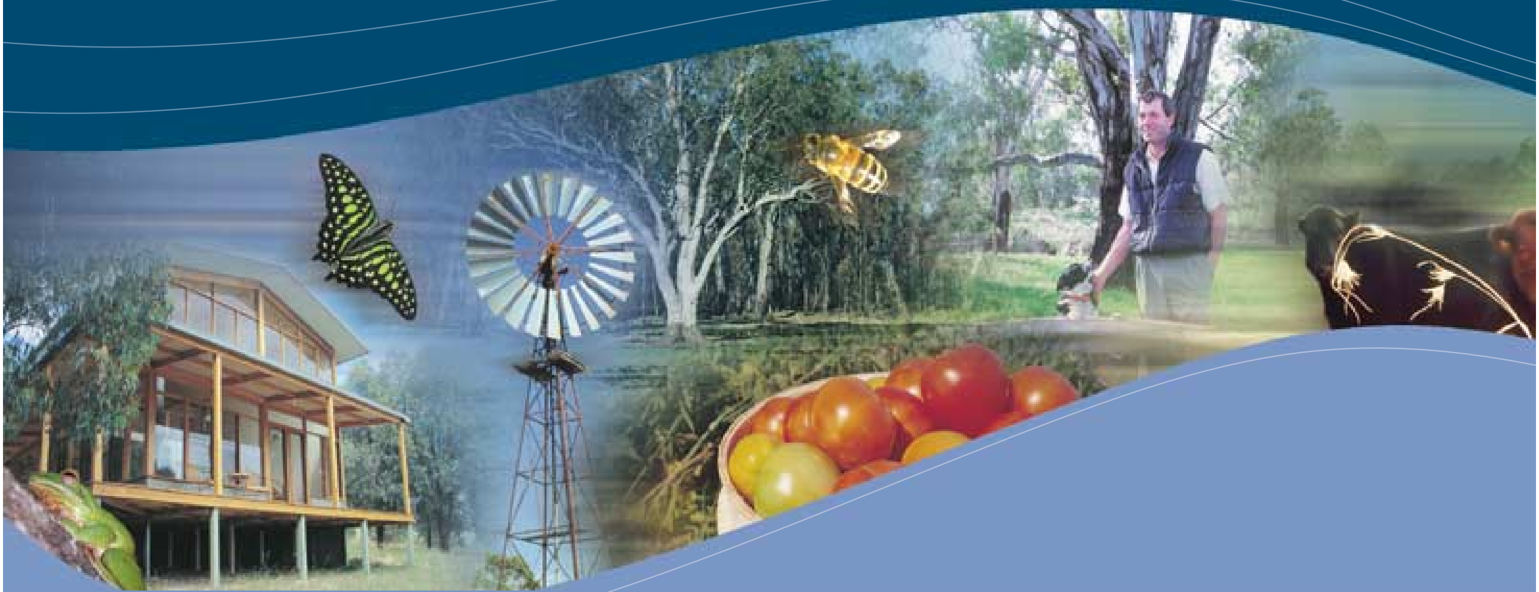
ECOSYSTEM SERVICES PROJECT

NATURAL ASSETS



An Inventory of Ecosystem Goods and Services in the Goulburn Broken Catchment

PEOPLE ▸ ENVIRONMENTS ▸ VALUES ▸ OPPORTUNITIES

Contents

Executive Summary

Key findings and policy issues

The Goulburn Broken Catchment enjoys the dual benefits of a buoyant economy and a socially vibrant community. Forecasts for the region indicate that this prosperity will continue to rise. The gross domestic product for the Catchment is predicted to grow from $2.97 billion in 1996 to $4.27 billion in 2005. However, some portions of the Catchment are facing the challenges associated with the decline of traditional agricultural enterprises.

The Catchment's economic and social wealth is inextricably woven into the fabric of the region's natural resource base. In order to maintain this base it is essential that natural assets and the ecosystem services that flow from them remain healthy and viable.

To achieve ecological, economic and social health the Ecosystem Services Project, of which this inventory is the first step, aims to learn with communities how to deliver the right information to policy developers and decision makers in an effort to move towards more sustainable land management practices. The key findings and policy issues central to this goal are set out below, and can be found in greater detail in Chapter 6 of the report.

KEY ISSUE 1

Integrating management across ecosystem services

An important task is to evaluate the interactions between ecosystem services and the multiple benefits they provide. Priorities for further study include exploring the relative Catchment benefits of:

- **Re-establishment of the Lower Goulburn River floodplain.**
- **Alternative revegetation strategies.**
- **Nutrient management.**

KEY ISSUE 2

Managing land-use intensification

Land-use intensification will need to be carefully managed to avoid unacceptable off-site impacts on natural assets and the ecosystem services they provide. Key issues include identifying:

- **"Win-win" solutions** through improved farm management practices.
- **Limits to growth** before environmental thresholds are crossed.
- **Offsets** that could allow the impacts of land-use intensification to be traded.

KEY ISSUE 3

Managing transitions in land-use

Land-use and land ownership change in the Catchment provides an unrealised vehicle for improving environmental outcomes. There are opportunities to:

- **Work with local government** to ensure that all land-use change leads to a net gain to the environment.
- **Develop markets for ecosystem services** that operationalise effective cost sharing.
- **Rationalise assets** to support sustainable land management practices.
- **Create commercial opportunities** that restore perennial vegetation.

KEY ISSUE 4

Managing vegetation—a hub in the landscape

Protecting remnant vegetation and strategic re-establishment of trees and other vegetation are fundamental to restoring the full suite of ecosystem services. An urgent task is to:

- **Quantify multiple benefits** of vegetation to further build upon cost-sharing arrangements.

KEY ISSUE 5

Managing cultural, heritage and option values

Catchment planning will need to take account of the life-fulfilling values of nature, including Indigenous culture, the intrinsic values of biodiversity, and landscape amenity. This can be achieved by:

- **Local planning** that explicitly articulates and manages for these values.

KEY ISSUE 6

Maintaining soil health

Soil management is perhaps the single most significant on-farm ecosystem service issue in the Catchment. Key issues include:

- **Acidification, sodicity and soil carbon** and their long-term impact on the productivity of soil.
- **Soil biodiversity** evaluation and its significance to different land-uses.
- **Soil loss** evaluation and its extent and implications.

KEY ISSUE 7

Accounting for the value of non-agricultural land and water uses

Tourism, recreation and lifestyle living are established industries/land-uses in the Catchment that are affected by land and water management regimes.
Key opportunities include:

- **Assessment of the dependence** of these growth industries on natural assets.
- **Catchment planning** that explicitly includes non-agricultural land and water uses.

KEY ISSUE 8

Managing water and salinity

The ecosystem services inventory has reaffirmed water management as a key issue for the Catchment with a focus on salinity (including end of valley targets), environmental flows and nutrient management.
Key opportunities include:

- **Improving on-farm practices** including water use efficiency, nutrient and groundwater management.
- **Identifying and facilitating land-use changes** required to achieve water and salinity outcomes.

KEY ISSUE 9

Anticipating and adaptively managing emerging issues

Emerging and longer term issues which would benefit from further study include:

- **Climate change** adaptation and emission reductions.
- **Pollination** and its role in horticulture, lucerne and other pollen dependent crops.
- **Native insects and invertebrates** and their role in pest control, soil productivity and the breakdown and absorption of waste.
- **Waste management** impacts of heavy metals, agro-chemicals and high-sodium wastes.
- **Shade and shelter** and their roles, costs and benefits.

WHAT ARE ECOSYSTEM SERVICES?

Ecosystem services flow from natural assets (soil, water systems, plants, animals, other living organisms and the atmosphere) to provide us with financial, ecological and cultural benefits. Examples of ecosystem services include: provision of clean water, maintenance of liveable climates and fertile soil, pollination, and fulfillment of cultural and intellectual needs. If natural assets are not maintained the benefits from ecosystem services decline. Conversely, if we maintain our natural assets and use them more effectively, we will benefit from greater returns.

