are recognised but not separated (Box 4.12). The need for acquiring collateral data to aid in the identification of land use from remote sensors is noted.

The classification system is hierarchical with the class level being defined by the detection capability of the various remote sensor systems and the type of land use that can be inferred from that data, for example Level 1 is appropriate for satellite data and is essentially Land Cover type, whereas Level 2 is a mixture of land cover types and land uses defined from higher resolution satellite or air photo data types. The approach is resource oriented and does not cope well with multiple land uses, nor does it incorporate information on management practices.

Although not recommended as a classification schema for adoption by the Commission, this system is useful in that the accompanying documentation enumerates specific requirements that need to be satisfied in a remote sensor based classification schema. These are:

1. Minimum level of interpretation accuracy should be at least 85%.
2. The accuracy of interpretation for different categories should be about equal.
3. Results should be repeatable.
4. The classification should be applicable over extensive areas.
5. The categorisation should permit vegetation and other types of land cover types to be used as surrogates for activity.
6. The classification should be valid for data acquired at different times of year.
7. Should allow effective use of sub-categories.
8. Aggregation of categories must be possible.
9. Comparison with future land use data should be possible.
10. Multiple uses of land should be recognised where possible.

BOX 4.11 *SOTER* LAND-USE ORDERS, GROUPS AND SYSTEMS

- Settlement/ Industries
  - residential use
  - industrial use
  - transport
  - recreational use
  - excavations
- Agriculture
  - annual field cropping
    - shifting cultivation
    - fallow system cultivation
    - ley system cultivation
    - rainfed arable cultivation
    - wet rice cultivation
    - irrigated cultivation
  - perennial field cropping
  - non-irrigated
  - irrigated
  - tree & shrub cropping
    - non-irrigated tree crop cultivation
    - irrigated tree crop cultivation
    - non-irrigated shrub crop cultivation
    - irrigated shrub crop cultivation
- Animal Husbandry
  - extensive grazing
    - nomadism
    - semi-nomadism
    - ranching
  - intensive grazing
    - animal production
    - dairying
- Forestry
  - exploitation of natural forest
    - selective felling
    - clear felling
- Mixed Farming
  - agro-forestry
  - agro-pastoralism (cropping & livestock systems)
- Extraction/Collecting
  - exploitation of natural vegetation
  - hunting and fishing
- Nature Protection
  - nature and game preservation
    - reserves
    - parks
    - wildlife management
  - degradation control
    - non-interference
    - interference
- Unused

Box 4.12 USGS LAND COVER AND LAND USE FOR REMOTELY SENSED DATA

1 Urban or built-up land
- 1.1 Residential
- 1.2 Commercial and Services
- 1.3 Industrial, etc.

2 Agricultural Land
- 2.1 Cropland and Pasture
- 2.2 Orchards, vineyards
- 2.3 Confined feeding operations
- 2.4 Other agricultural

3 Rangelands
- 3.1 Herbaceous rangeland
- 3.2 Shrub and brush rangeland
- 3.3 Mixed rangeland

4 Forest Land
- 4.1 Deciduous
- 4.2 Evergreen
- 4.3 Mixed

5 Water

6 Wetland

7 Barren land

8 Tundra

9 Perennial Snow and Ice

The above requirements for the use of remote sensed data in land use mapping are well accepted internationally. However, the recommended sensor type for each level of classification requires review due to the increased capabilities of sensors since the schema was originally proposed.

4.11 LAND USE CLASSIFICATION FOR LAND USE MONITORING -- CANADA

Canada, like the Murray-Darling Basin Commission, saw the need for both land use and land cover information as an integral part of rational land management program. While the existing Canada Land Inventory contained a 'land use' component, this was not seen a meeting the needs of the day, and more specific recording of land cover and use was required (Gierman 1981).

This classification is comprehensive and hierarchical, and it clearly recognises the inter-relationships between land use and land cover in an integrated fashion. Box 4.13 indicates the primary groupings of activities; there are three levels of information below this. However it does not appear to make provision for management aspects of land use that may be of

importance to many users of the data. Nevertheless, there are many lessons in it for the development of a locally based classification system, and the principles on which it is based are as relevant here as in Canada:

- the classification system should be hierarchical
- land use variables should form separate classification systems
- the system should be coded to allow easy computer manipulation of data
- the system should be independent of data gathering method
- the classification systems should be comprehensive
- the systems should be compatible with existing systems at some level or levels
- the classes should be pure
- there should be some attempt to separate land use activities into two major classes based on whether the activity makes use of the land for productive purposes or is located on the land

BOX 4.13 LAND USE CLASSIFICATION -- CANADA

- Agricultural activities
- Forestry activities
- Wildlife related activities
- Extraction activities
- Recreation activities
- Dwelling activities
- Manufacturing and storing activities
- Commercial activities
- Providing Institutional services
- Other
- Unused land - idle land
- No perceived activity
- Land in transition

CHAPTER FIVE

THE PROPOSED LAND-USE CLASSIFICATION – PRINCIPLES, CONCEPTS AND STRUCTURE

5.1 INTRODUCTION

This chapter discusses the principles, concepts and structure of the proposed classification. The aim is to present a classification framework that will be able to support the information needs of land-use managers. This is presented independently of reference to any particular mapping technique that will, by reasons of technology or resources, apply constraints to actual map scales and attribution accuracy. The practicalities of mapping and appropriate mapping methodologies will be discussed in Chapter 6.

5.2 PRINCIPLES

The development of the proposed classification has been undertaken with a number of key principles in mind:

a) **Utility:** The dataset should be based on identification and delineation of types and levels of intervention in the landscape, rather than the more conventional but less utilitarian descriptions of land use based on outputs. This recognises both the current imperative to deal with processes of land degradation rather than the symptoms, and the role of the Murray-Darling Basin Commission and related agencies to manage for outcomes of land-use practices rather than the more traditional outputs.

   The structure of the dataset should give precedence to modelling capabilities of the data over monitoring capabilities, and precedence to monitoring capabilities over descriptive uses.

   There are some data items that will be quite important to the use of the dataset but which do not form part of the basic discriminants. The structure of the dataset should allow for the recording of such information.

b) **Generality:** While the prime users of the dataset are likely to be interested in processes or outcomes, some important potential users of the dataset identify more clearly with commodities or outputs (whether they are using commodities as a surrogate for processes is not relevant here). The structure of the dataset should accommodate this group of users, if possible, without unduly compromising the integrity of the dataset.

c) **Self-evidence:** The classes erected should be as obvious and self-evident as possible to simplify and streamline the data collection phase and the classification process.

d) **Simplicity:** The structure and classes should be as simple as possible, consistent with utility factors.

e) **Flexibility in use:** The dataset should have a hierarchical structure to permit ready aggregation of related land uses for presentation and use of the data at a range of scales.

The classes erected should be relevant at a variety of scales, recognising that there will be a variety of users at a variety of scales, and that different land-uses will require definition at different scales.

f) **Robustness:** The structure of the dataset should be robust, to allow for further subdivision within a given level of the structure or the addition of additional levels or classifications within a given level to meet particular needs. These may be local needs (particular forms of land use relevant only to local conditions), or needs specific to a limited set of land uses where a greater level of detail of information or map scale is justified. The dataset structure also needs to be able to accommodate multiple uses of land without compromising the integrity of the dataset.

g) **Compatibility:** The structure should be able to incorporate information from other classifications with as little recoding of information as possible. While existing data is not extensive, additional data takes resources to collect and existing data should be drawn on where appropriate.

h) **Primacy of data:** The data assembled should be as close to primary data as possible. Primary data is more amenable to manipulation and re-interpretation. Data that is entered into the dataset after it has been interpreted has little capacity for interpretation in another fashion, especially if our understanding of land-use systems and their impacts on the landscape change.

i) **Documentation:** There should be a clear definition of classes, their boundaries and their derivation.

5.3 CONCEPTS

5.3.1 Land-use and Management Systems *vs.* Land-Use

Many of our uses of the land and water resources are totally dependant upon modification of the landscape. Unfortunately, some of these modifications carry the seeds of their own demise -- the change imposed on the landscape will be self-defeating if not recognised and preventative actions taken.

The rising groundwater tables under many irrigation areas are perhaps the classic example of the modification leading to the demise of the utility of the land if left unchecked. Application of irrigation water, in excess of the capacity of the pasture or crop to use the water, often results in percolation of excess water into the groundwater system. If this water is unable to escape, the groundwaters will rise, locally or regionally, into the root zone. Often the rising waters mobilise salts stored in the sub-soil and bring them into the root zone, restricting or preventing productive plant growth. Preventative actions may include changing the application rate of water or the method of application of water to minimise groundwater accessions, or the installation of drainage, to control the rising groundwater.

Many other forms of land degradation are also now recognised to be a consequence of some of the actions related to the use of the land. A knowledge of the processes invoked by the use of the land can be an essential component of devising and promoting measures to minimise land degradation.

A range of forms and levels of intervention in the natural landscapes which result from our use of the land can be readily identified. These include:

- the deliberate or incidental modification of the vegetation;
- the virtually complete removal of the native vegetation and its replacement by other species and other communities, often of a different structure;
- the introduction of hard-hoofed animals which are able to graze the vegetation closer to the ground than are native animals;
- the application of water though irrigation to support out-of-season plant growth;
- the application of chemicals as fertiliser or for crop protection;
- the concentration and disposal of wastes -- inert, putrescible and septic;
- the extensive development of hard-surfacing (rooves, roads, etc.) generating substantially more run-off water; and
- the total modification of the land surface through levelling and landfill.

It is clear from our current knowledge of process that any of these, individually or in combination, are capable of exerting a marked effect on the stability and productivity of the landscape. If the Commission's objectives of ecologically sustainable land-use are to be met, resource management programs must take a process-based approach – that of treating the cause rather than the symptom of land degradation and production losses. This demands a knowledge of the land-uses of an area – of type, extent and intensity – so that the process can be correctly identified.

The basis of the proposed land-use classification is that the outcome of land-use and management is more important to the wider communities (particularly those in the contracting states) than the commodities produced. This is not to suggest that the productive aspect is not relevant, but rather that ecologically sustainable land-use must be the long term and over-riding objective of actions supported by the Murray-Darling Basin Commission.

Equally, the proposed classification is biased towards rural or the broader land-uses. This is not to suggest that the more urban-based uses are not important, but rather that they require less definition for the Commission's purposes.

The term 'land-use' in this context is somewhat of a misnomer -- what is of interest is more the **land management systems**. Nonetheless, the term **land-use** is still a useful expression, provided the full extent of the activities under consideration is recognised.

The proposed classification contains five primary classes, and a number of secondary and tertiary classes. Further information about the management of the identified land-uses can be tagged to specific areas of a particular land-use. This information may relate to the grazing management, irrigation management or other aspects as appropriate. All the recorded information is available for interrogation and sorting for specific purposes.

5.3.2 Prime Uses

Most land is subject to a range of concurrent uses, each with their own impacts and consequences. Ideally, a land-use classification should be able to identify all significant uses, however reality demands that only a limited suite be identified.

The proposed classification requires the identification of the Prime Use, *defined in terms of the management objectives of the land manager*. The other incidental or Ancillary Uses can be identified and tagged to the parcel of land irrespective of its prime use, and the data manipulated to meet specific objectives. Ideally, a land-use system based classification should identify the use with the greatest (potential) impact on the land where there are a number of uses. However, this would have significant operational difficulties and possibly lead to inconsistent classification. A classification based on the main use by the nominated land manager is simpler and would give the same result on most occasions.

To take a single example, production forest has the prime management objective of the production of timber in any of a number of forms -- saw-logs, chip-logs or firewood. However the forest may also provide opportunities for conservation and recreation, for honey production and for grazing of domestic animals for the production of

food or fibre. These other uses may be achieved without significant detriment to the primary objective of timber production.

However there are clear differences in the primary objectives of the management agency and the constraints that may be imposed on changes in practices to meet land or water degradation issues may be quite different. In any case, the management information tagged to a given parcel of land is able to identify where land-used for primary production is irrigated with waste-water, so the information is not lost in the dataset and all land identified as irrigated with waste-water can be retrieved.

5.3.3 Ancillary Uses

It is recognised that there is often a range of concurrent uses of any one parcel of land. These Ancillary Uses too may have their impacts on the landscape and should not be ignored. The proposed land-use classification recording system provides for the recording and manipulation of information on these Ancillary Uses.

Taking the example of production forest, timber production may be the recognised land-use while the forest may also provide water, and recreation and conservation opportunities. Impacts from timber production may include gross vegetation disturbance (mechanical removal and burning) and road and stream crossing construction leading to marked changes in native flora and fauna populations and to quantity and quality of water in the surface water system. Depending upon the silvicultural system adopted, the vegetation disturbance may happen once in fifty to a hundred years, and the various impacts become attenuated over time. Ancillary uses such as recreation may have a range of impacts on the soil itself, on the quality of water in the stream system (pollution by human wastes and by sediment resulting from the recreational use, particularly along the riparian zone), and on the native flora and fauna. These impacts are more likely to be continuing, and it is a matter of conjecture whether the impacts from the Ancillary Use would, in total, approach or even exceed the impacts of the Prime Use.

It must be recognised that a minimum level of achievement of land-use objectives such as conservation can be achieved on almost any land, irrespective of the Prime Use. A degree of discretion is required in identifying and recording Ancillary Uses to avoid trivial recordings and to maintain a coherent and useful dataset.

5.3.4 Management Factors

There are many examples where the land-use itself is not the primary determinant of the impact on the landscape, but the management of that land-use is. The **management system of the land** therefore becomes a critical part of the dataset and needs to be recorded in an appropriate fashion and stored so that it can be retrieved and manipulated as required.

Again, taking production forest as an example, there is a range of silvicultural systems that could be used in the management of the resource. Each of these systems has their own impacts on the landscape, and an understanding of the nature an extent of these impacts requires a knowledge of the type of silvicultural system in use. The impacts of timber harvesting by clear-felling on water yield from ash-type forests in southern Australia are relatively well known; the interval between harvesting (rotation length) is critical to managing the water yield and is implicated in periodic reductions in water quality. Informed water management therefore requires a knowledge of the silvicultural systems and rotation lengths in use in the catchment to enable rational management of the water resource where the quality or quantity of water is important.

Similarly, calculation of the impacts of irrigation on the landscape (locally or regionally) requires a knowledge of the irrigation system (flood-, ditch-, spray- or trickle-irrigation), the rate and frequency of application, and often the source (and therefore quality) of the water applied. This can be as equally important as the form of production (such as pasture or crop) in managing accessions to groundwater.

5.3.5 Overlay Uses

There are a number of uses of the land that cannot be adequately represented as Prime or Ancillary Uses for various reasons. These uses may not be capable of being clearly defined on a map (such as honey production -- the actual area of land used by the bees for foraging cannot be clearly defined), or the use of the land occurs through the actions of another party (such as water production from land not owned or managed by the water supply authority). Such uses are perhaps best identified and delineated (to the degree possible) by a series of 'overlay' maps. This information should be recorded in a form that lends itself to later manipulation to meet specific needs.