The Ecosystem Services Project is studying a cross section of ecosystem services that underpin key economic sectors within Australia such as dairy, horticulture, beef, wool and cropping. Quality of life industries such as recreation, rural sub-division and tourism are also being examined. Possible changes to these services under various land management scenarios are being considered in partnership with a range of stakeholders. Our ultimate aim is for scientists and communities to learn together how to deliver the right information to policy developers and decision makers in an effort to move towards more sustainable land management practices.

Focusing on ecosystem services encourages us to look at landscapes and ecosystems and the processes going on in them in a different way that can reveal new problems and new opportunities. Considering ecosystem services broadens the set of benefits and values from nature beyond the relatively narrow set currently considered in decision making. Because ecosystem services flow from interactions among the whole set of processes occurring in ecosystems, an ecosystem services approach forces us to view our catchments holistically rather than looking at individual components in isolation from one another. An ecosystem services approach focuses on the values that people, rather than scientific theories, discern from nature, and this allows us to document the lessons learned in the Goulburn Broken Catchment in ways that have immediate relevance to land managers in this and other catchments.

In the Goulburn Broken Catchment, the Ecosystem Services Project is a partnership between CSIRO, The Myer Foundation, The Goulburn Broken Catchment Management Authority, Land and Water Australia, government representatives and, most importantly, the Catchment community.

OBJECTIVES OF THE INVENTORY

This inventory of ecosystem services in the Goulburn Broken Catchment is a first step towards our ultimate aim. It gives an insight into what services are currently provided, and forms the basis for a more detailed assessment of what might happen to those services under a set of scenarios for the future. The inventory report sets out to achieve a number of objectives including:

- Describing the full range of goods (the things people value) produced in the Goulburn Broken Catchment.
- Identifying the dependence of these goods on various ecosystem services.
- Identifying the ecosystem services of highest priority in the Goulburn Broken for further study and management.

THE GOULBURN BROKEN CATCHMENT

Considered the "food bowl" of Australia, the Goulburn Broken Catchment is located in Northern Victoria, Australia. The Catchment is a diverse region consisting of the irrigated region in the north, the central dryland grazing and cropping region, and the southern high country valued for its tourism and recreational uses. The Catchment's total area is almost 2.5 million ha of which approximately two-thirds have been cleared for agriculture. Approximately 200,000 people call the Catchment home, of which 17,000 are employed in agriculture and associated industries.

A number of ecological, economic and social trends are occurring in the Catchment, which include:

- Increasing population and employment in service industries, and growth in less traditional farming activities such as grapes and olives.
- Land-use intensification in dairy, horticulture and vegetable industries.
- Strong economic growth; the Gross Domestic Product (GDP) of the Catchment is expected to rise from $2.97 billion in 1996 to $4.37 billion in 2005. A large proportion of this GDP is underpinned by the economic activity supported by natural assets and the ecosystem services that flow from them.

One of the key ecological threats in the Catchment is the implications of past clearing of native vegetation, which has increased salinity, negatively impacted on water quality, and diminished habitat for species. Nutrient management, water quality, soil health and pest management are all considered significant issues in the Catchment. The region is both a positive and negative contributor to climate stability.

CONCEPTUAL FRAMEWORK OF THE INVENTORY

A conceptual framework has been developed which illustrates the role of ecosystem services in maintaining natural assets and in supporting the production of goods of value to the Goulburn Broken community.

Natural assets refer to the stock of natural resources from which many goods are produced while goods are all things produced in the Catchment that are of value to humans. Ecosystem services, therefore, contribute to the economic and social well-being of people in and beyond the Catchment in two ways:

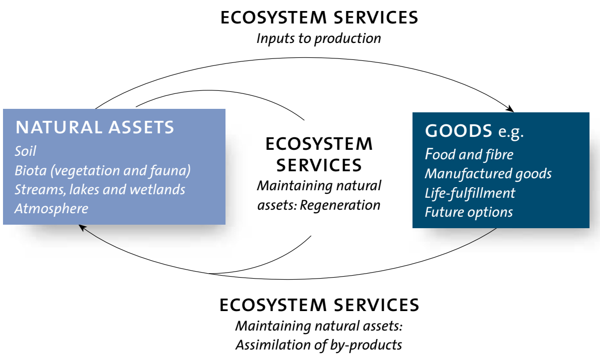
- Through the use of natural resources to provide an ***input to production*** of a good or service (for example, the service of pollination uses the natural asset of plants and animals).
- By ***maintaining natural assets*** via two pathways (first, through the regeneration capacities of natural assets, such as nutrient cycling in soils, and second, through the assimilation of by-products arising from production processes or from consumption of goods such as the assimilation by vegetation of carbon dioxide from industry).

The key question revealed by this simple conceptual framework is:

Can our natural assets be managed in a way that sustains the ecosystem services that in turn support the production and consumption of goods from the Catchment?

DIAGRAM 1

Ecosystem services conceptual framework



CATEGORISING GOODS AND ECOSYSTEM SERVICES IN THE CATCHMENT

In consultation with the Catchment community, the inventory has attempted to document the full range of goods that are produced in the Catchment. These goods are broadly categorised under one of the following sectors (noting the gross value of production from each):

- Primary Industries—$1,147 million
- Processing and Manufacturing—2,927 million
- Housing and Construction—$276 million
- Electricity and Water—$198 million
- Service Industries—$2,000 million
- Environmental, Cultural, and Aesthetic Goods—significant value not easily expressed financially

A more detailed disaggregation of these goods and their contribution to the regional economy is contained in Chapter 4 of the report.

The services under discussion in this report are as follows:

Pollination is the service of fertilising flowers allowing for seed and fruit production, and is critical to the regeneration of plants and to the production of fruits and seeds.

Life-fulfilling services are the provision of aesthetic beauty, cultural, intellectual, and spiritual inspiration, sense of place, existence value, scientific discovery, and serenity.

Regulation of climate relates to the services provided by plants, animals and other organisms, that regulate atmospheric composition and weather patterns creating a habitable environment.

Pest control is the service of controlling organisms that are unwanted or cause damage to things that are valuable to people.

Genetic resources are part of biodiversity which consists of ecosystem, species and genetic diversity.

Maintenance and regeneration of habitat is the service of maintaining the biota through processes of regeneration, the maintenance of viable populations of flora and fauna and the management of vegetation to facilitate production, dispersal and growth of seed.

Provision of shade and shelter is the service provided by vegetation that ameliorates extremes in weather and climate at a paddock scale for plants, animals and structures.

Filtration and erosion control relates to the functions performed by soil components (including soil biodiversity) and vegetation in minimising soil loss and filtering sediments from water to improve water quality.

Maintenance of soil health is required to sustain biological productivity, promote air and water quality and maintain plant, animal and human health.

Healthy waterways are defined by a balance of fish, invertebrates, plants and algae in waterways, with the appropriate in-stream, riparian and floodplain habitats for these organisms to live in.

Regulation of river flows and groundwater levels is the service of collection and distribution of water through rivers, lakes, wetlands and groundwater systems. The mitigation of floods is also included in this ecosystem service.

Waste absorption and breakdown captures the role played by various organisms (terrestrial and aquatic) in absorbing and breaking down wastes.

Essays on each of these ecosystem services can be found in Chapter 7 of the report.

RANKING AND IDENTIFYING PRIORITY ECOSYSTEM SERVICES

The major task undertaken in this inventory has been a first assessment of the relative importance of each ecosystem service to each land-use/industry in the Catchment. The criteria used include:

- overall importance/impact;
- importance at the margin (i.e. the importance of a small change in the provision of a service); and
- manageability.

These criteria have been used to determine whether a particular service receives a high, medium or low ranking. The purpose has been to evaluate which ecosystem services are of critical importance to the Catchment. This includes an assessment of those ecosystem services that are most at risk from existing management practices.

Of course all of the ecosystem services are important in one way or another. However, the objective has been to identify those of particular importance to each industry and/or land-use.