5.4 STRUCTURE

The proposed land-use classification is based on a three level structure: Primary Classes, Secondary Classes, and Tertiary Classes, with the opportunity for identifying and recording Ancillary Uses (using the same basic classes as the Prime Use) and key Management

Factors or Dominant Management regime **for any area of land at any level in the classification.**

There are five Primary Classes (Box 5.1), 28 defined Secondary Classes (Boxes 5.2, 5.3, 5.4, 5.5 and 5.6) although this can be expanded if required and, at this stage of development, 131 Tertiary Classes.

5.5 SCALES OF INFORMATION

As previously discussed, different levels of information can and should be portrayed at different scales. They should also be collected at different scales. Once in the Geographic Information System, the mapped information could be treated as though it is scaleless although this is not truly the case. It is the practicalities of collection and presentation of information, not the category of land-use that determine the scale. The classification system and hierarchy is not based on any predetermined scale but is designed to be flexible. To effectively use this flexibility of scale requires that accurate information on the derivation of data entries be maintained; that is, there is a need for adequate meta-data information.

Clearly, information should not be presented at a scale larger than at which it was collected, and the scale of presentation should be commensurate with the detail required. If the Commission were to show broad land-use across the whole Basin on a single map, a scale of 1:1 000 000 or smaller would be appropriate. Only the Primary Use classes could be reasonably presented at this scale. As the detail required to be presented increases, the scale must also become larger.

For example, if the need was to identify all areas currently under an irrigation farming system on a whole-of-Basin basis, then a scale of 1:2 000 000 might be appropriate. Such a map could not accurately define the boundaries of all areas, and may well have to omit small areas simply through the difficulty in presenting small areas at the scale chosen.

Equally, the scale required to adequately represent the land-use in a specific area of interest will change. The scale required to show the irrigation based land-uses along the lower River Murray may well be 1:25 000, while a scale of 1:100 000 may be adequate to show the irrigation areas along the Namoi Valley.

The scale of information controls the amount of detail in the dataset The generality of the linework and the potential spatial error (how close is the line indicating the boundary of a specified land use to the real boundary) increases as the scale decreases. Information collected at smaller scales cannot be realistically presented at larger scales because the positional accuracy of the linework decreases.

BOX 5.1 THE BASIC STRUCTURE OF THE CLASSIFICATION: PRIME, ANCILLARY AND OVERLAY USES, MANAGEMENT FACTORS

==========>>>>> INCREASING LEVELS OF INTERVENTION IN THE LANDSCAPE ==========>>>>>

PRIMARY CLASSES	**CONSERVATION AND RECREATION**	**PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS, AND RELATED USES**	**PRIMARY PRODUCTION FROM DRYLAND AGRICULTURE**	**PRIMARY PRODUCTION FROM IRRIGATED AGRICULTURE**	**INTENSIVE USES**
SECONDARY CLASSES	CONSERVATION RESERVES CLOSED WATER SUPPLY CATCHMENTS UNUSED LAND MULTIPLE USE AREAS RECREATION AREAS	ROUGH GRAZING PRODUCTION FOREST PLANTATIONS	PASTURE AGROFORESTRY CROPPING/PASTURE ROTATIONS PERMANENT CROPPING HORTICULTURE OTHER	PASTURE AGROFORESTRY CROPPING/PASTURE ROTATIONS CROPPING HORTICULTURE OTHER	RURAL LIVING URBAN USES INSTITUTIONAL USE UTILITIES TRANSPORT & COMMUNICATIONS INTENSIVE PRIMARY PRODUCTION/PROCESSING MINING/EXTRACTIVE INDUSTRY WASTE TREATMENT AND DISPOSAL OTHER
MANAGEMENT FACTORS	*Managing agency* *Access* *Fire* *Visitor facilities*	*Rotation length* *Silvicultural system* *Grazing system* *Fire*	*Cultivation machinery* *Fertilisers* *Pesticides* *Rotation length* *Fallow system* *Stock type* *Stocking rate* *Grazing system* *Soil Conservation*	*Cultivation machinery* *Rotation length* *Irrigation type* *Irrigation frequency* *Irrigation volume* *Stock type* *Stocking rate* *Soil conservation* *Water source*	*Irrigation type* *Irrigation frequency*
OVERLAYS	Water production (domestic, irrigation, industrial, thermal power, hydro-power), honey production, recreation (bushwalking, ski-ing, fishing, other), Heritage Agreement areas, Quarantine Areas, Sites of Significance, Conservation Covenants, other areas of particular conservation significance				

BOX 5.2 PRIMARY CLASS -- CONSERVATION AND RECREATION

CONSERVATION AND RECREATION

Land used primarily for conservation and/or recreation purposes based on the essentially natural ecosystems present. The land may be reserved by government specifically for such purposes, or may be simply unused by either decision or circumstance.

CONSERVATION RESERVES
- Wilderness Areas
- Reference Areas
- Flora and Fauna Reserves
- National Parks
- Aboriginal Heritage Areas
- Other Conservation Reserves

CLOSED WATER SUPPLY CATCHMENTS

UNUSED LAND
- Remnant native vegetation
- Pastoral leases
- Exclusion or Rehabilitation areas
- Other

MULTIPLE USE AREAS
- State Parks
- Regional Parks
- Other

RECREATION AREAS
- Alpine Resorts
- Other resorts
- National Parks
- Other

MANAGEMENT FACTORS:

MANAGING AGENCY:	*State/State-Koori/ State-Trust/Private*
ACCESS:	*Restricted/Unrestricted*
FIRE:	*Routine management tool/Undesirable/ Not relevant*
VISITOR FACILITIES:	*Provided/Not provided*

BOX 5.3 PRIMARY CLASS -- PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS, AND RELATED USES

PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS, AND RELATED USES

Land used primarily for primary production, based largely on essentially native vegetation. The structure of the vegetation generally remains intact, despite some deliberate modification. The category also includes tree/shrub plantations.

ROUGH GRAZING
- Semi-arid rangeland
- Semi-arid shrubland
- Semi-arid grassland
- Tablelands
- Alpine
- Forest - riverine
- Forest - montane
- Other

PRODUCTION FOREST
- Brush/broom
- Eucalyptus oil
- Firewood
- Hardwoods
- Cypress Pine and other native softwoods
- Mixed Hardwoods and Softwoods
- Riverine forest
- Rainforest
- Other

PLANTATIONS
- Brush/broom
- Eucalyptus oil
- Firewood
- Native Hardwoods
- Native Softwoods
- Native Riverine species
- Exotic Hardwoods
- Exotic Softwoods
- Rainforest
- Other

MANAGEMENT FACTORS:

ROTATION LENGTH:	*Years*
SILVICULTURAL SYSTEM:	*Clear felling/ Selective logging/Strip thinning/Patch cutting/ Other*
GRAZING SYSTEM	*Permanent stocking/ Seasonal stocking*
FIRE	*Control burning used/not used*

BOX 5.4 PRIMARY CLASS -- PRIMARY PRODUCTION FROM DRYLAND AGRICULTURE

PRIMARY PRODUCTION FROM DRYLAND AGRICULTURE

Land used primarily for primary production, based on dryland farming systems[1].

PASTURE
- Native/Semi-improved native species
- Improved pasture (annual species)
- Improved pasture (perennial species)
- Leguminous pasture species
- Multi-layered pasture systems
- Forage
- Other

AGRO-FORESTRY
- Improved pasture (annual grasses), trees
- Improved pasture (perennial grasses), trees
- Leguminous pasture species, trees
- Cropping, trees

CROPPING/PASTURE ROTATIONS
- Winter cereals
- Annual pasture
- Perennial pasture
- Lucerne
- Oilseeds
- Grain legumes
- Summer cereals
- Lucerne
- Other

PERMANENT CROPPING
- Winter cereals
- Oilseeds
- Grain legumes
- Summer cereals
- Lucerne
- Cotton
- Other

HORTICULTURE
- Orchard - stone fruit
- Orchard - pome fruit
- Orchard - citrus
- Orchard - other
- Nuts
- Vineyard - grapes
- Vineyard - hops
- Berry fruits
- Vegetables - potatoes
- Vegetables - tomatoes
- Vegetables - corn
- Vegetables - peas/beans
- Vegetables - other

[1] The recording system will have to be designed to allow for multiple uses. particularly within Secondary Classes, to adequately reflect the variety of land use systems in existence.

BOX 5.4 PRIMARY CLASS -- PRIMARY PRODUCTION FROM DRYLAND AGRICULTURE (continued)

Horticulture (continued)
- Plant/tree nurseries
- Cut flowers
- Other

OTHER

MANAGEMENT FACTORS:

CULTIVATION MACHINERY: *Mouldboard-disc implement/ Tined implement/Blade plough-Rod weeder*
FERTILIZERS USAGE *Type,/extent*
PESTICIDE USAGE *Type/extent*
ROTATION LENGTH: *Years*
FALLOW SYSTEM: *Long fallow/Short fallow/No fallow Mechanical fallow/Chemical fallow/*
STOCK TYPE: *Dairy cattle/ Beef cattle/Sheep/Horses/Goats/Deer/Other*
STOCKING RATE: *Head per hectare*
GRAZING SYSTEM: *Rotational grazing/ Permanent stocking/Seasonal stocking*
SOIL CONSERVATION: *% subject to soil conservation works/% subject to soil conservation practices*

BOX 5.5 PRIMARY CLASS -- PRIMARY PRODUCTION FROM IRRIGATED AGRICULTURE

PRIMARY PRODUCTION FROM IRRIGATED AGRICULTURE

Land used primarily for primary production, based on irrigated farming systems[2]

PASTURE
- Improved pasture (annual species)
- Improved pasture (perennial species)
- Leguminous pasture species
- Multi-layered pasture system
- Forage
- Other

AGRO-FORESTRY
- Improved pasture (annual species), trees
- Improved pasture (perennial species), trees
- Leguminous pasture species, trees
- Cropping, trees

CROPPING/PASTURE ROTATIONS
- Winter cereals
- Annual pasture
- Perennial pasture
- Lucerne
- Oilseeds
- Grain legumes
- Summer cereals
- Other

CROPPING
- Winter cereals
- Lucerne
- Oilseeds
- Grain legumes
- Summer cereals
- Annual pasture
- Perennial pasture
- Lucerne
- Rice
- Cotton
- Tobacco
- Other

HORTICULTURE
- Orchard - stone fruit
- Orchard - pome fruit
- Orchard - citrus
- Orchard - other
- Nuts
- Vineyard - grapes
- Vineyard - hops
- Berry fruits
- Vegetables - potatoes
- Vegetable - tomatoes
- Vegetables - corn
- Vegetables - peas/beans
- Vegetables - other

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2 The recording system will have to be designed to allow for multiple uses. particularly within Secondary Classes, to adequately reflect the variety of land use systems in existence.

BOX 5.5 PRIMARY CLASS -- PRIMARY PRODUCTION FROM IRRIGATED AGRICULTURE (continued)

Horticulture (continued)
- Plant/tree nurseries
- Cut flowers
- Turf
- Other

OTHER

MANAGEMENT FACTORS:

CULTIVATION MACHINERY: *Mouldboard-disc implement/ Tined implement/Blade plough-Rod weeder/Other*
ROTATION LENGTH: *Years*
IRRIGATION TYPE: *Flood/Ditch/Spray/Trickle*
IRRIGATION FREQUENCY: *Number per year*
IRRIGATION VOLUME: *ML per hectare*
STOCK TYPE: *Dairy cattle/Beef cattle/Sheep/Horses/ Deer/Goats/Other*
STOCKING RATE: *Head per hectare*
SOIL CONSERVATION: *% subject to soil conservation works/ % subject to soil conservation practices*
WATER SOURCE: *Irrigation District/Private diversion/ Private storage/Groundwater-artesian/ Groundwater-sub-artesian/Waste water*

BOX 5.6 PRIMARY CLASS -- INTENSIVE USES

INTENSIVE USES

Land likely to be subject to extensive modification, generally in association with closer residential settlement -- residential/ commercial/public service uses, etc. The common feature is the potential level of modification of the landscape rather than the use itself.

RURAL LIVING
URBAN USES
- Residential
- Commercial services
- Manufacturing and Industrial
- Public services
- Recreation and cultural
- Other

INSTITUTIONAL USE
- Defence
- Research stations
- Other

UTILITIES
- Electricity generation/transmission
- Water storage/treatment
- Gas treatment/storage/transmission
- Other

TRANSPORT AND COMMUNICATIONS
- Aerodromes/airports
- Roads/freeways
- Rail-yards/rail lines
- Navigation/communication facilities
- Ports and associated facilities
- Other

INTENSIVE PRIMARY PRODUCTION/ PROCESSING
- Intensive animal industry
- Processing plants
- Other

MINING/EXTRACTIVE INDUSTRY
- Open cut mine
- Sub-surface mine
- Surface workings
- Shallow surface workings
- Overburden and/or spoil dumps/dams
- Other

WASTE TREATMENT AND DISPOSAL
- Storm-water
- Landfill
- Solid garbage
- Incinerators
- Sewage and associated wastes
- Other

OTHER

BOX 5.6 PRIMARY CLASS -- INTENSIVE USES (continued)

MANAGEMENT FACTORS:

IRRIGATION TYPE: *Flood/Ditch/Spray/Trickle*
IRRIGATION FREQUENCY: *Number per year*

Scale also becomes important when considering matching this dataset with information in other datasets (overlaying information). There is limited point in attempting to draw inferences from two sets of information at markedly different scales because of errors due simply to varying accuracy of the linework.

A further consideration often overlooked is the accuracy of linework required. The actual boundaries of (say) intensive animal industries may not be particularly relevant; the number of animals in the enterprise is generally a more accurate indicator of the 'pollution potential' of the enterprise. In contrast, the spatial extent of broad-acre land-use such as lucerne cropping, for example, may be quite important in monitoring the success of land management programs in terms of adoption of new technology or controlling accessions to groundwater. The question that needs to be asked is *how wrong can the land-use information be?* This is not to suggest that a lowest common denominator approach should be adopted, but rather that the costs and benefits of additional accuracy of linework need to be considered.

In general, the following scales are likely to be applicable:

CLASS	PRESENTATION	COLLECTION
Prime Use -- Primary Class	1:5 000 000 1:2 000 000 1:1 000 000 1:250 000	 1:250 000 1:100 000
Prime Use -- Secondary Class	1:250 000 1:100 000	 1:100 000
Prime Use -- Tertiary Class	1:50 000 1:25 000 1:10 000	 1:25 000 1:10 000
Ancillary Uses	as for Prime Use	as for Prime Use
Overlay Uses	as for Prime Use	as for Prime Use

5.6 RECORDING OF INFORMATION

The structure of the classification has been designed with three particular features:

- **The ability to record complex units:** It is likely that most areas of land capable of being identified at the degree of resolution chosen, even at the paddock scale, will have more than one clear Prime Use (within the classes erected) within the boundaries of that unit. There will inevitably be a patchwork of Prime Uses. Rather than try to delineate each Prime Use, it is often more practical to identify a complex unit and treat it as such. It is desirable to record this variation, and it is proposed that the recording system allow for multiple Prime Uses and their relative proportions in the Unit.

  Similarly, the Management Factors are likely to form a complex. For example, tillage practices in a given area under a consistent winter cereal based rotations are likely to vary depending on the willingness and ability of the landholders to embrace new methods and equipment. The rate of this adoption of new methods will not be constant across a defined area, and the rate of adoption may be an important measure of the success of a land management program.

  While it is technically possible to map the areas subject to a specific practice and this may be extremely valuable information, it is costly to collect and may date very rapidly. Consequently, estimates of the relative proportion of alternative practices may be a more practical measure.

- **Flexibility of scale:** There will be a variety of scales relevant to a variety of users. The classification structure has been designed to be able to record information irrespective of scale. As additional areas are mapped for land-use, this new information can be incorporated into the dataset without corrupting previous information.

  Conventional mapping approaches usually undertake mapping from the coarse (Primary Class) level before more detailed mapping is done. In this case, any new mapping is refining existing information, and adding more detailed information within the previously established framework.

- **Flexibility of detail:** The classification allows for considerable flexibility in the amount of information actually recorded. The units on the map are defined firstly by their Prime Use, and subsequently by Ancillary uses. Additional detail can be incorporated through the overlays, through management practices, or the recording of mixed units. This allows for the progressive assembly of land-use information across the whole basin without requiring consistency of scale. Where there are particular reasons for describing and mapping the land-use of restricted areas, this information can be inserted into the dataset at the scale and level of detail collected with the knowledge that it can be retrieved at the scale or aggregated up into broader perspectives.

Clearly, specific procedures will have to be established, both for recording such information in the field and for entry of information into the GIS as well as the recording of meta-data on the origin, scale of collection and lineage of data.

5.7 FURTHER DEVELOPMENT OF THE STRUCTURE

While additional Primary classes are not envisaged, additional classes may be required at the Secondary and Tertiary levels to accommodate particular forms of land-use not apparent or not considered to be significant to date. The structure proposed allows for this, provided the new classes do not overlap existing classes. Procedures for the development of new classes will need to be developed if the integrity of the dataset is to be maintained.

Clearly the various potential users of the dataset will have differing requirements in terms of detail and scale. There will be occasions when a greater level of detail in the classification than provided will be useful for a particular purpose. The structure proposed lends itself to a fourth level of classes if required. Such a level of detail is unlikely to be required for Basin-wide perspectives but can be added at a state or regional level if required without affecting the integrity of the structure proposed.

While the proposed classification has been designed with Murray-Darling Basin conditions in mind, it is entirely feasible that the concept could be extended across Australia with the addition of more classes, particularly at the Secondary and Tertiary levels.

CHAPTER 6

MAPPING LAND-USE IN THE MURRAY-DARLING BASIN

6.1 INTRODUCTION

The classification schema presented in the preceding chapter represents an attempt to define and clarify the land use attributes that are required to be mapped for natural resource management purposes. This classification was arrived at without reference to any specific mapping technique. The task now is to develop a mapping methodology that will substantially provide the required information in a practical and cost effective way. As with the complementary Structural Vegetation data collection, BASINCARE Task 1, *'the enormity of the undertaking from a spatial and logistic perspective necessitates that the mapping methodology be simple, robust, pragmatic and most importantly able to produce a data set to satisfy the diverse range of user needs'* (emphasis added).

The Structural Vegetation data set, Task 1, is essentially a land cover mapping exercise. The mapping is based on both digital and visual interpretations of satellite imagery. Woody/Non-woody vegetation covers are discriminated adequately by relatively homogenous spectral reflectance such that a digital classification can be successfully used. Likewise some structural vegetation classes can be spectrally discriminated and digitally mapped where others require confirmation from more detailed air photo or on-ground identification. Non-woody vegetation classes such as grasslands and chenopods have been broadly discriminated and agricultural land has been visually inferred through a combination of reflectance and spatial pattern. The level of mapping of land cover that can be inferred to be a discrete land use type approximately equates with some of the Primary classes proposed in the Land Use classification scheme, *ie.* Forest, Dryland agriculture, Settlements.

The Land-use mapping requirements as outlined in the Secondary and Tertiary levels of the classification schema however are substantially different in terms of scale, temporal and spatial variation in use and in the nature and intensity of management application. These require a modified approach to mapping.

6.2 LAND-USE AND LAND-COVER

There is a common misunderstanding and mis-use of the terms 'Land Cover' and 'Land Use'. These terms are often used interchangeably but refer to quite different concepts and should be treated differently, especially in any mapping exercise based on the use of remotely sensed data. Gierman (1981) is one of the few who have displayed a clear understanding of the differences between and inter-relationships of land use and land cover. His land use classification makes good use of this understanding, while other

classifications often confuse the two and end up with a hybrid system that cannot provide the information it otherwise might.

Land Cover refers to the physical surface of the earth, consisting of various combinations of vegetation types, soils, exposed rocks, snow, ice, waterbodies, buildings and other constructs. This is the spectral reflectance data recorded by satellite and other remote sensing systems.

Land cover may change radically in response to seasonal change, climatic variability (such as drought); events such as wildfires, or as a response to land management practices that physically alter the land cover.

Land Uses are cultural artefacts. A land use refers to the management regime imposed on the land for a particular end purpose. This may result in no apparent change to land cover, as in the case of a forest being proclaimed as a conservation area, or in massive change in land cover type, as when forest is cleared and converted to agricultural use. In this latter case, the broad Land Use category (agriculture) has such a high correlation with an identifiable Land Cover type that the cover type can be used as a surrogate for activity and the Land Use is *inferred*.

Land uses described and defined by land tenure or cadastral boundaries (*eg.* conservation reserves) may extend over several differing land cover types (*eg.* forest, grassland, shrubland) and may have no identifiably unique expression.

In addition a single plot of land may easily have several concurrent land uses, some of which may be inferred from land cover, and some not.

Land use is also dynamic. The nature of the land use may change radically and rapidly, *eg.* from dryland pasture to intensive irrigated agriculture. Indeed, change itself may be an integral part of the land use regime such as in a pasture cropping rotation. In this case it is the **pattern of land cover** that can be used to infer land use. Remote sensing provides the most cost effective means of mapping land use across broad areas, enabling the spatial and temporal variations to be identified. However, the mapping of land use from such data is not without its problems:

- Land uses essentially defined by tenure are unlikely to be successfully mapped from satellite imagery alone even though some boundaries may be indicated from contrasting neighbouring land uses. Cadastre or tenure information is required.

- The spatial and spectral resolution of the satellite data also limits the level to which land uses may be inferred. For example, the land cover pattern may indicate a pasture/cropping land use but the type of crop (and hence specific management regime) may not be identifiable. Satellite imagery may be useful in delineating boundaries but local knowledge of the prevailing land use practices may be necessary to accurately attribute the mapping.

- Some land uses that have noticeably altered land cover type or pattern may be readily inferred visually, but the high inherent variability in cover type may preclude digital analysis.

6.3 SCALE ISSUES WITH REMOTELY SENSED DATA

Conventional line mapping methodologies typically begin with the consideration of the required scale of the end product and then proceed to collect data at the level of detail required to satisfy this end scale. If increased resolution is later required the process is iterated at the finer scales, with area coverage and resolution being ultimately constrained by cost factors.

Satellite remotely sensed mapping is almost the reverse approach. The data is collected at finest resolution **of the available sensor**, in the case of Landsat TM at 30 m pixel resolution. The digital data is analysed at this level and the resulting map information can be produced at this resolution, *ie.* the choice of sensor defines the basic mapping scale. As Landsat TM is the agreed data source for the BASINCARE projects mapping, presentation scales of 1:50 000 or smaller are appropriate with this data. If scales of 1:250 000 or 1:1 000 000 overviews are required it is a matter of aggregating mapped classes and possibly filtering out classes considered unimportant at these scales of presentation.

Consequent to these issues of scale and data resolution, the mapping methodology proposed for this exercise concentrates on the definition of at least the Secondary Class level, although it is likely that much of the Tertiary level of mapping may be achievable. Some Primary Class boundaries have been provisionally mapped as part of the land cover mapping of Task 1, these Primary Classes will be more accurately derived through regression or combination of the Secondary Classes.

Tertiary Classes are effectively the tactical level or land parcel level of land management, where land management is directly applied. Individual paddocks rapidly change in particular land management, *eg.* crop to fallow, then back again. Although this may be useful information, it is the group of paddocks that make up a management unit or a coherent land management class that is the most appropriate mapping target. Typically, these groups of paddocks are defined by accurate land parcel boundary data and as such offer a unit by which the spatial data may be recorded and manipulated.

Although useful spatial mapping may be achieved at the paddock scale with Landsat TM imagery, spatial definition is not usually adequate to define paddock boundaries at the accuracies used for cadastral data management. This however does not preclude the land-use analyst from digitising paddock boundaries direct from the image. Although this is not spatially accurate in cadastral terms, the ability to uniquely identify paddocks (within accurate parcel boundaries) is a very useful tool in measuring changes in land-use practices. This approach has been used effectively in the NSW Catchment Agricultural Management System (CAMS) study (see Chapter 4.4).

6.4 LAND-USE CLASSES DEFINED BY CADASTRE

Not all secondary classes in the schema, however, have a physical boundary identifiable from satellite imagery. The 'Conservation and Recreation' primary level and subsequent secondary classes are largely defined by tenure and require cadastral data to define their boundaries. Mapping these classes is a relatively straight forward GIS task. These land uses are defined by cadastral data that is available to differing degrees in the various state and federal agencies:

1. **National:** AUSLIG holds digital land tenure information (public/private land boundaries) at a scale of 1:250 000 for the whole country (as at 1991).

2. **Queensland:** Cadastral data to individual property level for the whole state should be available by early 1994. Automated land title system is due to be commissioned by mid 1994. Tenure administration (administration of Crown leases) should also be operating by mid 1994.

3. **New South Wales:** The digital cadastre database is complete for the entire state. Property cadastre information has been collated for the Western division of the state, and an active program is underway to compile all Crown land information.

4. **Victoria:** A program of digitising the cadastre of all public land boundaries is underway and due for completion by mid 1994. Cadastre capture for private land has begun under the Land Information Management System program but is at an early stage.

5. **South Australia:** Public land boundaries are available in digital form. Leasehold information is partially complete but possibly out of date.

6. **ACT:** Cadastral Survey level. All property boundaries.

The above data are defined at, or exceed the 1:100 000 scale. In cases where 1:100 000 data is unavailable, coarser resolutions are often available; in Victoria, for example, complete public land boundary coverage already exists but at a scale of 1:500 000. This may be adequate for interim mapping products if required, but the linework is known to be not sufficiently accurate for use at the 1:100 000 scale.

Given the generally advanced stage of cadastral mapping, or at least, public/private boundary mapping, it is not expected that definition of these areas will be a significant problem for land-use mapping in the Basin. However, due to the variation in standards and mapping scales it would be prudent to initiate an assessment of the data before use.

Other classes, particularly those on private land, do not lend themselves well to mapping by cadastre.

6.5 LAND-USE CLASSES DEFINED BY CADASTRE AND LAND-COVER

Those land-uses contained within the 'Production from Relatively Natural Environments and Related Uses' Primary division can for the most part be defined by a combination of cadastral information and by information derived from the structural vegetation mapping of Task 1, *eg.* hardwood plantations.

Relatively low impact land uses such as grazing may or may not be identifiable as apparent land cover changes. Again, cadastral or tenure style information such as lease boundaries may be necessary.

Those land uses contained within the 'Intensive Uses' Primary class are (within the Murray-Darling Basin) commonly of a relatively small area although their effect may be highly significant. At the mapping scale of 1:100 000, most features would be displayed as point data. Any large areas should also have been provisionally mapped in Task 1.

Clearly there is a significant role for a GIS component to the mapping at an early stage. It may be necessary to instigate an inventory of ancillary data sets, *eg.* cadastre, grazing lease boundaries, etc., along the lines of M305 Task 2. This would be best done early in the mapping program as significant efficiencies can be achieved in subsequent mapping by using this boundary data during the mapping of other adjoining land uses.

6.6 DIGITAL CLASSIFICATION *vs* VISUAL INTERPRETATION

An extensive literature review of some 176 papers and abstracts on the use of satellite imagery for land use mapping indicates that digital classification is only moderately successful with typical accuracies being in the order of 60-65%, and then only if limited to a small number of discrete land use classes. The spatial and spectral resolution of the satellite instruments set some of these limits, however the high spectral variability inherent in many land uses, especially agricultural land uses, is the dominating constraint to digital classification accuracies. For example, a wheat field may be freshly ploughed; have emergent growth, a mature crop or stubble; each of these phases has greatly contrasting spectral responses, but are all nevertheless a 'wheat field' land use.

Although, spatial classifiers and 'expert' systems are under development, most of the currently available digital classifiers are restricted to using only spectral data.

Visual interpretation of hardcopy imagery or on-screen enhancements commonly exceeds 95% accuracy levels. By including the interpreters own specialist (*eg.* agricultural) knowledge the visual interpreter is able to incorporate the spectral information as well as a recognition of spatial patterns, variability in spatial relationships and other ancillary data not included in the imagery.

Digital enhancement techniques can be usefully employed to improve image contrast and boundary discrimination for visual interpretation. Multi-temporal data improves classification accuracies by mapping changes in the spectral response over time. It is the understanding of the sequence of these changes with time (*ie.* expert knowledge) that leads to improved classification (refer to NSW CAMS project, Chapter 4.4). The mapping methodology based on visual interpretation by local 'experts' will therefore remain the method of choice for some time yet.

6.7 MAPPING TECHNIQUES BASED ON LANDSAT TM IMAGERY

The information necessary for the Murray-Darling Basin Commission strategic uses require mapping at a scale of 1:100 000 with attributing at the Secondary Class level of major land cover types with attached tables of dominant land management regimes. This level of mapping is appropriate to the resolution of Landsat TM data.

At the tactical level of mapping required by local land managers, the Tertiary Class level, complete digital identification of land-use is reliably not achievable with the current satellite technology, however in most cases it should be possible to map to the spatial limits of the Tertiary Class land-uses using TM imagery with a visually interpreted major land management type. This level of detail falls at the land parcel or even paddock scale. Although spatial mapping discrimination is possible, effective data management and locational accuracy at this scale would require accurate cadastral boundaries.