The table below is a high level summary of a systematic process through which the ecosystem services most highly ranked for each industry have been identified. Chapter 5 of the report presents these results in greater detail. In particular, for each highly ranked service the key issues and potential management responses are identified for each industry.

Appendix 1 outlines the methodology used for the rankings and then presents results for all industries and land-uses across all ecosystem services. Rationale for each ranking is provided and has been subject to an open and transparent process of review by both Catchment and external scientific experts.

WHERE TO FROM HERE?

This inventory has evaluated the state of all ecosystem services in the Goulburn Broken Catchment and identified a set of priority issues for future management.

Many of the key issues raised in the report (contained within Chapter 6, and a summary of which is found at the beginning of the Executive Summary) are familiar to the Catchment and are consistent with existing natural resource management strategies. However, a number of new and challenging issues emerge when we take an ecosystem services perspective.

The ecosystem service approach is different from other approaches to natural resource management because of the focus on managing natural assets for the values they provide, rather than focusing on the problems that arise from inappropriate natural resource management. It also highlights the interdependence of ecological processes and the need to adopt holistic management strategies that are capable of adapting to address uncertainty.

From this point we will move to more detailed evaluation of some of the key issues that have been identified. It is expected that further analysis of these key issues will be required at two scales.

Regional scale assessment will evaluate the importance and management of all ecosystem services at a Catchment scale. Impacts across different land-uses and the interactions between different ecosystem services will need to be considered. This approach will broaden and strengthen the already developing discussion about priorities for land-use change in the Catchment and following on, the policies and tools that facilitate the structural changes required.

Localised scale evaluation will identify a limited number of issues that are of particular importance or represent key economic opportunities for the Catchment. These studies will provide the opportunity to evaluate the relative costs and benefits of alternative management strategies at an enterprise scale.

TABLE 1

Highly ranked ecosystem services in the Catchment

Ecosystem service	*Land-use/Industry*											
	Dairying – on farm	Fruit and grapes	Vegetables	Grazing	Crops	Intensive animals	Forestry	Food processing	Housing	Water production	Recreation	Areas of culture/future options
Pollination		■										
Life-fulfillment	■			■					■			■
Regulation of climate	■	■				■		■				
Pest control		■	■	■	■							
Maintenance and provision of genetic resources				■								
Maintenance and regeneration of habitat		■	■	■			■		■		■	■
Provision of shade and shelter	■	■		■	■				■			
Maintenance of soil health	■	■	■	■	■							
Maintaining healthy waterways	■	■		■			■	■		■	■	
Water filtration and erosion control			■	■	■					■		
Regulation of river flows and groundwater levels	■	■			■					■	■	
Waste absorption and breakdown	■	■	■	■	■	■		■	■	■	■	

Chapter 1

Introduction

There are billions of species on this planet, most of them unknown to us. The way species interact with each other is a constant source of fascination. Giant whales rely on tiny sea-creatures for food and honey-eater birds rely on flowers for food and in turn the flowers rely on the birds for pollination and thus reproduction. Below the ground, bacteria, worm-like animals, insects, fungi and many other tiny creatures need one another for food, control one another's numbers and keep the soil fertile. These types of interactions among and between species and their surrounding environments are what define "ecosystems".

Ecosystems in turn, provide many "services" from which humans benefit. Ecosystem services are the transformation of a set of natural assets (soil, biota, air, water) into things that we value. For example, when fungi, worms and bacteria transform the raw "ingredients" of sunlight, carbon and nitrogen into fertile soil this transformation is an ecosystem service. However, if we allow natural assets to decline, so do the benefits. Conversely, if we look after and maintain our natural assets, we will benefit from greater returns.

Some other examples of ecosystem services include:

- Provision of clean and pure water.
- Maintenance of liveable climates and atmospheres.
- Pollination of crops and native vegetation.
- Control of the vast majority of species that could become pests, weeds, or diseases.
- Protection from extreme weather.
- Fulfillment of many people's cultural, spiritual, intellectual needs.
- Provision of options for the future that we cannot foresee.

Ecosystem services are little understood and too sophisticated for us to reproduce even with the most advanced technology, yet the important roles of these services are not being recognised adequately in economic markets, government policies or land management practices. As a result, ecosystems and their functions are in decline.

Knowledge about ecosystem services is needed by people managing rural land so they know, for example, which insects pollinate their crops, how remnant vegetation contributes to the control of insect pests and regulation of water tables, and how soil biodiversity maintains the fertility of the soil. Likewise, urban water authorities and people living in towns and cities need to understand the links between land management and water quality, air quality, waste disposal, and other important aspects of urban life. We need to improve our understanding of how it can be in urban and rural Australians' financial interests to invest in these ecosystem goods and services. Around the world, many scientists, economists, lawyers, policy makers and agencies are advocating the concept of ecosystem services as a way to help humans better understand their vital relationships with the natural world.

It is becoming more and more clear that maintenance of ecosystem services has potentially large economic, social and ecological benefits. In Australia, the economic value of Melbourne's water catchment is predicted to be greater if managed for both water and timber than for timber alone. Early data indicate that better management of soil organisms is likely to lead to more fertile soil, natural control of pests and diseases, and less need for fertilisers, pesticides and water in many agricultural systems. Native insects are important pollinators of several Australian crops (e.g. cashews, macadamias, custard apples, mangoes), providing a much more efficient service than mechanical pollination, and often outperforming introduced honey bees.

In order to address these issues, the Ecosystem Services Project is studying a cross section of ecosystem services that underpin key traditional agricultural industries within Australia such as dairy, horticulture, beef, wool, and cropping. As well, ecosystem services that support the growing "quality of life" industries such as recreation, rural sub-division and tourism are also being examined. Possible changes to these services under various land management scenarios are being considered in partnership with a range of stakeholders. Our ultimate aim is for scientists and communities to learn together about how to deliver the right information to policy developers and decision makers to move towards more sustainable land management practices.

CSIRO Sustainable Ecosystems and The Myer Foundation initiated the Ecosystem Services Project. The project has since grown to include a large number of partners including: Five CSIRO Divisions, Land and Water Australia, The Goulburn Broken Catchment Management Authority, The Rainforest Cooperative Research Centre, The Cotton Cooperative Research Centre, The University of New England and a range of community and government representatives.

The case study regions in which we are currently working include:

- The Goulburn Broken Catchment in Victoria.
- The Atherton Tablelands in Queensland.
- The Brigalow belt in Queensland.
- The Rangelands of NSW.
- The Gwydir Catchment of NSW.
- The Onkaparinga Catchment of South Australia.
- The Blackwood Catchment of Western Australia.

DIAGRAM 2

Case study regions

The Ecosystem Services Project has been active in the Goulburn Broken Catchment for over 18 months. In order to continue to move the project forward, a number of key steps are needed, several of which have been completed.

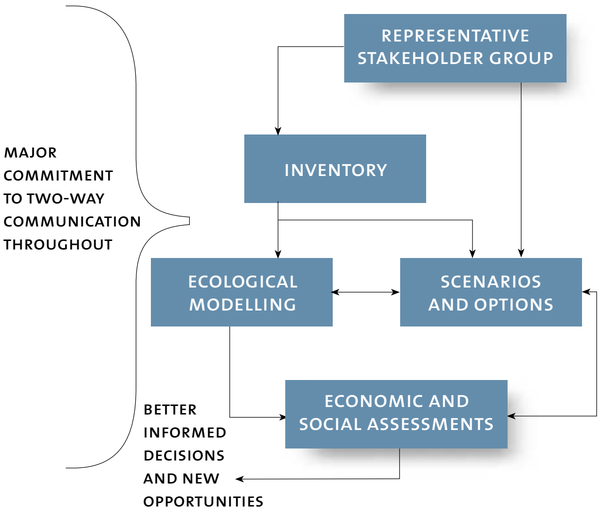
First and foremost, the success of the project depends on the continued support, interest, and involvement of the full range of stakeholders and decision makers. Numerous stakeholder workshops, data gathering, presentations and liaising with industry bodies have characterised the project. It is driven by a full partnership between CSIRO, the Goulburn Broken Catchment Management Authority, and other representatives of the communities within the Goulburn Broken Catchment. This partnership has been formalised and a Steering Committee oversees the project's developments.