It is at the paddock level that change (or application of improved land use practices) occurs. Paddock boundaries may be mappable with TM imagery but the precise nature of the land use may not be identifiable directly from the imagery. The paddock level is the most dynamic level of land use change where 'actual' land management can be attributed. This would include a degree of land cover variability (and land management variability) but would still be able to be grouped into a coherent 'dominant' land use category. It would be the task of the regional land manager to estimate the percentage areas of land use practice at this level that would be recorded in attribute tables associated with the 'dominant' land use. It is the change in these measures of land use practice at the paddock level that is the primary indicator of the effectiveness of Murray-Darling Basin Commission land use policy.

The following mapping techniques have been developed primarily for the dryland and irrigation agriculture areas and concentrate on satisfying at least the Secondary level of the classification schema at the spatial resolution of 1:100 000.

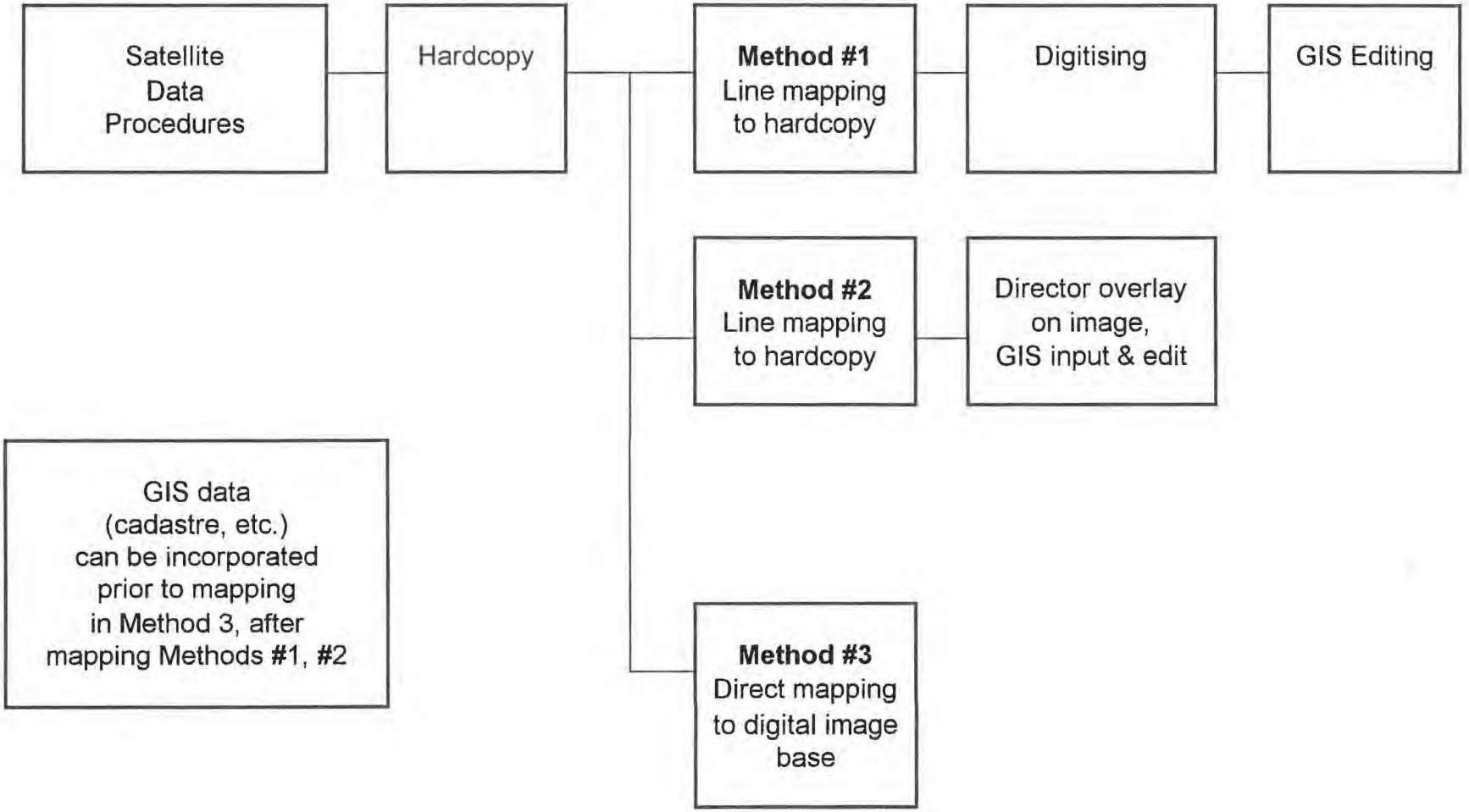
6.8 MAPPING METHODS

Three alternative methods are presented for comparison[3]. They all rely on visual interpretation by a 'local expert'. The choice of method depends on the relationship between the complexity of the land-use to be mapped, the mapping accuracies required (both spatial and attributing detail), and the cost effectiveness of the technique. The differences in the methods are apparent in aids to interpretation, speed of mapping, spatial accuracy, maintenance of consistency, and minimising data processing costs. The first two methods are not treated in great detail as variations of them are commonly employed in remote sensing based mapping exercises and are currently in general use in the M305 Task 1 project. Method 3, which is based on 'in-field' computer mapping, is under development as both a potentially more cost effective mapping method and, importantly, as a strategy for providing improved extension of remote sensing and GIS technology to the field operatives and land managers.

Each method is detailed and costed in turn, and subsequently evaluated, identifying advantages and disadvantages.

3 Water Resources/Queensland Department of Primary Industries, are using a similar technique for land use mapping, but are able to eliminate the need for photographic imagery. The variation merits further investigation before a final costing is established.

6.8.1 Schematic Comparison of Methods



6.8.2 Mapping Method #1: Conventional visual interpretation of hardcopy imagery and manual GIS data entry.

Workflow:

1. Data:

1.1 Acquire digital satellite image data
1.2 Geo-registration
  1.2.1 Collect grid control points
  1.2.2 Rectify image
1.3 Subset imagery

Digital data for 1989/90 previously acquired for Project M305, Task 1, could be used however preference is for current data.

2. Hardcopy

2.1 Enhance imagery
  2.1.1 Write imagery to tape
2.2 Negative production
2.3 Photographic enlargement and printing

Project M305 standards require mapping at the scale of 1:100 000; deriving the original linework from 1:100 000 scale imagery overlay and direct transfer to GIS does not conform to this requirement. The appropriate presentation scale would be 1:250 000. If collection at the 1:50 000 scale is necessary, hardcopy costs need to be multiplied by a factor of four.

Hardcopy print assumes the choice of the best band combination and enhancement has been made. This may not be the case for interpretation of all land cover types in the image.

3. Mapping

Hardcopy imagery is distributed to the regional land managers. (For simplicity, the NSW title of District Agronomist, or DA, is used hereafter to refer to land managers or their staff). Visual interpretation of imagery by local DA.

3.1 Visual interpretation of Land Use, boundary linework traced on acetate overlay.

3.2 Field verification

Assumes:

- *that the DA is familiar with and is skilled in the interpretation of satellite false colour imagery.*
- *that the DA produces accurate linework.*
- *that the DA conforms consistently with the classification nomenclature and scheme.*
- *that other work commitments allow time for completion of mapping.*

4. Data management.

4.1 GIS

4.1.1 Convert linework to digital form by:
  a) scanning
  b) manual digitising

4.1.2 Transfer digital data to GIS environment

4.1.3 Polygonisation:
  a) attributing
  b) eliminating
  c) map joining
  d) dissolving
  e) clipping

4.1.4 Import Cadastral data

4.1.5 Provisional plot; Return to DA for field checking

4.1.6 Editing, archiving, meta-data information.

4. Data management. (continued)

Conversion of linework by scanning maintains any errors introduced by the DA. Manual digitising introduces further spatial errors.

Direct use of manual linework introduces a large component of tedious and time consuming GIS editing. Decisions on minor changes are made by the GIS operator without adequate knowledge of the local conditions. These may only be minor but will introduce problems with future mapping comparisons where reasons for change may no longer be apparent.

6.8.3 Mapping Method #2: **Conventional visual image interpretation, alternate GIS data entry** (with linework used as guide to directly enter polygons over registered imagery in GIS format).

Workflow:

1. **Data:**

Rectification, subset, etc. as for Mapping Method #1.

Only 3 bands required for hardcopy product; 4 or 5 bands may be used for later on-screen enhancement.

2. **Hardcopy**

Hardcopy at 1:100 000 is considered adequate (can include here hardcopy overlays of cadastre)

Distribute to regional DAs.

3. Mapping

Linework

Same problems in interpretation of imagery and conforming to classification schema as in Method #1.

Accuracy of linework is not as important here as the linework is to be used as guides for GIS operator.

4. On screen mapping and GIS

Return of linework for digitising.

Digitising is done directly to screen using TM imagery as an underlay. Linework from DA is used as a guide by operator who is able to zoom to higher resolution (eg. 1:25 000) and more accurately place line boundaries (thereby conforming with mapping standards for 1:100 000 presentation).

Decisions on placement will still be made by operator who may or may not have adequate local knowledge.

Other GIS-based information deemed relevant can be incorporated to assist in operator placement of boundaries (eg. cadastral information). Combined operations of data entry, interpretation and GIS editing are likely to be limited by the number of skilled GIS operators available.

6.8.4 Mapping Method #3: **Mapping directly to image map-base in field** (no hardcopy linework)

Workflow:

1. Data

1.1 TM imagery as Methods 1 and 2 4 band

Rectification, subset, etc.

2. **Hardcopy**

Distribute to DAs

3. **Digital data**

Input data to portable field software (*eg.* TerraScan or ArcView)

Provisional examination of imagery by operator. Import ancillary GIS data - Land Use defined by cadastre, Forest boundary, etc., in digital overlay form, registered to imagery.

4. Mapping

4.1 Project team visit area (or workshop).

DA refers to hardcopy.

DA or operator draws direct to screen with DA advice.

Not necessary to complete complex boundaries, eg. boundary of forest, these can be shown on screen as guide and overlapping polygon completed. This is later clipped by GIS operators using same data. Polygons stored in DXF or Arc/Info format (already geo-registered) and exported to any of the GIS system (by modem if required).

Polygons can be labelled by operator.

4.2 DXF files returned to GIS operator - imported electronically (concurrent land uses can be mapped at the same time using a separate DXF overlay).

Using Project teams

With a dedicated project team:

a) identify approx 12 to 16 strategic regional centres for mapping workshops
b) either DA attend centre or team goes to DA
c) prior to mapping workshop:
   i) TM imagery, registered and subset by 1:100 000 mapsheet
   ii) cadastre (*eg.* public/private land boundaries) subset from GIS as DXF file
   iii) structural vegetation map or Tree Cover boundaries subset as DXF overlay
   iv) any other GIS-based information deemed relevant on overlay
   v) hardcopy imagery sent to DA for familiarisation

d) all information ported to TerraScan or ArcView on portable system. Hardcopy provided for reference/overview.

Digital data displayed on screen with structural vegetation overlay. DA indicates Land-use mapping boundaries from local knowledge. Project operator maps linework direct to screen forming DXF file (already registered for direct porting to GIS).

DXF file returned to GIS section (by modem?) and clipped by structural vegetation boundaries; cadastre added and attributes added; should be little need for additional editing (*eg.* slivers, etc.).

Advantages of Project Team in Method 3

1. The Project Team maintains the momentum of the mapping program. A DA working alone may shift the mapping program down the priority list when confronted by local problems. A dedicated mapping team takes the mapping to the DA, and provides expertise in computer mapping. DA is only there to advise through local knowledge and does not have to learn computing skills.

2. The Project Team provides consistency of interpretation of classification scheme, in direct consultation with local expert.

3. The digital data can be enhanced on-site with different band combinations, zoom enlargement to equivalent scale of 1:25 000 or better. The resultant linework is much more accurate than penwork at a scale of 1:100 000.

4. DA supplied with other data types, *eg.* structural vegetation type, park boundaries, cadastre, land systems, etc., in digital form to assist boundary location and attributing, *ie.* all mapping decisions are made by the DA, not the GIS operator who may have limited competency in identifying land use.

5. DXF file overlays (cadastre or structural vegetation from Task 1) can be used to assist mapping by defining complex boundaries (*ie.* complex boundaries need not be followed but clipped in later). The resultant mapping is also in DXF file format (standard input to most GISs).

   (Note: the linework is already registered precisely to mapbase and therefore no GIS editing for slivers, etc., is required).

6. This approach is equivalent of taking total Remote Sensing and GIS operational skills and information base to the regional office or into the field. Software can be field portable on laptop either with attached GPS or geo-registered data - enabling field sites to be identified directly on display of satellite imagery.

Disadvantages

1. cost of workshops

2. travelling for project team

3. cost of software

4. assumes a high level of local knowledge by DA. If this is not the case, a greater component of field time (as against office contact) is required, with consequent cost ramifications.

CHAPTER SEVEN

COSTING FOR LAND-USE MAPPING PROGRAM

7.1 SUMMARY TEMPLATE

The various options for data acquisition and pre-processing, for hardcopy production, for the mapping component, and for the GIS component of data handling have been costed out and presented as a series of templates. These are based on certain assumptions as to costs per mapsheet, per unit travel or per night accommodation.

The Summary Template below provides the overview, while the following individual templates provide the detailed cost breakdown.

Summary Template

Data	Hardcopy	Method #1	Method #2	Method #3
Template 1 $281 567	*Template 2* $157 161	Mapping *Template 3* $356 407	*Template 3B* $356 407	*Template 3C* $223 418
Sub Total	$438 355	GIS		
		Template 4A $517 261	*Template 4B* $379 994	*Template 4C* $179 486
	Sub Totals	$873 668	$736 401	$401 904
	Supervision @ 20%			
	labour component SCI-4	$185 625	$192 151	$99 338
	Woody/Non-woody vegetation map	$263 934	$263 934	$263 934
	Sub Totals	$1 323 227	$1 192 486	$765 176
	Project Co-ordination 10%	$1 455 549	$1 311 734	$841 693
	Data costs from above	$438 355	$438 355	$438 355
	TOTALS	**$1 893 904**	**$1 750 089**	**$1 280 048**

Costs not included

1. Allowance for interstate travel
2. Computer hardware
3. Computer depreciation

7.2 BASES FOR ESTIMATION OF COSTS

The estimated times for processing are based on methods used by the Remote Sensing and GIS Sections of the Natural Resources Systems Branch, Department of Conservation and Natural Resources, Victoria; using ERMapper image analysis software and ARC/INFO GRID module installed on networked SUN Unix workstations. **At this stage these costings are indicative only, with variations necessary according to computer processing infrastructure and the combination of mapping methods ultimately applied.**

The following costs have been assumed in the preparation of the individual templates for the assembly of detailed project costing:

7.2.1 Salaries

Project team based on	SCI-2 (2nd increment)	$35 668
	SCI-4 supervision	$46 219

7.2.2 On-costs

With approximately 36% on-costs (details differ with each state)

SCI-2 = $186.40/day

SCI-4 = $241.70/day

7.2.3 Data

473 1:100 000 mapsheets

64 TM images 4 channels of data @ $2 950 per scene

5 channels @ $3 750 per scene

(bulk purchases may attract a substantial discount)

7.2.4 Accommodation

$107.25/night

7.2.5 Vehicle costs

100 000 kms @ $0.45¢/km

7.2.6 Workshops

Assumption for workshops at 16 key locations in catchment equates to approximately 30 mapsheets to be processed at each location.

7.3 COST TEMPLATE 1

Acquisition and pre-processing of imagery		
1.1	Digital satellite image data Level 5 processing, 4 bands 64 scenes @ $2 950 each scene	$188 800
	Level 5 processing, 5 bands 64 scenes @ $3 750 each scene	$240 000
1.2	Geo-registration	
	1.2.1 Collect grid control points from best available reference	
	1.2.2 Complete first order affine transformation	
	For RMS error <0.8 64 scenes @ 2 days/scene: 128 days	$23 859
1.3	Subset imagery and store in GIS library	
	1.3.1 Embed mapsheet boundaries	
	1.3.2 Subset to 473 x 1:100 000 mapsheets 5 mapsheets/day: 95 days	$17 708
TOTAL	**4 bands**	**$230 367**
TOTAL	**5 bands**	**$281 567**

7.4 COST TEMPLATE 2

Production of hardcopy imagery		
2.1	Image subsetting, enhancement, writing to tape 473 mapsheets @ 3 mapsheets/day: 158 days	$29 451
2.2	Negative production 473 @ $140 each	$66 220
2.3	Photographic Enlargement to 1:100 000 scale 473 @ $100 each	$47 300
	Second copy: 473 at $30 each	$14 190
TOTAL		**$157 161**

Recent advances in other hardcopy production methods, *eg.* electrostatic plotters, have resulted in the capacity to produce plots of near-photographic quality, with greatly reduced costs. The costs quoted above are for photographic quality prints. This may be substantially reduced according to the requirements of each mapping method or by the nature of the land-cover of the mapping area.

7.5 COST TEMPLATE 3A

Method #1: Mapping Component

3.1	Mapping		
	Interpretation of land use; Linework, attributing		
	473 sheets @ 3 days/sheet x 283.8 weeks or 1 419 days		$264 500
	Acetate overlay: 473 sheets @ $10/sheet		$4 730
3.2	Field verification		
	473 sheets @ 2 sheets/day	237 days	$44 176
	Travelling: approx. 150 km/sheet; 71 000 km @ 45¢		$32 000
	Personal expenses: 100 nights @ $110/night		$11 000
	(Number of nights reduced, assumes travel relatively local from regional centres)		
TOTAL			**$356 407**

7.6 COST TEMPLATE 4A

Method #1: GIS Component

4.1	GIS		
	4.1.1 Scanning or digitising		
	473 sheets @ $250/sheet		$118 250
	Supplementary scanning/digitisers:		
	100 sheets @ $250/sheet		$25 000
	4.1.2 Upload/transferring		
	473 sheets @ 3 sheets/day	148 days	$27 587
	4.1.3 Labelling, editing and checking		
	473 sheets @ 0.5 sheets/day	946 days	$176 334
	4.1.4 Import Cadastral style data		
	473 sheets @ 2 sheets/day	236.5 days	$44 083
	4.1.5 Plotting		
	2 x field sheets returned to DA for field verification		
	1 x GIS working, 1 x reference		
	4 x 473 sheets @ $20/sheet		$37 840
	4.1.6 Final editing, edge matching, map joining, dissolving, archiving		
	473 sheets @ 1 sheet/day	473 days	$88 167
TOTAL			**$517 261**

7.7 COST TEMPLATE 3B

Method #2: Mapping (same as for Method 1 for mapping phase)

1.1	Acquisition of Imagery		
	As per Template 1	4 Band	
		5 Band	
2.1	Production of Hardcopy Imagery		
	As per Template 2		
3.1	Mapping		
	As per Template 3A		$356 407
TOTAL			**$356 407**

7.8 COST TEMPLATE 4B

Method #2: GIS component

4.1	GIS		
	4.1.1 Download imagery from GIS library or storage media		
	473 sheets @ 5 scenes/day	95 days	$17 633
	4.1.2 Import cadastral style data		
	473 sheets @ 2 sheets/day	236 days	$44 083
4.2	Copy DA: linework direct to screen edit and attribute		

Note: land uses are more complex in the more humid parts (approximately 70%) of Basin and the linework is consequently more complex. In the drier interior (approximately 30%) of Basin, the land use is dominated by large scale grazing -- defined by leasehold boundaries and the linework is correspondingly less complex. Therefore the costed time for copying linework has been correspondingly reduced along these percentages.

143 sheets @ 1 day/sheet	1 133 days	
330 sheets @ 3 day/sheet	(aver. 2.4 day/sheet)	$211 191

4.3	Plotting		
	2 x field sheets set to DA for checking		
	2 x 473 sheets @ $20/sheet		$18 920
4.4	Final editing, archiving		
	473 sheets @1 day/sheet	473 days	$88 167
TOTAL			**$379 994**

7.9 COST TEMPLATE 3C

Method #3: Mapping

1.1	Data as Template 1		
2.1	Hardcopy as Template 2		
2.2	Distribute hardcopy to regions		
3.1	Export image data from GIS library or storage media to ArcView or TerraScan format on laptop		
	473 sheets @ 5 sheets/day	95 days	$17 633
	3.1.1 Export Cadastre, structural vegetation boundaries to DXF format - import to TerraScan or to floppy disks		
	473 sheets @ 5 sheets/day	158 days	$29 451
4.1	Visual interpretation by DA		
	2 map/day x 2 persons (DA and operator)		$88 167
	158 x 2 = 315		
5.1	Field checking minimised		
	473 sheets @ 1 day/sheet	473 days	$88 167
TOTAL			**$223 418**

7.10 COST TEMPLATE 4C

Method #3: GIS component

6.	Mapping		
	6.1.1 Import DXF into GIS		
	Edit and attribute, clip by cadastre, etc.		
	473 sheets @ 2 sheets/day	237 days	$44 083
	6.1.2 Plotting		
	2 x field sheets to DA		
	2 x 473 sheets @ $20/sheet		$18 920
	Note: If the appropriate software is held in the office, this operation can be replaced by electronic transfer of data @ (say) 10 sheets/day		
	6.1.3 Final editing archiving		
	473 sheets @ (minimum) 2 sheets/day	237 days	$44 083
	Travelling 100 000 km @ 45¢/km		$45 000
	(includes project group and DA field checking)		
	Accommodation 240 days @ $110/day		
	16 locations x 30 maps @ 2/day		$26 400
TOTAL			**$178 486**

CHAPTER EIGHT

RECOMMENDATIONS

8.1 A COMBINED LAND-USE AND VEGETATION MAPPING STRATEGY

One of the primary aims of the natural resource knowledge sets being collected for the management of the Murray-Darling Basin is to provide monitoring information, both for monitoring the state of the Basin and for monitoring the effectiveness of policy and works. This assumes that at least a second mapping exercise will cover the Basin to identify any trend.

The data used for the Task 1 project is for the period 1989-90. If the Land-use mapping project were to go ahead, it would not commence until about 1995. Given the dynamic nature of land-use, it would be very difficult to verify land-uses inferred from 1990 data in key areas, and indeed would be misleading. It is strongly recommended that any land-use mapping only be attempted using current data. This would require the purchase of an extensive new data set but would allow for the integration of both the Land-use mapping and for the update of the structural vegetation data set.

8.2 RECOMMENDATIONS

1. The proposed Land-use classification, principles and structure (pending review) be adopted as the standard framework for collection and assembly of land-use information in the Murray-Darling Basin.

2. That the Commission endorse in principle and subject to a detailed project specification, a program of Land-use mapping for the Murray-Darling Basin based on the visual interpretation of 1995 Landsat TM data, supplemented where necessary by higher resolution data types or derived attribute data.

3. That one or more pilot projects be instigated to test the relative accuracies of the mapping methods proposed and to more tightly define the project costs and methods. In particular, the practicality of field based computer mapping techniques based on TerraScan and ArcView style software packages should be assessed. Several pilot project will allow testing of both the classification and the methodology in a range of environments.

4. That Woody/Non-woody vegetation cover mapping projected for 1996 be combined with the land-use mapping exercise. This cover type represents the most significant and complex mapping boundary between major land-use classes. Inclusion of this digitally derived boundary adds significant efficiencies to the land-use mapping procedure.

The Woody/Non-woody vegetation layer (1995) can be overlayed with the Woody/Non-woody vegetation layer for 1990 to indicate area change (monitoring capability). Likewise it can be overlaid on the Structural cover to indicate change by structural type (given that structure itself is less likely to change than area cover).

The derived and verified 1995 Land-use can be overlaid on the raw 1990 imagery as an indicator of 1990 land-uses, and hence change. This 'retro-mapping' may not achieve the accuracies of using current imagery but will give good quality indicative information on land-use changes for the 1990-95 period.

5. That an inventory of relevant GIS boundary data be compiled. Given the importance of secondary data sources, in particular cadastral information, in defining certain land use types and in the contribution to the efficiency of mapping procedures, an inventory of relevant GIS boundary data and an assessment of the relative accuracies of the various data sources identified is likely to improve the effectiveness and efficiency of data capture.

6. That an Inter-agency Reference Group be established to facilitate the use and further development of the land use classification. The functions of this Interagency Group should include:

   - further development of the Management Factor data filed(s) and means of recoding Management Factors
   - resolution of anomalies in definition and allocation of activities as mapping proceeds
   - development of a data coding scheme
   - review and revise definitions
   - approve expansion of the land use classification structure as required and appropriate
   - specification of mapping units, *eg.* minimum polygon size, use of point and line features.

   Such a group could operate by correspondence, or meet only in conjunction with other relevant gatherings.

7. The proposed schema be forwarded to ANZLIC for review before finalisation of its Draft National Land Use Codes. Such a review should include issues relating to GIS standards, protocols and meta-data requirements as well as the basic structure of land use classes in rural lands.

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APPENDIX A

A LAND-USE CLASSIFICATION FOR THE MURRAY-DARLING BASIN:

DEFINITIONS AND DESCRIPTIONS

A1 PRIMARY CLASSES

Five Primary Classes are recognised, listed in general increasing level of intervention and potential level of impact on the natural landscape. It was found necessary to adopt some variations to this general principle in order to arrive at a logical and functional grouping of land-uses.

Each of the classes established is, for the sake of convenience, given a brief title. This title is intended to be indicative only of the range of land-use and management systems included. The accompanying definitions and descriptions should be consulted where the allocation of a particular land-use is in question or where apparent discrepancies or anomalies in grouping emerge. The classification is intended to be flexible such that new land-uses or management systems can be accommodated so long as there is no conflict with other existing items.

A1.1 CONSERVATION AND RECREATION USES

The land is used primarily for conservation and/or recreation purposes, based on the maintenance of the essentially natural ecosystems present.

There is generally a relatively low level of intervention in such land, with the anticipated consequence that there will be little land or water degradation as a result of the use of such land. This must be qualified by recognition that much of the land subject to these uses is quite incapable of supporting more intensive uses (and therefore intervention in the landscape) and often bears the scars of such use. Such land may also have limited capability for many recreation-based uses because of the inherent fragility or instability of the natural ecosystems. There may also be change in the condition of the land in response to natural process in isolation from any imposed use.

The land may be reserved by government specifically for such purposes, with the form of reservation reflecting the degree of protection afforded to the natural ecosystems -- ranging from Wilderness Areas and National Parks, where the prime objective is the maintenance of essentially natural ecosystems, to Alpine Resorts, where there is necessarily much vegetation and earth disturbance for access, ski-runs and lodges.

Some land may be simply unused by either a conscious decision of government or by the landowner, or by circumstance. Such land has been included in the Conservation and Recreation category as it would be subject to a low level of intervention under current circumstances. Naturally, the use of such land may change over time, as may the use of any other land.

A1.2 PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS, AND RELATED USES

This land is used primarily for primary production, based on limited change to the native vegetation structure.

Such land is generally subjected to definite but relatively low levels of intervention. As described for the previous class, relatively low levels of land or water degradation would be expected on such land, tempered by the recognition that, in many cases, the reason this land is not used more intensively (and therefore subject to a higher level of intervention) is its limited capability for such more intensive uses. this land too may bears the scars of previous attempts to use it beyond its capabilities.

The structure of the native vegetation generally remains intact despite some deliberate modification, however the floristics of the vegetation may change markedly. Where the native vegetation structure was savanna, open woodland or grassland, the land may be grazed for food or fibre production. Where the native grasses have been deliberately and extensively replaced with improved species, the use should be treated as primary production (see following Primary Classes).

The category includes land with woodland or forest managed primarily for timber production or the production of allied substances (eucalyptus oil, cut flowers, foliage, or broom/brush). It also includes tree and/or shrub plantations established for the express purposes of later harvesting. While this use may initially appear to fit more comfortably with farming/cropping, the level of intervention is more similar to other land-uses in this class than in the farming categories.

A1.3 PRIMARY PRODUCTION FROM DRYLAND AGRICULTURE

Land in this class is used primarily for primary production, based on dryland farming systems.

The level of intervention has increased to the extent where native vegetation has largely been relaced by introduced species through clearing, sowing of the new species or the dominance of volunteer species, and often the application of fertiliser that has rendered the native vegetation unable to compete with the introduced species. Stock are also likely to have had a strong influence by preferentially

eating out the more palatable native species, again rendering them at a competitive disadvantage with the introduced or other native species. The class also includes the grazing of certain native species (such as Mitchell Grass) which are recognised as valuable pasture species.

While the level of production has often risen markedly from this land compared to its native state, the risk of land or water degradation has often also increased markedly.

The range of activities in this category includes pasture production for stock, cropping and fodder production, and a wide range of horticultural production.

A1.4 PRIMARY PRODUCTION FROM IRRIGATED AGRICULTURE

Land in this category is used primarily for primary production, based on irrigated farming systems.

The level of intervention in the landscape has progressed well beyond the replacement of native vegetation with introduced species. The intervention includes the application of water to encourage additional growth over normally dry period, such that many of the farming systems on irrigated land now bear little resemblance to the dryland systems from which they developed.

The potential impact on the landscape has increased enormously, with the potential to lift groundwater levels, both locally and regional (depending upon the hydrogeology of the land) and concomitant mobilisation of salt stores already in the ground. The net result may be, apart from markedly increased production, threats to sustainable land-use both on- and off-site through either or both waterlogging and salinity.

A1.5 INTENSIVE USES

Land in this class is likely to be subject to extensive modification, generally in association with closer residential settlement -- residential/commercial/public service/industrial uses, etc.

The common feature is the potential level of modification of the landscape rather than the use itself. The level of intervention may be sufficiently high as to completely remodel the natural landscape -- the vegetation, the surface and groundwater systems and the surface of the land itself.