The next necessary step in the process was gathering information about the Catchment. This information gathering was in the form of an inventory of the entire range of goods produced in the Catchment, and the natural assets and ecosystem services that the goods are dependent upon. The ecosystem services were ranked to identify those that are of highest importance (based on a number of factors). This document is the result of the inventory process. Numerous people within the catchment have had input into the development of this inventory. With the knowledge gaps identified, and a focus on priority areas, it will now form the basis of moving the project forward.

The next phase of the Ecosystem Services Project involves scientists, economists and stakeholders developing a joint understanding of the ecological, social and economic processes that currently affect delivery of ecosystem services and the welfare of Australians inside and outside the Goulburn Broken Catchment. This includes a consideration of how things might change in the future and what that means for the decisions that land managers and policy makers will have to make. As indicated in Diagram 3 on the next page, this will involve development of the simplest possible ecological models, coupled with identification of scenarios and visions for the Catchment by its residents, and approaches to assessing economic implications of a range of decision options. All of this will be built on what has been learned from the inventory and associated dialogue with stakeholders.

DIAGRAM 3

Key elements of the approach to assessing and valuing ecosystem services.



We acknowledge however, that many information gaps exist. Information on most ecosystem processes is limited, and so is our ability to be sure what will happen in the future. The contributions of ecosystem services to the economy and social processes in the Catchment are difficult to quantify. We can say with confidence, though, that a large proportion of the quality of life and prosperity enjoyed by residents of the Catchment is under pinned by ecosystem services.

When we have high uncertainty about ecosystems and their role in supporting our lives, and we have little insight into what we might be doing to manage our environments, we can do little more than speculate about the future. As we reduce our uncertainty and increase our ability to manage we are better able to predict our future. In between is the option to explore possibilities and opportunities in an informed way. This inventory of ecosystem services is a step in a journey of exploration we are all taking to move us further away from speculation and closer to prediction. The residents of this Catchment started this journey some years ago. We hope that our application of the ecosystem services concept will contribute substantially to making the journey beneficial and short.

1.1 HOW TO FIND THE INFORMATION YOU REQUIRE

This document contains a wealth of information about economic and ecological trends in the Goulburn Broken Catchment, the conceptual approach to the inventory, a categorisation of goods produced in the Catchment and how ecosystem services underpin the production of those goods, the methodology for the ranking process used to identify key ecosystem services, land management actions, sorted by industry, that take into account ecosystem services, a key issues section, and finally, specialists' commentary on over 15 different types of ecosystem services.

You may however, only be after specific information in this document, and the following breakdown should assist you to find the information you need.

Description of Ecosystem Services

Chapter 1—Introduction
Chapter 2—Overview and trends
Section 4.2—Overview of ecosystem services and their role in the Catchment
Chapter 7—Specialist's commentary on ecosystem services

Conceptual Framework & Methodology

Chapter 3—Conceptual framework
Chapter 5—Methods for identifying priority services
Appendix 1—Ranking tables

Industry/Land-use Issues

Executive Summary
Chapter 2—Overview and trends
Section 5.2—Key issues for different land-uses and industries in the Catchment
Chapter 6—Key findings and policy issues

Information about the Goulburn Broken Catchment

Chapter 2—Overview and trends of the Goulburn Broken Catchment

Chapter 2

Overview and trends of the Goulburn Broken Catchment

GEOGRAPHIC, LAND-USE AND INSTITUTIONAL OVERVIEW

Considered the "food bowl" of Australia, the Goulburn Broken Catchment is located in Northern Victoria, Australia. The Catchment is a diverse region consisting of the irrigated region in the north, the central dryland grazing and cropping region, and the southern high country valued for its tourism and recreational uses. The Catchment's total area is almost 2.5 million ha of which approximately two-thirds has been cleared for agriculture. About 200,000 people call the Catchment home of which 17,000 are employed in agriculture and associated industries.

The Catchment can be divided into three broad zones:

Irrigated Agriculture Dominated by dairy, cropping and horticulture (fruit). This zone accounts for 270,655 ha of the Catchment.

Dryland Agriculture (Riverine Plains & Hills) The total dryland area accounts for 1,397,130 ha. The plains are characterised by cropping and some intensive industries. The hills are dominated by pastoral industries including sheep and cattle.

Highland Public Forest (Hills) Public land accounts for 690,603 ha and is dominated by national parks and public forestry.

The Goulburn Broken Catchment has a number of key organisations that help in the management of the region's natural resources, and who are key stakeholders to the Ecosystem Services Project.

The Goulburn Broken Catchment Management Authority is a non-profit statutory authority, and is responsible for the coordination, planning and implementation of the regional Catchment Management Strategy.

Goulburn Murray Water is the government owned business charged with the allocation of bulk water entitlements for irrigators and urban users of water.

Goulburn Valley Water is the region's major urban and industrial water supply and waste disposal authority.

Department of Natural Resources and Environment conducts research, information relating to production and resource management, and regulation relating to crop and animal health and public land management.

The maps on the following pages illustrate the primary land-uses within the Catchment.

TRENDS IN POPULATION, EMPLOYMENT AND LAND-BASED INDUSTRIES

The population of the Catchment is predicted to grow from 182,679 in 1996 to approximately 210,000 by 2021 (an annual rate of 0.6%). The Shepparton Irrigation Region contains 63% of the population of the Catchment, but the largest population growth is predicted for the dryland shires adjacent to the Hume Freeway. These areas are within commuting distance from Melbourne, which is leading to interest in using land for rural lifestyle, cheaper housing and new industries, including thoroughbred horse breeding, wine grape production, mushroom farming and olives (Young and Associates 2000). This is increasing land values in the area and making it less cost effective to purchase land to use for traditional agricultural enterprises. Some of the increased land value is attributable to retained native vegetation, giving value to this component of biodiversity not recognised in the past.