The extent of modification reaches a peak with urban development where the run-off characteristics of the land are extensively modified, the nutrient balances are totally changed, there may be substances discharged into the environment that were never present before, and

the use has totally remodelled the landscape. The effects of this may be felt both locally (although the modification may rightly be seen as an essential part of the use) and regionally, particularly in the downstream parts of the surface water system.

This category is somewhat of a mixture of uses -- the common theme being the extent to which the landscape may be remodelled. Not all uses, or all occurrences of a particular use, will involve total modification of the natural landscape. However the potential is there, and it needs to be recognised.

A2. SECONDARY AND TERTIARY CLASSES

The Secondary and Tertiary Classes are listed, in general, in increasing order of potential levels of intervention in the landscape.

A2.1 CONSERVATION AND RECREATION

A2.1.1 Conservation Reserves

This class of uses is based on the explicit assignment of conservation objectives by the managing agency (often government but sometimes by the private landowner).

The classes recognised are based on the system of reservations established by governments -- which unfortunately are not consistent across states. This will produce an extended list of classes, greater than would otherwise be necessary to cover the range of uses. For most practical purposes, it could be collapsed into a single class, even though it will be a relatively cheap set of data to capture.

In general, the listing provides for those reserves where the protection of conservation values is of paramount importance (and thereby less intervention with natural ecosystems) before reserves with multiple use objectives.

Wilderness Areas -- as defined by statute or regulation
Reference Areas -- as defined by statute or regulation
Flora and Fauna Reserves -- as defined by statute or regulation
National Parks -- as defined by statute or regulation
Aboriginal Heritage Areas -- as defined by statute or regulation
Other Conservation Reserves -- as defined by statute or regulation

These classes may need to be modified to conform with the accepted IUCN categories.

A2.1.2 Closed Water Supply Catchments

This covers land where there has been a conscious decision by government of the managing authority to close all or part of the catchment to other activities in the interest of protection of the water supply.

A2.1.3 Unused Land

This class of uses is based on recognition that there are areas of land that are unused (in the context of the Prime Use) but may be subject to Ancillary Uses.

The status of the land may be the result of a deliberate policy decision by the managing agency or simply the result of circumstances. In the latter case, the land is usually available for use but for various reasons, remans 'unused'. The status of this land could change readily.

Dense remnant native vegetation on private land has been included in the class to provide a clear means of identifying substantial areas of such land. Such land may be grazed by domestic stock and there may be limited extraction for firewood or for posts or poles for on-farm use. In allocating land to this class, consideration must be given to the level of intervention that the land receives.

Remnant Native Vegetation -- land carrying essentially native vegetation and not committed directly to other purposes. While stock may have access to such land, the density of tree cover precludes pasture growth to a large degree. Such land may in time be used for intermittent post- or pole-cutting or firewood production, and it should be treated as 'unused' unless there is clear evidence of such use at the time of assessment. This class will occur only on private or leasehold land. Considerable discretion will be required to ensure that trivial areas of remnant native vegetation are not recorded and to maintain separation of *Remnant Native Vegetation* and *Unused Land*.

Pastoral Leases -- (public) land available for leasing for pastoral or other purposes but, for various reasons, the lease(s) have not been taken up.

Exclusion or Rehabilitation areas -- land closed to active uses for quarantine purposes or for rehabilitation purposes.

Other -- for unused land not adequately covered above.

A2.1.4 Multiple Use Areas

This class covers land that is subject to a variety of uses, although conservation of the native landscape is generally a predominant objective.

State Parks -- as defined by statute or regulation
Regional Parks -- as defined by statute or regulation
Other -- land not adequate provided for above.

A2.1.5 Recreation Areas

Alpine Resorts -- areas of land dedicated by statute or regulation to alpine recreation, but excluding areas of major disturbance: accommodation, facilities and associated ski-runs (these should be placed in the Intensive Uses Class)
Other Resorts -- commercial recreation areas, usually involving provision of accommodation, but necessarily retaining a semblance of the natural ecosystem. (Totally modified areas such as sports grounds should be classified as Intensive Uses/Recreation)
National Parks -- areas reserved or known as National Parks, but where the recreation objectives overshadow the conservation objectives.
Other -- land not adequate provided for above.

A2.2 PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS, AND RELATED USES

A2.2.1 Rough Grazing

This class provides for recognition of land-uses based on grazing by domestic stock on native vegetation with limited or no attempt at pasture improvement.

It is virtually inevitable that some changes in species composition and even structure will have occurred, however the basic vegetation type is generally still evident. There may have been some stick-raking or aerial seeding, but no cultivation. Stock management is limited.

Semi-arid rangeland -- broad-acre grazing but sheep or cattle on native woodland or savanna
Semi-arid shrubland -- broad-acre grazing by sheep or cattle on native shrubland (particularly *chenopod* shrubland)
Semi-arid grassland -- broad-acre grazing by sheep or cattle on native grasslands
Tablelands -- the more humid areas of land subject to rough grazing, such as those of the New England Tablelands
Alpine -- seasonal grazing by cattle on alpine grass and shrublands
Forest-riverine -- grazing by cattle in riverine forests, dominantly red-gum forests
Forest-montane -- grazing by cattle in montane forests
Other -- rough grazing not adequately covered above.

A2.2.2 Production Forest

This land is managed for production from a relatively natural landscape, or from plantations. The common feature is the relatively infrequent or limited interference with the natural landscape.

Brush/broom -- land subjected to regular harvesting of broom/brush-type vegetation, including flowers and foliage

Eucalyptus oil -- land subjected to regular harvesting of vegetation for the purpose of extraction of eucalyptus oil

Firewood -- forest where the dominant harvesting of wood is for firewood or charcoal

Hardwoods -- forest of hardwood species where the dominant form of harvesting is the extraction of timber for milling or further processing

Cypress Pine and other native softwoods -- forest of softwood species (predominantly cypress pine) where the dominant form of harvesting is the extraction of timber for milling or further processing

Mixed Hardwoods and Softwoods -- mixed forests of naturally occurring stands of hardwood and softwood species where the dominant form of harvesting is the extraction of timber for milling or further processing

Riverine forest -- riverine forest (predominantly redgum along southern rivers) where the dominant form of harvesting is for milling or sleeper/post production

Rainforest[4] -- forest of rainforest species where the dominant form of harvesting is the extraction of timber for milling or further processing

Other -- for forest uses not adequately covered above.

A2.2.3 Plantations

This class provides for recognition of land where plantations of trees or shrubs have been established to provide for forest products, often previously obtained from native forests or shrublands.

Brush/broom -- land subjected to regular harvesting of broom/brush-type vegetation, including flowers and foliage

Eucalyptus oil -- plantations subjected to regular harvesting of vegetation for the purpose of extraction of eucalyptus oil

Firewood -- plantations where the dominant harvesting of wood is for firewood or charcoal

Native Hardwoods -- plantations of native hardwood species where the dominant form of harvesting is the extraction of timber for milling or further processing

[4] This class is included for completeness, however it is recognised that most forest management agencies no longer provide for the harvesting of rainforests.

Native Softwoods -- plantations of native softwood species where the dominant form of harvesting is the extraction of timber for milling or further processing

Native Riverine species -- plantations of native riverine species where the dominant form of harvesting is for milling or sleeper/post production

Exotic Hardwoods -- plantations of exotic hardwood species where the dominant form of harvesting is the extraction of timber for milling or further processing

Exotic Softwoods -- plantations of exotic softwood species where the dominant form of harvesting is the extraction of timber for milling or further processing

Rainforest -- plantations of rainforest species where the dominant form of harvesting is the extraction of timber for milling or further processing

Other -- for plantation uses not adequately covered above.

A2.3 PRIMARY PRODUCTION FROM DRYLAND AGRICULTURE

This class provides for the identification of land-uses based on dryland farming systems. The class excludes any farming based on irrigation (see class below).

The farming systems are dependant upon either the utilisation of productive native pastures (such as Mitchell Grass) or the replacement of native vegetation by other species seen as being more productive. The systems involve the production and harvesting of the vegetation for its own sake for use on- or off-farm, or for the conversion to meat or fibre for later sale and use off-farm.

A2.3.1 Pasture

This class covers the various forms of pasture production, based on a significant degree of modification of the initial native vegetation.

Native/Semi-improved native species -- including Mitchell Grass grasslands of NSW and Qld

Improved pasture - annual species -- dominantly annual ryegrass and subterranean clover

Improved pasture perennial species dominantly phalaris/cocksfoot/perennial ryegrass and white clover

Leguminous pasture species -- dominantly lucerne

Multi-layered pasture systems -- fodder shrubs/trees (such as tagasaste) in a pasture

Forage -- forage species (maize, sorghum, etc.) direct-seeded into an existing pasture

Other.

A2.3.2 Agroforestry

This class covers the various combinations of tree growing in conjunction with pasture, fodder or crop production.

Improved pasture - annual species
Improved pasture - perennial species
Leguminous pasture species -- dominantly lucerne.
Cropping -- various.

A2.3.3 Cropping/Pasture Rotations

This class includes land managed by a range of farming systems comprised a mixture of pasture production and cropping enterprises, generally in predictable if not constant rotations.

These rotations may vary markedly over relatively short distances in response to both changes in the nature of the land and on preferences of the land manager. They may also change over time in response to market conditions. Nonetheless, the mix of enterprises in the rotation can have a significant impact on both the land and water regime. The classes described below therefore provide for a wide range of rotations.

Improved pasture - annual species
Improved pasture - perennial species
Winter cereals - wheat, barley, oats, rye, etc.
Summer cereals - maize, sorghum, etc.
Oilseeds - sunflower, safflower, canola, etc.
Grain legumes - vetch, field peas, faber beans, etc.
Lucerne
Other

The length of the rotation, which can be just as important as the mix of enterprises, can be recorded in the Management Factors section of the dataset.

A2.3.4 Permanent Cropping

This class includes land used solely for cropping (including fodder) without the use of stock.

Some areas of land are used exclusively for cropping, either because the land is able to accommodate such an intensive use because of its intrinsic nature, or because the pasture phase is not economic or not relevant to the land manager. Fodder production (such as lucerne hay) is treated as a crop -

there is no harvesting by stock involved. This category provides for a range of mixes of enterprises:

Winter cereals - wheat, barley, oats, rye, etc.
Summer cereals - maize, sorghum, etc.
Oilseeds - sunflower, safflower, canola, etc.
Grain legumes - vetch, field peas, faber beans, etc.
Lucerne
Cotton
Other

A2.3.5 Horticulture

This class covers the wide range of enterprises that fall into the horticulture category, each with its own set of management practices.

The relatively high use of fertiliser and cultivation for weed and moisture control as well as sowing or harvesting is common to many. The following list endeavours to identify the major horticultural crops -- major in terms of either area involved or extent of intervention in the landscape.

Orchard - stone fruit
Orchard - pome fruit
Orchard - citrus
Orchard - other
Nuts
Vineyard - grapes
Vineyard - hops
Berry fruits
Vegetables - tomatoes
Vegetables - potatoes
Vegetables - corn
Vegetables - peas/beans
Vegetables - other
Plant/tree nurseries
Cut flowers
Other

A2.4 PRIMARY PRODUCTION FROM IRRIGATED AGRICULTURE

These classes include those agricultural uses that depend on irrigation as some stage. It includes those uses that require only one or two irrigations per year, through to those uses that are totally dependant on irrigation water for much of the growing season.

Information on the rate of application of water -- an important determinant of the likely impact of irrigation on the landscape -- can be recorded in the Management Factors section.

A2.4.1 Pasture

These classes cover the various forms of pasture production, based on a significant degree of modification of the initial native vegetation and the application of irrigation water at some stage of the year.

Improved pasture - annual species -- dominantly annual ryegrass and subterranean clover
Improved pasture - perennial species -- dominantly phalaris/cocksfoot/perennial ryegrass and white clover
Leguminous pasture species -- dominantly lucerne
Multi-layered pasture systems -- fodder shrubs/trees (such as tagasaste) in a pasture
Forage -- forage species (maize, sorghum, etc.) direct-seeded into an existing pasture
Other

A2.4.2 Agroforestry

This class covers the various combinations of tree growing in conjunction with pasture, fodder or crop production.

Improved pasture - annual species
Improved pasture - perennial species
Leguminous pasture species -- dominantly lucerne
Cropping -- various

A2.4.3 Cropping/Pasture Rotations

This covers land subject to various farming systems comprise a mixture of pasture production and cropping enterprises, generally in predictable if not constant rotations with an irrigation component in either the cropping or the pasture phase.

These rotations may vary markedly over relatively short distances in response to both changes in the nature of the land and on preferences of the land manager. They may also change over time in response to market conditions. Nonetheless, the mix of enterprises in the rotation can have a significant impact on both the land and water regime. The various commodities listed below therefore provide for a range of classes:

Winter cereals - wheat, barley, oats, rye, etc.
Summer cereals - maize, sorghum, etc.
Oilseeds - sunflower, safflower, canola, etc.
Grain legumes - vetch, field peas, faber beans, etc.
Improved annual pasture species - ryegrass, subterranean clovers

Improved perennial pasture species - phalaris/cocksfoot/perennial ryegrass/white clover, etc.
Leguminous pasture species -- dominantly lucerne
Other

A2.4.4 Permanent Cropping

Some areas of land are used exclusively for cropping supported by irrigation, either because the land is able to accommodate such an intensive use by its intrinsic nature, or because the pasture phase is not economic or not relevant to the land manager. Fodder production (such as lucerne hay) is treated as a crop -- there is no harvesting by stock involved.

The various commodities listed below therefore provide for a range of classes.

Winter cereals - wheat, barley, oats, rye, etc.
Summer cereals - maize, sorghum, etc.
Oilseeds - sunflower, safflower, canola, etc.
Grain legumes - vetch, field peas, faber beans, etc.
Lucerne
Rice
Cotton
Tobacco
Other

A2.4.5 Horticulture

There is a wide range of enterprises that fall into the horticulture category, each with its own set of management practices. However, the application of irrigation, the relatively high use of fertiliser and cultivation for weed and moisture control as well as sowing or harvesting is common to many.

The following list endeavours to identify the major horticultural crops -- major in terms of either area involved or extent of intervention in the landscape. The categories used may require recording as multiple uses to fairly reflect the complexity of actual land use.

Orchard - stone fruit
Orchard - pome fruit
Orchard - citrus
Orchard - other
Nuts
Vineyard - grapes
Vineyard - hops
Berry fruits

Vegetable - tomatoes
Vegetables - potatoes
Vegetables - corn
Vegetables - peas/beans
Vegetables -other
Plant/tree nurseries
Cut flowers
Turf
Tobacco
Other

A2.5 INTENSIVE USES

These classes cover the more intensive uses of the land, and particularly those uses that involve the greatest (potential) impacts on the landscape.

The label 'intensive uses' is applied because they all potentially involve intensive modifications of aspects of the natural landscape, often but not exclusively, the direct consequence of aggregations of people, meeting their day-to-day needs. For example, mining and extractive industries are not immediately related to settlements, but they can involve total remodelling of the landscape and are there potentially similar in impact to other intensive, urban-based land-uses.

A2.5.1 Rural Living

This may be quite a varied class, but generally covers those residential uses, clearly not closer urban residential use, depending upon septic tanks and on-site absorption systems for waste treatment and disposal of domestic wastes, and where grazing by domestic stock is more closely related to recreation than the production of income. It is likely that the allotment size will be in the range of 0.5 ha to 20 ha.

Some discretion will be required in discriminating between this category and either remnant native vegetation, grazing or grazing/cropping classes. The potential for production of significant income *vs* recreational or lifestyle aspects should be the prime basis for such discrimination.

A2.5.2 Urban Use

There is a wide range of activities in an urban setting. While the potential for complete modification of the landscape, is common, the potential to generate polluted run-off is also common. Different activities have the potential to impose additional impacts on the landscape.

Residential -- generally allotments of less than 0.4 ha and sewered; houses, flats, hotels, etc.
Commercial services -- shops, markets, etc.
Manufacturing and industrial -- factories, workshops, foundries, etc.
Public services -- those functions usually undertaken by government and allied organisations, including education, defence, community services, etc.
Recreation and culture -- sportsgrounds, camping grounds, swimming pools, museums, places of worship, etc.
Other -- relevant uses not adequately covered above

A2.5.3 Institutional Use

Defence -- significant areas of land devoted to defence purposes, such as tank ranges, testing areas, firing ranges, etc.
Research Stations -- government and non-government research and development areas
Other -- relevant uses not adequately covered above.

A2.5.4 Utilities

Electricity generation/transmission -- coal-fired, gas-fired, solar-powered, wind-powered or hydro power stations, sub-stations, powerlines, etc.
Water storage/treatment -- dams, reservoirs, water treatment plants (**Note**: waste-water facilities should be listed under the class: Waste Treatment and Disposal)
Gas treatment/storage/transmission -- facilities associated with the gas production and supply
Other -- relevant uses not adequately covered above.

A2.5.5 Transport and Communications

Aerodromes/airports -- facilities associated with air transport
Roads/freeways -- facilities associated with land transport
Rail-yards/rail lines -- facilities associated with rail transport
Ports and associated facilities -- facilities associated with water transport
Navigation/communication facilities -- radar stations, beacons, etc.
Other -- relevant uses not adequately covered above

A2.5.6 Intensive Primary Production/Processing

This class covers a variety of uses, based on either intensive forms of primary production or processing of primary produce.

Intensive animal industry -- feedlots, dairies, piggeries, poultry sheds, etc.

Processing plants -- sawmills, pulp mills, abattoirs, etc.
Other

A2.5.7 Mining/Extractive Industry

The mining and extractive activities, while occupying a relatively small area, may have a major impact on a much wider sphere. Discretion will be required to ensure that significant areas only are recorded.

Open cut mine -- deep workings where the area disturbed approximates the mine
Sub-surface mine -- major workings below the earth's surface, with a relatively small area of surface disturbance
Surface workings -- areas of major disturbance to relatively shallow depth, involving the use of heavy machinery; includes strip-mining and gravel extraction activities
Shallow surface workings -- mining or extractive industry generally at or near the surface, involving a minimum of heavy machinery, such as small-scale gold or opal mining
Overburden and/or spoil dumps/dams -- sites of deposition of overburden and spoil, of slime dams and related facilities
Other -- relevant uses not adequately covered above.

A2.5.8 Waste Treatment and Disposal

Aggregations of people inevitably lead to a need to treat and dispose of wastes. This may have a major impact on the landscape and any such land-use merits identification in its own right.

Storm-water -- facilities for the detention, treatment or disposal of storm-water
Landfill -- facilities for the disposal of solid inert wastes (but not including over-burden) by landfill
Solid garbage -- facilities for the disposal of putrescible wastes by landfill
Incinerators -- facilities for the incineration of any wastes
Sewage and associated wastes -- facilities for the storage, treatment and disposal of septic wastes.
Other -- relevant uses not adequately covered above.

A2.5.9 Other

Other -- land-uses not adequately covered in other classes.

(Note: discretion will be required to prevent this from becoming a large but trivial class.)

A3 MANAGEMENT FACTORS

As previously noted, the management of a particular use may be more important in determining the consequences for the landscape than the nature of the use itself. The proposed classification provides for the recording of key aspects of land management associated with various uses.

A3.1 Conservation and Recreation

Key management factors for conservation and recreation uses are:

Managing Agency -- State/State-Koori/State-Trust/Private
Access -- restricted/unrestricted
Fire regime -- routine management tool/undesirable/not relevant
Visitor facilities -- may require the use of surrogate indices such as facilities developed, or length of maintained tracks. etc., as a measure of visitor numbers

A3.2 Production from Relatively Natural Environments, and Related Uses

Key management issues for primary production from relatively natural environments are:

Rotation Length -- years
Silvicultural System -- clear felling/selective logging/strip thinning/patch cutting/other
Grazing system -- Permanent stocking/Rotational grazing/Seasonal grazing

A3.3 Primary Production from Dryland Agriculture

Key management issues for primary production from dryland agriculture are:

Cultivation machinery -- mouldboard/disc implements/tined implements/ blade plough-rod weeder
Rotation length -- years
Fallow system -- long fallow/short fallow/no fallow.
Mechanical fallow/Chemical fallow
Stock type -- dairy cattle/beef cattle/sheep/horses/goats/deer/other
Stocking rate -- head per hectare
Grazing system -- rotational grazing/permanent stocking/seasonal grazing
Soil conservation -- % subject to soil conservation works/% subject to soil conservation practices

(**Note:** there may be a case for converting stocking rates to a standard unit, *eg.* dry sheep equivalents.)

A3.4 Primary Production from Irrigated Agriculture

Key management issues for primary production from irrigated agriculture are;

Cultivation machinery -- mouldboard/disc implements/tined implements/blade plough-rod weeder
Rotation length -- years
Irrigation type -- flood/ditch/spray/trickle
Irrigation frequency -- number per year
Irrigation volume -- ML per hectare
Stock type -- dairy cattle/beef cattle/sheep/horses/deer/goats/other
Stocking rate -- head per hectare
Soil conservation -- % subject to soil conservation works/% subject to soil conservation practices
Water source -- irrigation district/private diversion/private storage/groundwater-artesian/groundwater-sub-artesian/waste water

(**Note:** there may be a case for converting stocking rates to a standard unit, *eg.* dry sheep equivalents.)

A3.5 Intensive Uses

Key management issues for the intensive uses are:

Area of hard surfaces: roads, rooves etc
Drainage works
Un-coordinated drainage

Generally settlement based uses are at a relatively small spatial scale and exhibit highly specific management regimes and effects, often closely related to modes of economic production. The draft ANZLIC land-use code appears to cover these areas quite effectively. It is the off-site effects of settlement based land-uses that can become significant in terms of areas affected.

A4 ANCILLARY USES

It is recognised that there is often a range of concurrent uses of any one parcel land. These Ancillary Uses too may have their impacts on the landscape and should not be ignored.

These Uses should be recorded in the same fashion as the Prime Use, the difference being the Ancillary Use is supplementary to the prime management objective of the land manager. Some discretion will be required to prevent the dataset being cluttered with trivial Ancillary Uses.

A5 OVERLAY USES

There is a further category of uses, termed Overlay Uses, where the use is independent of the Prime Use, often undertaken by people or groups remote from the land manager. These uses are not confined within property boundaries, and the spatial extent of land subject to such uses may not be capable of precise definition.

Such uses should not be recorded on the same map as the Prime Uses but should form part of one or more overlay maps that can be used in conjunction with the major maps of the dataset.

A5.1 Recreation

This class provides for the recording of informal recreation sites -- where there is no reservation for recreation, but where recreation is able to exert a significant influence on the landscape. It is assumed that most forms of recreation involve a degree of camping and vehicular access.

Where accommodation is provided by formal structures, the Prime Use of the land should be identified. Areas such as downhill ski-fields and associated facilities would be excluded from the class, but areas of snow used for cross-country ski-ing would be included, even though the Prime Use may be Conservation and Recreation/Conservation Reserves.

Bushwalking
Ski-ing
Fishing
Other

A5.2 Honey Production

While the sites used for beehives can be identified, the actual flight of the bees cannot. The simplest means of identifying the land-used for honey production is to locate the major beehive sites and draw circles around them, representing the approximate flight capability of the bees, modified by the likely presence of suitable bee fodder plants.

A5.3 Water Supply Catchments

Water for domestic, industrial, irrigation or power generation is important to contemporary society. The land-use for this purpose can and should be clearly delineated. Some discretion will be required to avoid trivial entries (*ie.* the identification of very large catchments to small run-of-the-river supplies).

Domestic
Irrigation
Industrial
Thermal power station
Hydro-power station
Other

A5.4 Conservation/Heritage Agreements/Listings

Certain areas of land are formally recognised for conservation or heritage values, irrespective of their Prime Use, and often covering more than one parcel of land.

World Heritage listing
National Estate listing
Conservation Covenant
Heritage Agreement
Other

APPENDIX B

LAND USE MAPPING: A DISCUSSION PAPER[5]

The Murray-Darling Basin covers one seventh the area of Australia. It hosts a range of significant natural resources, the economic value of which accounts for about one third of the national output from rural industries. It is vital to Australia's balance of trade and to the existence of almost 3 million people who depend directly on its natural resources.

For decades, attention has focussed on the River Murray and its salinity problems. It is now obvious that major problems extend throughout the basin, including degradation of the land, the natural environment and the human cultural environment. In 1987, it was estimated that losses to agriculture alone amounted to $260 million per year, and costs due to river salinity $35 million per year.

The River Murray Basin Ministerial Council was established in 1985. It provides a strategic focus for planning and management for the sustainable use of the Basin's natural resources. The Council is concerned with policy issues requiring common action by member Governments - Commonwealth, New South Wales, Victoria and South Australia.

In 1987 the Ministerial Council published a major study of the Basin's environmental resources that detailed the extent and severity of their degradation. This Environmental Resources Study became the base document for the Natural Resources Management Strategy (NRMS).

The NRMS provides a framework for coordinated effort across the Basin to halt degradation and to better manage the resources of the Basin.

Problems identified

Some of the most serious Community concerns noted in the Environmental Resources study relate to:

- rising salinity level in soils and streams;
- deteriorating quality of water supplies;
- land degradation (*eg.* soil erosion and acidification);
- decline and loss of native vegetation;
- loss of natural habitats;
- over commitment of, and competing demands for, water;
- supplies (*eg.* irrigation, industrial and recreational);
- cultural losses (*eg.* aboriginal heritage sites).

Strategic Aims

The aims of the Strategy are to:

- prevent further degradation of natural resources;
- restore degraded resources;
- promote sustainable use practices;
- ensure appropriate resource use planning and management;
- ensure a long term viable economic future for Basin dependants;
- minimise adverse effects of resource use;
- ensure self-maintaining populations of native species;
- preserve cultural heritage;
- conserve recreation values;
- ensure Community and Government cooperation.

(Extracted from the Executive Summary, Murray-Darling Basin Natural Resources Management Strategy, Murray-Darling Basin Ministerial Council, August 1990)

5 This Paper was prepared to promote thought and discussion as to the direction(s) that the land use mapping program should take. It provided the first conceptualisation of the ideas that are reflected in this report. The paper was distributed to attendees of the Workshops prior to the workshop. Despite its relatively unfinished nature, it proved extremely useful in crystallising ideas.

1. BACKGROUND

The Natural Resources Management Strategy adopted by the Murray-Darling Basin Commission has identified knowledge-based activities as a key component of the program for improved management of the natural resources of the Basin. It has identified, amongst its priority activities for funding:

- *digitising existing information on land capability, use and degradation information for manipulation and use by agencies and the Commission.*

This is in recognition of the need to manage our natural resources from an informed position -- knowledge gained from each of these datasets may contribute to improvements in management of the resources of the basin through better deployment of resources to support key activities, improvements in the development of sustainable land use systems or simply the selection of management practices which are appropriate for the various types of land.

Graetz, Fisher and Wilson[6] make a strong case for understanding of the nature, extent and trend of 'Landcover'[7] as a central component of improved management of the continent. Their thesis is:

- Landcover supports all terrestrial life by providing food and shelter

- Landcover is the surface that mediates the exchanges of energy and matter between the Earth's crust, the lithosphere, and the overlying atmosphere, including the Sun. In this interface, there is the biosphere -- the thin layer of living organisms of which the landcover is the terrestrial component. The components of this surface, of landcover, are most commonly vegetation and soil, and much less commonly, the water of wetlands.

- Landcover, because it is living influences the exchanges of energy and matter between the lithosphere and the atmosphere. These exchanges of energy and mass are more familiarly known as the Hydrologic Cycle, the Carbon Cycle, and the Nitrogen Cycle. Together this flow of energy to and from space and the cycling of elements comprises the Climate System and the Biogeochemical Cycles.

- any change in Landcover will have consequences for living organisms. These consequences can be either benign or detrimental and be influential in the short or long term.

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[6] Graetz D, R Fisher and M Wilson (1992). **Looking Back. The changing face of the Australian continent, 1972-1992.** CSIRO, Australia.

[7] Landcover is the surface that mediates the exchanges of energy and matter between the Earth's crust, the lithosphere, and the overlying atmosphere in which is included the Sun. In this interface, there is the biosphere -- the thin layer of living organisms of which the landcover is the terrestrial component. The components of this surface, of landcover, are most commonly vegetation and soil, and much less commonly, the water of wetlands.

Most European activities have implications for Landcover, either by harvesting it to support human needs (food, fibre or fuel), by its removal to support other activities (pasture development for domestic stock, also to provide food or fibre), or its inadvertent removal or debilitation (recreational pressure). Informed management of land and water resources demands consideration of the impacts of such activities on the whole system -- of Integrated Catchment Management.

Modern approaches to resource management now take a strongly integrated approach -- of examining the processes involved in the deliberate or inadvertent modification of the environment, and designing management to minimise or obviate adverse impacts or to maximise productive aspects. Ignoring the processes risks ineffective application of resources and degradation of the land and water resource.

2. ROLE OF LAND USE INFORMATION IN INFORMED RESOURCE MANAGEMENT

Information on the use of an area of and is but one component of improved management of the basin's natural resources. The nature of the land (and by implication, the capabilities of the land) and the condition of the land (including trend in condition) are also important.

The **nature of the land** is integral to the development of sustainable land use systems -- without knowledge of the nature of the land and therefore its capability for nominated uses, it is unlikely that optimal levels of production will be achieved and it is unlikely that remedial measures to minimise any adverse impacts on the land will be devised or implemented. Clearly, land not used within its capability will degrade with potential outcomes of total loss of the land resource, a major change in its productive capacity, and/or loss of value of the associated water resources.