DIAGRAM 4

Land-use – % of area

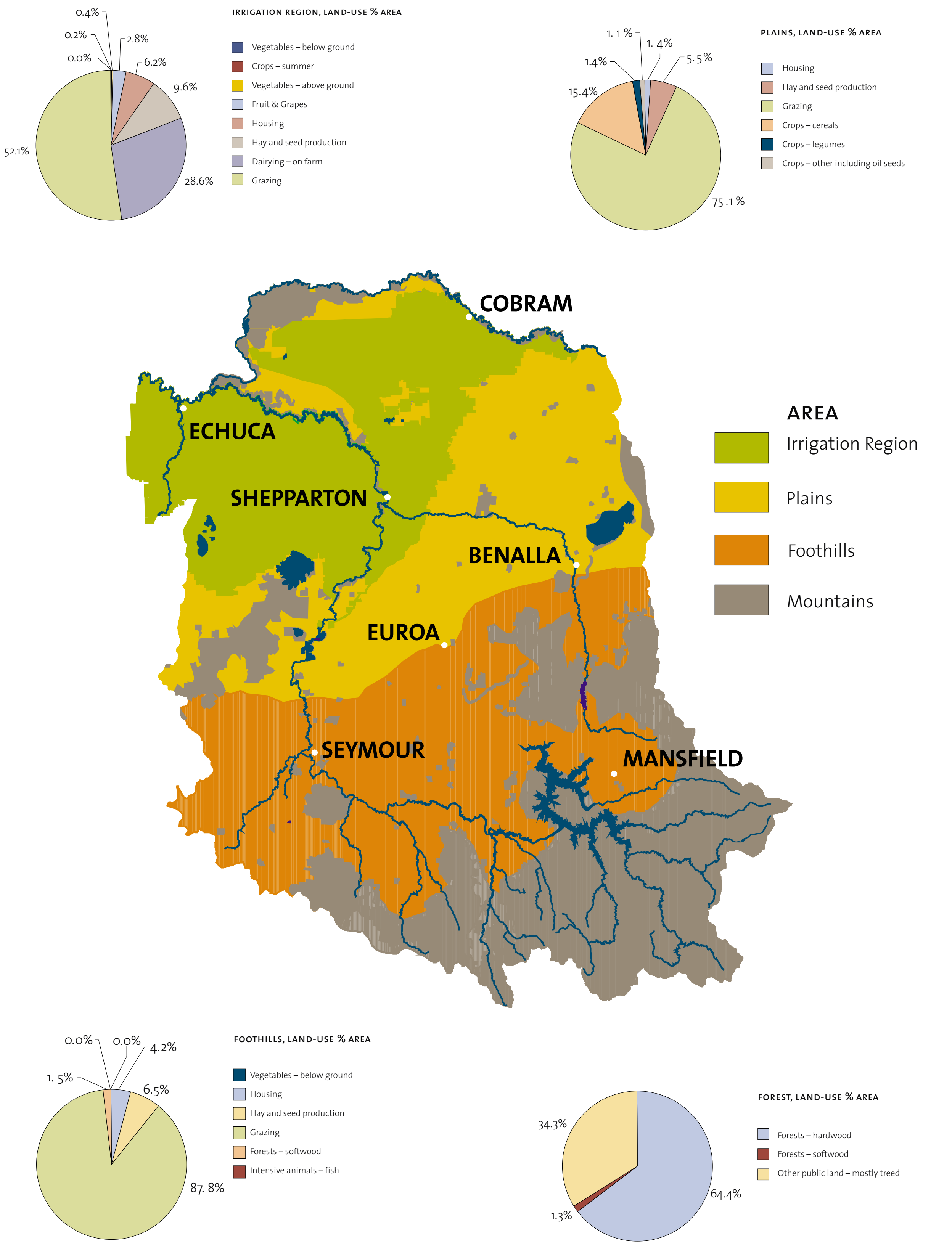
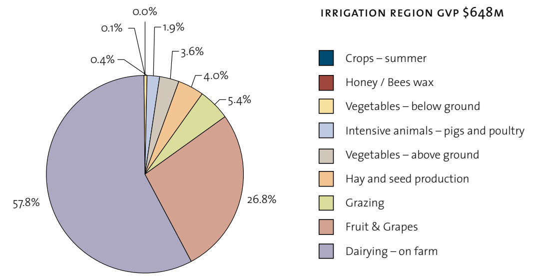
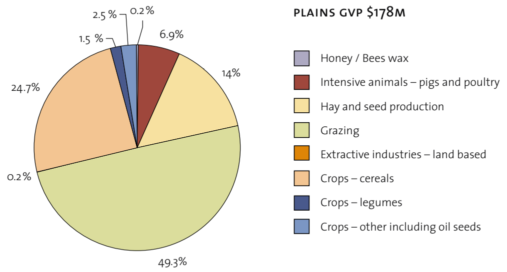
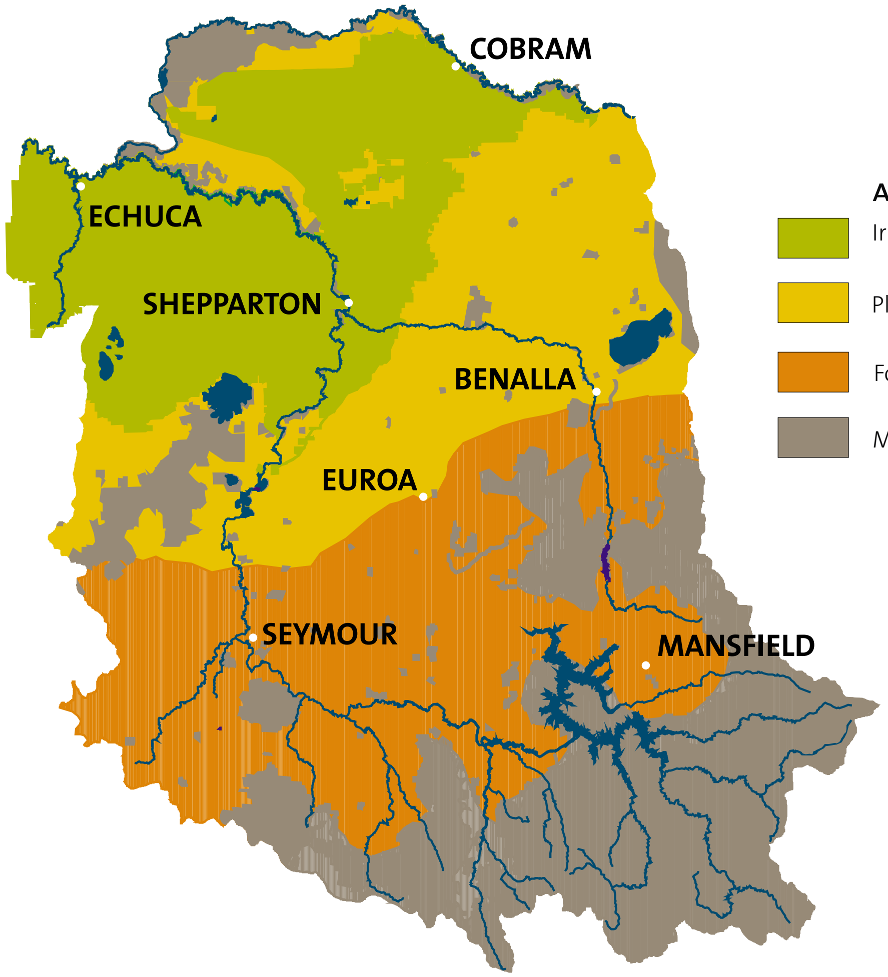


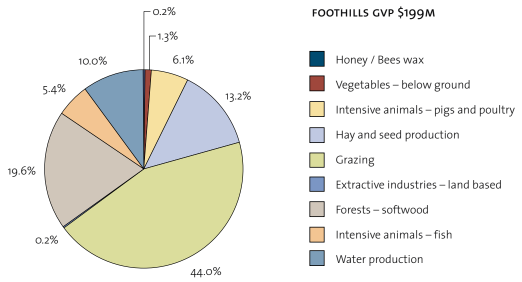
DIAGRAM 5

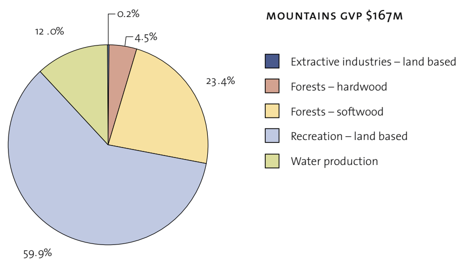
Gross Value of Production % of Area ($1996 – 97)











The socio-economic structure of the Catchment is changing rapidly. The average age of farmers is increasing, due largely to young people leaving or choosing not to enter agricultural industries. This is predicted to lead to large changes in land ownership, farm amalgamation and/or rural sub-division in the next decade. In large parts of the region small farms are not generating enough income to be viable, leading to increasing dependence on off-farm income.

Total employment in the Catchment has risen from 74,000 in 1996 to around 77,000 in 2000, and is predicted to reach 81,000 by 2005. The increase is expected to be mainly from a 6% increase in employment in value-adding components of dairy, horticulture, meat, stock feed, fibre and timber industries and a 54% increase in industries providing services to agriculture and processing (Young and Associates 2000). On-farm employment in current industries is expected to decrease, while employment in intensive new industries, including new horticultural developments (orchards, wine grapes, olives, vegetables, mushrooms), horse breeding and new softwood plantation developments, is expected to increase by about the same amount. This will mean that there will be little or no increase in employment on-farm (it is expected to remain at around 12,000), but that the type of work done on-farm will change considerably from traditional practices.

Other sectors expected to grow are retail and wholesale, business services such as computing, finance, legal and accounting (in the regional centres), and the natural resource-based tourism industry. The region's rivers, lakes, wetlands and alpine features provide many opportunities for employment through outdoor recreational services and accommodation.

The economic performance of the Goulburn Broken Catchment is dependent on the strong rural sector, the associated value-adding industries, and a range of other natural resource-based industries. The Gross Domestic Product (GDP) of the Catchment is expected to rise from $2.97 billion in 1996 to $4.27 billion in 2005. A large proportion of this GDP (around 70% in the judgement of several Catchment managers canvassed) is underpinned by natural assets and the ecosystem services that flow from them.

TRENDS IN NATURAL ASSETS

Processes and trends with respect to natural assets are discussed in more detail in the expert commentaries at the end of this report. The following is a brief summary drawn from a range of past assessments.

Soil

Clearing of native vegetation and replacement with shallow rooted annual pasture and crops in the dryland has led to rising water tables and increased salt in the surface soils. The Catchment contains about 4,500 ha of land that are affected by dryland salinity, which is growing at 5% per year. The major impacts of salinity are expected to be destabilisation of river banks and increased salt in water, which in turn affects costs and productivity of a range of agricultural enterprises. A lot of salt moves from the dryland region of the Catchment into the irrigation region and the River Murray causing concerns about water quality. Water tables also are rising in the irrigation area and severe salinisation is predicted by 2020 if nothing is done.

There are significant areas of sodic (high sodium) soils in the Catchment, which can be unstable and erode easily. Sodic soils interact with salinity, irrigation and rainfall in various ways that can either enhance or mask the effects of sodicity. Understanding sodicity in the context of changing irrigation regimes and rising water tables is an emerging challenge for the Catchment.

The acidity of soils has increased in many parts of the Catchment since the practice of European-style agriculture began over 150 years ago. Overuse of fertilisers and sub-clovers contributes to soil acidity. Acidity affects the structure of the soil and its ability to support native vegetation, crops and pastures.

Biota

The ecosystem services provided by biota depend on there being a diversity of life forms performing a range of functions. This diversity is part of what we call biodiversity. Diverse species underpin processes that help prevent erosion and control salinity, filter and purify water and assimilate wastes, provide protection from floods and control of pests and diseases, maintain fertile soils that are the basis for agriculture, attract tourists, and provide cultural, spiritual and intellectual fulfillment in different ways to all people. Science is not able at this time to predict the impact of losing species on delivery of ecosystem services, so we have to conclude that there are risks in species loss that should be minimised.

In the Goulburn Broken, the suites of species that make up ecosystems have undergone considerable change since European settlement through development of primary industries, including agriculture, mining and forestry.

The Goulburn Broken Native Vegetation Strategy reports that several vegetation types have been reduced to a small proportion (2-9%) of their former abundance and range in the mid and lower Catchment, and pressures are ongoing. Ninety-five species of plants and 85 animal species are considered threatened. Overall, only around 7% of the native vegetation cover of the region at European settlement remains. Although much of this clearing occurred in the 19th Century, it has continued throughout the 20th Century. There is still gradual degradation of roadside and stream vegetation in the mid-lower Catchment and fragmentation of habitat, which affects the viability of species.

Another threat to the natural asset of biota is the wide array of pests and weeds expanding in the Catchment and threatening the viability of farms. There are 70 species of noxious weeds. Exotic animals considered pests in the Catchment include rabbits, wild dogs, horses, pigs, foxes, feral cats, and goats. In waterways, carp are a major problem, stirring up sediment and causing decline of native species. Some native animals are also considered pests when their numbers increase to levels that threaten agricultural enterprises. Problem species include kangaroos, wallabies, cockatoos, galahs and wombats.

Waterways

Pollution of waterways by nutrients flowing from irrigation drainage, sewerage, sediment mobilisation, and intensive animal industries has become a major issue in the Catchment. One major consequence is the blooms of blue-green algae that occur frequently in the Catchment and downstream, threatening health of people and stock and threatening industries such as tourism.

The increased use of streams and rivers in the Catchment by people since settlement has led to problems like stream instability, bank erosion, flooding, and associated threats to public and private assets and habitat. River flows vary greatly due to irrigation needs. Operation of Eildon and the Goulburn Weir has allowed regulation of flows for industrial purposes. These flows differ in pattern across the year from the pre-regulation pattern, which will have implications for river ecosystems.

Atmosphere

Like the rest of the world, the Goulburn Broken Catchment is only beginning to grapple with the question of how its industries and other land-uses affect the composition and function of the atmosphere. The Goulburn Broken Catchment has a lot at stake in relation to climate change and stability. The region's primary industries—agriculture, fruit growing and dairy—would suffer negative impacts from climate change. The region is both a positive and negative contributor to climate stability. Contributions to greenhouse gas emissions are made through intensive dairy, cattle and sheep farming, while carbon sinks are provided in the Catchment through existing vegetation and revegetation efforts.

MEASURES BEING TAKEN TO ADDRESS ENVIRONMENTAL ISSUES

Rural landholders and industries in the Catchment are investing $30-40 million annually in farm infrastructure to support their share of the implementation of the Goulburn Broken Regional Catchment Strategy (Young and Associates 2000). The Catchment strategy provides protection against land and water degradation through improved water use efficiency, improved drainage, reduced soil salinity and waterlogging, improved water quality, more stable soils and enhanced biodiversity.

A wide range of activities is under way to combat problems such as those discussed above. These activities involve partnerships between the Catchment Management Authority, Department of Natural Resources and Environment (DNRE), Landcare, and community groups and individuals. The partnerships include a major salinity program, a waterway program aimed at improving water quality and fish numbers, a program to improve management of floods, and programs to improve whole-farm planning, create wetlands, combat pests and diseases, implement the objective of net gains in biodiversity, and protect and establish vegetation to regulate water flows and support farm incomes. Uptake of environmental programs has been high in the Catchment, in part because it has been possible to demonstrate public as well as private benefits and to improve public/private cost-sharing accordingly.

FUTURE ECONOMIC GROWTH

Local government has identified a range of areas in which future economic growth is expected to occur in the Catchment (reported in detail by Young and Associates (2000) and summarised in the present report).

Improved management practices

Productivity is expected to increase with implementation of best-management practices, particularly in the dairy and horticultural industries. Impacts of wastes are expected to be reduced by innovative waste minimisation technologies and practices, including use of waste as fertiliser for the vegetable industry.

Growth in existing agricultural industries and development of new ones

There is potential for growth in irrigated and dryland cropping, softwood plantations, and stockfeed processing. New irrigation development will be facilitated by identification of Prime Development Zones. New large dairy and horticultural operations (orchard, olives, wine grapes) are expected, together with new investment in thoroughbred horse breeding, mushroom composting and growing, pig and poultry production, and aquaculture. Small producers are predicted to develop cooperatives and joint ventures to market boutique products.

Increased value adding

Business leaders in the Catchment argue that future economic prosperity will be linked with greater value-adding to existing and new products, including timber, through processing and packaging.

Growth in packaging, transport and services sectors

The next five years is expected to see the growth of Shepparton, Echuca, Cobram, and Benalla as regional service centres. Shepparton will grow as a business and training centre. Growth is also expected in the packaging sector, and new investment in the transport and storage sectors.

Growth in tourism and recreation

Tourism and recreation are expected to become larger industries in the Catchment over the next five years and beyond. This growth will include food and winery tourism, river-based recreation and tourism, and all-season promotion of rivers, lakes, forests, and mountains for ecotourism. Accommodation services associated with tourism and recreation will also grow. The attractiveness of rural lifestyle and potential for semi-urban developments within commuting distance from Melbourne are already increasing demand for land in the central part of the Catchment, and this trend is expected to continue.

AN ECOSYSTEM SERVICES APPROACH

At the commencement of this inventory, many of the ecological issues in the Catchment were known, and the major issues have been discussed widely within the Catchment community. Plans have been developed to deal with major threats and to take advantage of opportunities, and projections into the near future suggest continued prosperity. More than any other catchment in Australia, the Goulburn Broken seems ready to face the future well prepared. However, based on the trends summarised in this chapter, several big issues arise that could be considered from an ecosystem services perspective.