The **condition of the land** is an indicator of the sustainability of current land use. Where the condition of the land has changed as a result of a change in land use, there is generally insufficient information to make persuasive judgements on the capability of the land to support the new use. Where the land has degraded through use, it may be that the land has adjusted to the new use and has stabilised or it may continue to degrade, again will loss of the resource, loss of productive capacity or damage to associated water resources as potential outcomes. Where the condition of the land continues to deteriorate, clearly the use has exceeded the capacity of the land, and remedial measures and/or a change in land use is required.

While information on land condition is important, it is the trend in land condition that is a crucial component in informed resource management.

Land use information too has the potential to be a key element of informed land resource management, provided the right information is assembled. Information of the uses made of a broad area of land (such as the Murray-Darling Basin) may be used in three broad ways:

a) Description

The information is used to simply describe the various uses made of the land with its outputs -- wheat, sorghum, beef, etc. The information may be presented as a map of as a table of areas devoted to each use, or with production (tonnes of wheat, head of stock, etc.).

While this information clearly has some uses -- in making comparisons of the relative importance of nominated uses in the economy of the basin -- it has severe limitations in policy development particularly about the allocation of resources for the development and application of improved land management systems. The descriptive element requires additional judgements to be made, particularly about the likely success of any new management system.

b) Monitoring

Changes in land condition can be difficult to measure satisfactorily and creditably, such that emerging trends can be related to changes in management, let alone the difficulty in excluding natural variation due to spatial variation resulting from the variation in the nature of the land, temporal variations resulting from seasonal changes in moisture regimes, phenological changes in vegetation, etc. It is often simpler and equally reliable to measure changes in land use or land management practices as a measure of the impact of land management programs on the condition of the land.

If the trend in land use can reasonably be expected to indicate movement towards or away from sustainability, this can be exceedingly useful information in the overall management of the resources of the Murray-Darling Basin.

c) Prediction

It is in the arena of prediction of future trends in land condition, either without intervention or as a result of land management programs, and in the development of sustainable land management systems where land use information has its greatest value.

By understanding the nature of a particular land use and its effect on the land and water resources, its spatial extent in the basin and the nature/capabilities of the land that is so used, assessments can be made of the likely long term effects on the land and associated water resources, and appropriate management programs instigated before major land degradation problems surfacing.

However this does imply a need to map/describe forms and levels of intervention in the landscape rather than land use *per se*. A land use such as winter cereal production is not particularly informative if the prevention of wind and water erosion is an objective. The cropping systems used in the production of winter cereals in southern Australia range from continuous cropping through to minimum tillage, each with a quite different set of impacts on the environment. If the type and level of intervention in the environment were mapped/described, then the degree of cultivation, the extent of chemical

(fertiliser and herbicide) usage, the length of the rotation and the inclusion of legumes in the rotation, are far more important than the end product -- wheat or barley -- in the management of the land and water resources of the basin.

If the processes leading to loss of productive capacity of the land or of the land itself is not identified and understood, it is unlikely that remedial measures will be satisfactory in the long term. There is the strong risk that the symptoms, rather than the cause, will be treated. The almost inevitable result is a mis-allocation of resources for land management programs, over-utilisation of the land resource, and continuing degradation of the land and water resources.

3. FORMS OF LAND USE INFORMATION

The forms in which the land uses of the Murray-Darling Basin are described will have a significant bearing on the utility of the dataset. The previous discussion made passing reference to the opportunities for both mapped and tabular information.

Maps provide the spatial context -- the distribution and relative abundance of the land uses, and their relationships to special features or values such as rivers. Maps also provide an effective means of exploring relationships between land use and land type or land condition. Modern electronic equipment is more than capable of overlaying two or more thematic maps and presenting a consolidated map, highlighting particular combinations regarded as being important.

Tabular data is more useful in comparing numerical aspects of land use information - how much of the basin is committed to a nominated land use in comparison with another, how the area of a particular land use has changed over a particular period, etc.

Fortunately, modern Geographic Information Systems are adept at handling both sets of data -- generating tabular data from the mapped information -- and providing opportunities for modelling of impacts of land use on the land and water environments across the whole or restricted parts of the basin.

The forms of land use mapped should be clearly defined in terms of the type and level of intervention in the landscape, defined in term relevant to the protection of the land and water resources and their productive potential -- in terms relevant to the management of the land and water resource. The maps should then be based on these descriptions and area statements prepared from the maps. The three forms of information will then form the land use dataset.

4. STRUCTURE OF THE DATASET

The way the dataset is structured will have a significant bearing on its utility. Structures that have inherent flexibility will clearly be more useful to a range of users than structures with a great deal of rigidity. The most obvious form of flexibility is one that allows for aggregation of land uses to group those with common

characteristics, thereby allowing greater or lesser degrees of generalisation of land use across the whole basin.

There is limited value in mapping land use at a level of detail applicable only to basin-wide perspectives -- there are many legitimate potential users with regional and local perspectives. However mapping land use at a level of detail applicable to these latter users without giving thought to possible generalisation of the data will almost certainly lead to a relatively inflexible dataset or one from which generalisations can be made only with some considerable effort.

The most obvious form of flexibility which could/should be built in is that of a hierarchical structure, in which major divisions of land use types are made on the basis of the type of intervention in the landscape, and subsequent divisions are based more on the level of intervention.

Under such a scheme, the first division might well be on the lines of: conservation reserves/timber production/grazing/cropping/residential and industrial use, etc. Subsequent divisions may well be on the basis of irrigation/dryland farming, minimal tillage/conventional tillage, etc., with further divisions based on even closer examination of the land management system.

Such an hierarchical system allows considerable freedom in presentation/analysis of the data, with basin-wide perspectives being based on upper level divisions, and more detailed pictures of land use taking full advantage of the full detail of the dataset. There is also some freedom in the degree of detail collected/assembled at any one time or for any one area. Less detailed parts of the dataset do not necessarily invalidate the broader information, provided the same basic format is used to collect and assemble the data.

Similarly, the dataset should be constructed in such a fashion as to allow for later further subdivisions to meet particular needs. If the original structure is soundly based, the basic structure can be modified to provide locally important data without invalidating other parts of the dataset. For example, local variations of a more standard management technique may be developed to counter particular local conditions conducive to a certain form of land degradation. Later mapping/documentation of the rate of adoption of this technique could still be done within a robust framework. Again, an hierarchical system will facilitate local modifications to meet local needs.

5. SUMMARY

Suggested basic principles for assembly of the land use dataset are:

1. The dataset should be considered to consist of descriptions, maps and tabular information.

2. The dataset should be based on identification and delineation of types and levels of intervention in the landscape, rather than the more conventional but less utilitarian descriptions of land use based on outputs. This would recognise both the current imperative to deal with processes of land degradation rather

than the symptoms, and the role of the Murray-Darling Basin Commission and related agencies to manage for outcomes rather than the more traditional outputs.

3. The structure of the dataset should give precedence to predictive capabilities of the data over monitoring capabilities; it should give precedence to monitoring capabilities over descriptive uses.

4. The dataset should have an hierarchical structure to permit ready aggregation of related land uses, with major divisions based on types of intervention in the landscape.

5. The structure of the dataset should be robust, to allow for greater subdivision to meet particular needs. These may be local needs (particular forms of land use relevant only to local conditions), or needs specific to a limited set of land uses where a greater level of detail of information or map scale is justified.

APPENDIX C

LAND-USE MAPPING REQUIREMENTS WORKSHOPS:

OBJECTIVES, FORMAT, AGENDA AND SCHEDULE

Workshops have been held in each state to define land-use mapping requirements. Key state personnel were identified representing a variety of land management agencies and invited to contribute to the formulation of a standard land-use mapping classification schema.

C1 OBJECTIVES OF WORKSHOP

1. to explore requirements for land use mapping in discharge of agencies' land management responsibilities in the Murray-Darling Basin.

2. to explore options for structuring of the land use dataset to best meet the land management needs of co-operating agencies, and, as far as possible, reach consensus on the optimal structuring of the dataset.

3. to examine past, current and projected efforts in land use mapping and identify existing datasets which could be assembled into a basin-wide map of land use.

C2 FORMAT OF WORKSHOPS

The general format was a single session workshop, involving up to twenty agency staff with operational, policy and research responsibilities in the Murray-Darling Basin, and lasting four to six hours.

Representatives of each agency were be asked to make a brief presentation of past, current and projected land use mapping which their agency has undertaken, and to identify any lessons to be learnt from such exercises.

There was the opportunity for each discipline area/agency to put forward their needs in terms of content, detail and scale, and any thoughts on structuring of the data set to meet specific objectives.

The information gained from the workshop was used to prepare the proposed land use classification for presentation to the Murray-Darling Basin Commission.

C3 WORKSHOP AGENDA

1. **Welcome and scene-setting** (Jim Baxter, 15-20 min.)
   - Murray-Darling Basin Commission
   - TASK M305
   - current task, methodology
   - workshop program
   - objectives of workshop
   - reporting, draft to be circulated
   - land use mapping task

2. **Presentation of discussion paper on land use mapping for Murray-Darling Basin Commission** (Les Russell, 15 min.)

3. **what has been done in the past** (Agency representatives, 60 - 120 min.)
   - presentations by each agency
     - objectives
     - scale
     - coverage
     - structure

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DOC_, 60 - 120 min.)

6. **Close**
   - circulation of draft report to MDBC to participants for comment at completion of workshop program

C2 SCHEDULE OF WORKSHOPS

Workshops were held in:

Canberra	August 31, 1993
Bendigo	September 3, 1993
Bathurst	September 7, 1993
Brisbane	September 9, 1993
Toowoomba	September 10,1993
Adelaide	September 23,1993

Some 40 senior land managers have attended the workshops (see following pages for details of attendees).

APPENDIX D

LAND-USE MAPPING REQUIREMENTS WORKSHOPS:

PARTICIPANTS

NAME	ORGANISATION	ADDRESS	TELEPHONE	FACSIMILE
Victoria				
BRUCE WESTON MARK IMHOFF	DEPT OF AGRICULTURE/ SCL	5 MACARTHUR ST, EAST MELBOURNE 3002	03 651 1760	03 654 4772
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COLIN SMITH TOM SPEEDIE	DCNR	NORTH WEST AREA OFFICE PO BOX 401, BENDIGO 3550	054 446 666	054 446 688
ROBERT CHAFFE	DCNR	46 AITKEN STREET, ALEXANDRA 3714	052 721 633	
SUSAN RYAN	DCNR	OSBORNE STREET, BENDIGO 3550	054 446 777	
SHELLEY HERON	DCNR/OFFICE OF THE ENVIRONMENT	1/240 VICTORIA PARADE, EAST MELBOURNE 3002	03 412 4135	
DAVID LANE	DCNR/PEST MANAGEMENT	PO BOX 48, FRANKSTON 3199	03 785 0108	03-785 2007
DAVID REES	DCNR/LAND AND CATCHMENT APPRAISAL	KTRI, BALLARTO ROAD, FRANKSTON 3199	03 785 0130	03-785 2007
BRIAN GARRETT	DCNR BENALLA	57 BRIDGE STREET WEST, BENALLA 3672	057 611 609	057 624 611
New South Wales				
GRAEME DUDGEON	NSW DEPT. OF AGRICULTURE	161 KITE STREET, LOCKED BAG 21, ORANGE 2800	063 913 193	063 913 206
JOHN BENSON	ROYAL BOTANIC GARDENS	MRS MACQUARIE'S ROAD, SYDNEY 2000	02 231 8149	02 251 7231
GREG ROBERTS	NATIONAL PARKS AND WILDLIFE SERVICES	PO BOX 402, ARMIDALE 2350	067 737 211	067 711 894
KIM RITMAN	LIC	PO BOX 143, BATHURST 2795	063 328 465	063 318 095
ANNE BRADY	DEPT OF WATER RESOURCES	PO BOX 3720, PARRAMATTA 2124	02 895 7472	02 895 7867
DAVID LOANE	STATE FORESTS	LOCKED BAG 23, PENNANT HILLS 2120	02 980 4268	02 451 0614
PETER HOUGHTON	SOIL CONSERVATION SERVICE, DEPT CONS. AND LAND MANAGEMENT	GPO BOX 39, SYDNEY 2001	02 228 6538	02 228 6537

Queensland				
DAVID FREEBAIRN	APSRU, DEPT PRIMARY IND.	PO BOX 102, TOOWOOMBA 4350	076 314 391	076 332 678
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ED POWER	DPI	203 TOR STREET, TOOWOOMBA 4350	076 314 330	076 331 572
ROB PRESTON	DPI FOREST SERVICE	GPO BOX 944, BRISBANE 4001	07 234 0326	07 234 0124
TIM DANAHER	DPI DROUGHT RESEARCH GROUP	MEIERS ROAD, INDOOROOPILLY 4068	07 877 9589	07 877 9606
GAIL KELLY	QLD DEPT OF LANDS	LOCKED BAG 40, COORPAROO 4151	07 896 3095	07 896 3765
MIKE GRUNDY	DPI RESOURCE ASSESSMENT & PLANNING	MEIERS ROAD, INDOOROOPILLY 4068	07 371 8258	07 877 9395
ED POWER	DPI LAND SERVICES SOUTH REGION	PO BOX 102, TOOWOOMBA 4350	076 314 237	
BRUCE THOMSON	DEPT. ENVIR. & HERITAGE QNPWS	PO BOX 1578, TOOWOOMBA 4350	076 398 366	
PETER AYRISS	DPI LAND SERVICES (GIS)	PO BOX 102, TOOWOOMBA 4350	076 314 240	
LAMOND GRAHAM	DPI PRINCIPAL PROJECT OFFICER	PO BOX 102, TOOWOOMBA 4350	076 314 403	

South Australia				
RUSSELL FLAVEL	P I, GIS UNIT	NORTHFIELD RESEARCH LAB. GPO BOX 1671, ADELAIDE 5001	08 266 8360	
PETER BROOKE-SMITH	DEPT HOUSING & URBAN DEVELOPMENT, GIS SECTION	GPO BOX 667, ADELAIDE 5001	08 207 2045	
JUDITH KIRK	GIS SECTION, DEPT OF HOUSING & URBAN DEV.	GPO BOX 667, ADELAIDE 5001	08 207 2064	
DAVID CRESSWELL	GIS SECTION, ENGINEERING & WATER SUPPLY	SCIENTIFIC SERVICES, EWS, ADELAIDE 5000	226 2518	
KYM PERKIN	P I (SA), GIS GROUP	NORTHFIELD RESEARCH LAB GPO BOX 1671, ADELAIDE 5001	08 266 8432	
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MEGAN TUTTY	ADELAIDE HILLS SOIL CONSERVATION BOARDS	LENSWOOD HORTICULTURAL CENTRE (DPI) LENSWOOD 5240	08 389 8834	