Water Quality

Management of water quality has been on the Catchment's agenda for some years, and water availability is getting more and more attention. The roles of ecosystems in providing water filtration and purification services, and in affecting the distribution and availability of water, have been acknowledged more in this Catchment than in most. However, there is still a need to consider how these services can be used more effectively and efficiently, how their cost-effectiveness compares with technological alternatives, and how the needs of the ecosystems themselves for water can be factored into calculations and plans.

Flood Mitigation

Flood management, particularly in the lower Goulburn River, has been considered in terms of costs of maintaining levees and costs of compensation for levee failure. However, the protection from flood damage provided by vegetation, wetlands, and natural drainage systems in ecosystems has not yet been factored into discussions, nor have the water filtration, waste assimilation, biodiversity and life-fulfilling services that might be provided by wetlands under alternative flood-mitigation strategies. A range of social, economic as well as ecological issues are entwined in the issue of flood mitigation, and all need to be considered in an informed debate. An ecosystem services approach could contribute ecological and economic information to broaden that debate.

Healthy Waterways

The health of streams, including populations of native fish, is another big issue that the Catchment is having some success addressing. An ecosystem services approach would put the health of streams into the broader context of processes occurring at all scales within the Catchment.

Soil Health

Soil fertility and structure are of course a major concern throughout Australia due to the degradation that has occurred since the commencement of European-style agriculture. Arguably, the decline has been slowed or even reversed in same places within the Catchment, and strategies are in place to see improvement into the future. Those improvements largely involve addition of chemicals like lime and fertiliser. The role of soil micro-organisms and vegetation in maintaining the health and structure of soil has received little attention. An ecosystem services approach would seek to document convincing examples of tangible benefits to farmers and the broader Catchment community from better management of biodiversity in and above the soil.

Life-fulfillment

As interest in the lifestyles, views and experiences offered by the Catchment grows, immigration into the Catchment will bring potential benefits as well as threats. Looking at the life-fulfilling services provided by ecosystems in the Catchment, how these services might be maintained, how they interact with other services, and what the ecological, economic and social implications might be, is part of an ecosystem services approach to considering the Catchment's possible futures.

Pest Control and Pollination

Better use of nature in pest, weed and disease control has certainly been considered in the Catchment, but managers have told us that these services deserve much more attention. The service of pollination, on the other hand, had barely been considered anywhere in the world until fears were raised about possible declines in pollinators that could threaten crops as well as native vegetation. How likely are decreases in pollination in the Catchment, and what effects could they have? A focus on ecosystem services reveals this issue as one to consider further.

All of these issues are, of course, strongly interrelated and must be managed in an integrated way. A focus on ecosystem services is one way to help us all focus on the possible paths to sustainability. Neither scientists nor anyone else have enough information to say exactly what sustainability is or how to get there. A sustainable future could have many different forms. We can say confidently, however, that a sustainable future must provide the full range of services currently provided by ecosystems. The task of policy makers and land managers is to match land management with land capability. This inventory of ecosystem services in the Goulburn Broken Catchment gives a look into what services are currently provided, and forms the basis for a more detailed assessment later of what might happen to those services under a set of scenarios for the future.

Chapter 3

Purpose and conceptual framework

3.1 PURPOSE OF THE INVENTORY

One of the central components of the Ecosystem Services Project in the Goulburn Broken Catchment is to produce an inventory of ecosystem goods and services. There are numerous reasons why an ecosystem services approach to the inventory is necessary. First, such an approach encourages us to look at landscapes and ecosystems and the processes going on in them in a different way that can reveal new problems and new opportunities. Second, considering ecosystem services broadens the set of benefits and values from nature beyond the relatively narrow set now considered in decision making. Third, because ecosystem services flow from interactions among the whole set of processes occurring in ecosystems, an ecosystem services approach forces us to view our catchments holistically rather than looking at individual components in isolation from one another. Fourth, the concept of ecosystem services give us a framework to consider the quality of relationship between humans and the environment beyond the five or so years of current predictions. Finally, in line with the expressed wishes of people in the Catchment, an ecosystem services approach allows us to document the lessons learned in this Catchment in ways that have immediate relevance to land managers in other catchments.

With this approach in mind, the Inventory report sets out to achieve a number of objectives including:

- Describing the full range of goods produced in the Goulburn Broken Catchment.
- Identifying the dependence of these goods on the natural processes delivered through ecosystem services.
- Identifying the ecosystem services of highest priority in the Goulburn Broken for further study and management.

In turn, these objectives raise a number of very important questions:

1 How do we categorise the goods produced in the Catchment and the ecosystem services that support their production?

2 How do we determine the relationship between goods and the ecosystem services?

3 How do we rank the importance of the different ecosystem services?

4 How do we identify priorities for further study and management?

In answering these questions it must be recognised that there are many gaps in our knowledge of how nature supports the production of goods. For example, it is often asserted that up to 10-15% of a farm can be devoted to native vegetation and this will have a positive impact on productivity due to benefits associated with a number of ecosystem services including: reduced pest loads, reduced water logging, and shade and shelter for stock. Similarly, there is increasing evidence that natural ecosystems play a key role in producing goods like clean and pure water, and services like assimilation of wastes, which are important to people in towns and cities even more than they are to farmers. These benefits are often asserted but are not backed up by quantitative analysis. Hence, much uncertainty exists in terms of the significance of the impacts over different timeframes and scales. Often the scientific studies required to identify empirical relationships are yet to be undertaken.

The approach taken in this study has been to combine local knowledge within the Catchment with the knowledge of leading experts in the disciplines covered by the range of ecosystem services. This has been done to identify priority issues that require further study.

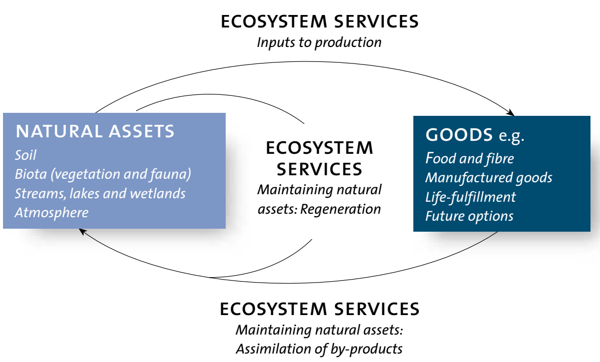
The results of the inventory are summarised in the following chapters , which are structured against the four questions highlighted above. Questions one and two are addressed in chapter four and questions three and four are addressed in chapter five. The data used are contained in the appendices to the report. The rest of this chapter outlines the way we have applied the concept of ecosystem services.

3.2 CONCEPTUAL FRAMEWORK FOR UNDERSTANDING THE ROLE OF ECOSYSTEM SERVICES

In this section a conceptual framework is developed that outlines the role of ecosystem services in maintaining natural assets and in supporting the production of goods and services of value to the Goulburn Broken community and beyond the Catchment. The framework is depicted in the diagram below.

DIAGRAM 6

Ecosystem services conceptual framework



The diagram defines ecosystem services by highlighting their role in linking the environment (natural assets) with the things that people value (goods). In order to understand this, it is important to define ***natural assets*** and ***goods*** carefully.

Natural Assets are the stock of natural resources from which many goods are produced. At the highest level these assets can be described as: soil, biota (vegetation, fauna and other living organisms), water systems (streams, lakes and wetlands), and atmosphere. Natural assets must be kept in good condition for at least two reasons. First, their health directly impacts on their capacity to continue to provide inputs to production; and second, natural assets have value in their own right to the extent that people derive value directly from their existence.

If natural assets are well managed they have the capacity to provide for human needs forever. This stands in contrast to human made assets that have a limited life, for example a car or a factory. Natural assets are continuously depleted and regenerated by ecosystem services, and the challenge is to ensure these assets are not depleted faster than they regenerate.

Goods are all things produced in the Catchment that are of value to humans. In this study we emphasise the role of natural assets in the production of goods. However, it is important to also recognise the role of manufactured capital, technology, labor and social institutions in the production of goods. Goods are generally produced using a range of natural and human-made inputs.

The most obvious goods that are dependent on ecosystem services are agricultural products such as wool, wheat and beef. But the scope is much broader. Recreational opportunities, for example, can be viewed as goods or products coming from natural and human-made assets, as can less tangible products such as the value provided by a beautiful view, or the well-being derived by a weekend's retreat from Melbourne, or the peace of mind from knowing that other species are being maintained in viable populations.

The natural assets, ecosystem services, and goods considered in this report are introduced in Table 2 on page 21.

Ecosystem services, therefore, contribute to the economic and social well-being of people in and beyond the Catchment in two ways.

- Through the use of natural resources (derived from natural assets) to provide an ***input to production*** of a good. For example, fruit production is dependent on the service of pollination, which in turn is dependent on the natural asset of biota to provide insect pollinators. Similarly, crops are dependent on the service of nutrient cycling, which uses the natural asset of soil.
- By ***maintaining natural assets*** via two pathways. The first is through regenerating natural assets. Examples include maintaining soil health through nutrient recycling or maintaining native plants and animals through regeneration of native habitat. The second is through the assimilation of by-products arising from production processes or from consumption of goods. Examples include the assimilation of carbon dioxide from industry by vegetation or the detoxification of chemicals by micro-organisms.

The key question revealed by conceptualising natural assets, goods and ecosystem services in this way is:

Can our natural assets be managed in a way that sustains the ecosystem services that in turn support the production and consumption of goods in the Catchment?

A number of complicating factors must also be considered. First, although we think we have identified most goods produced in the Catchment, the relative importance of different goods in any particular part of the Catchment is constantly changing. A good example is the growth of lifestyle farming and agro-forestry which is replacing cropping and grazing in some areas.

Second, we have not been able to make full recognition in this report of the ability to substitute other assets for natural assets in the production of goods. For example, fertilisers, pesticides and imported fodders can be substituted for ecosystem services in high input grazing systems, which complicates our assessment of how important ecosystem services are to that land-use. This raises important issues to be addressed in subsequent work in this project such as the pros and cons of more intensive agricultural systems in the Catchment. They bring higher on-farm returns, but may have higher off-site impacts such as nutrient run-off to waterways.

Third, the Goulburn Broken is not a closed system, which means that the import and export of goods and assets must be considered. Many goods consumed in the Catchment are produced elsewhere. Likewise the Catchment is a significant exporter of agricultural produce. Assets may also be imported such as machinery or fertiliser. Some impacts external to the Catchment will need to be considered. A good example is the contribution that the Catchment can make to meeting water quality targets for the Murray River which provides Adelaide's drinking water.

Fourth, the role of markets and institutions in determining land-use and production methods will need to be considered in the later stages of this project. These considerations affect predictions of how important ecosystem services will be to the land-use in the future. Importantly, an assessment of the potential future changes in composition of goods produced and consumed in the Catchment will need to be made.

Despite these complications the framework presented here provides a powerful way in which to define and then consider the value of ecosystem services. They are the link between our natural assets and the goods we consume. This study tests whether our ignorance of ecosystems has led us to take our natural assets for granted and thus deplete them gradually over many years.

We need to know about the full range of ecosystem services so we can take account of them in making better informed, and more efficient, land-use and management decisions.

TABLE 2

List of categories of natural assets, ecosystem services and goods in the Goulburn Broken Catchment

Natural Assets	*Ecosystem Services*	*Goods*[1]
Rivers, lakes and wetlands Biota (flora, fauna and other living organisms) Soil Atmosphere	Pollination Life-fulfillment Regulation of climate Pest control Maintenance of genetic resources Maintenance and regeneration of habitat Provision of shade and shelter Prevention of soil erosion Soil fertility Maintenance of soil health Maintaining healthy waterways Water filtration Regulation of river flows and groundwater levels Waste absorption and breakdown	**Primary Industries** **Dairying (on farm)** – milk **Fruit & Grapes** – all fruit including grapes, berries, kiwi fruit and citrus **Vegetables (above & below ground)** – mainly tomatoes and potatoes **Grazing** – wool, meat & horses **Crops** – barley, oats, wheat, triticale (cereals) beans, lupins, peas, faba beans, chick peas (legumes) canola, safflower (oil seeds) irrigated maize, millet, sunflower (summer crops) **Hay and seed production** – feed and seed **Intensive animals** - Pigs & poultry – pork, bacon, eggs, chicken meat - Fish – fish, yabbies and eels - Horses – breeding, racing, recreation **Apiculture** – Honey/beeswax **Forests (Hardwood, Softwood)** – timber, firewood **Mining (Land & water based)** – gravel, minerals and sand **Other** – flowers, emus, llamas, ostriches, deer, goats, turkeys **Processing/Manufacturing** Dairy – powder, cheese, butter oil, milk Fruit & Grapes – cans, soups & wines Vegetables (tomatoes) – tomato sauce/paste, canned tomatoes Wood products – woodchips, pulp, sawlogs, pine chips, particle board, posts, poles Other goods – steel goods, clothing, printing **Housing and construction** Urban and rural real estate **Electricity, Gas and Water** **Water Production (Surface and sub surface)** – urban water, irrigation, secondary and tertiary industries **Hydroelectricity** – electricity **Service industries** **Wholesale and retail trade** – wholesalers, shops, mechanical repairs **Transport and communication** – road, rail, water and air transport and communication **Finance and business services** – banking, finance, insurance, real estate, technical support **Housing services** – dwelling ownership **Public administration** – public administration and defence **Community services** – health, education, welfare, religious and community organisations **Entertainment and Recreation** – recreational services and hospitality (hotels and restaurants) **Environmental, Cultural, and Aesthetic Goods** **Biodiversity** – values associated with diversity of animals and ecosystems **Aesthetic values** – views and scenic amenity **Cultural values** – cultural and natural heritage **Option Values** – values associated with future (unknown) values

1 Goods have been aggregated by key industries and land-uses. Examples of the goods associated with each land-use are provided.

Chapter 4

Categorising goods and ecosystem services in the Catchment

4.1 CATEGORISING GOODS PRODUCED IN THE CATCHMENT

The conceptual framework developed for this study highlights the need to define ecosystem services in the context of the linkages they establish between natural assets and the production of goods that are of value to humans. A necessary starting point, therefore, is to define the goods produced in the Catchment and begin the process of assessing their value.

Table 3 on page 24 provides a summary of key land-uses and industries in the Catchment, the area of land associated with their production and the quantity, and value of goods produced. It summarises some aspects of the value of key goods from the Catchment. A more detailed table, noting data sources, is available in Appendix 2. Goods have been assigned to one of the broad sectors discussed below.

Primary industries. The significance of primary industries and their dependence on the full range of natural assets and ecosystem services is self-evident. As a result considerable care has been given to ensure all major land-uses are covered.

Processing and manufacturing. The vertical integration of primary production and processing sets the Goulburn Broken Catchment apart from many other agricultural regions in Australia. Value-adding to key industries within the Shepparton Irrigation District provides the backbone of the regional economy.

Housing and construction. Housing and construction is a significant contributor to the regional economy. Rural subdivision and development is a major issue for local councils within the Catchment. Estimations put annual investment in excess of $100 million in new infrastructure in the farming and food processing sectors.[1]

Electricity and water. Water is a key good provided by natural systems within the Catchment. It is both a key input to production and significant good in its own right. The impacts of electricity supply (which is largely imported) and distribution are, however, not considered in detail in this report.

Service industries. Service industries such as human health, transport and education are undoubtedly interconnected to ecosystem services. For example, the ecosystem service of maintaining clean air has positive impacts on health. However, these linkages are often indirect and for this reason were considered beyond the scope of this report[2]. A key industry that is more directly dependent on ecosystem services is tourism. It is estimated that the value of tourism to the Catchment is in excess of $100 million.

Environmental, cultural, and aesthetic goods. This category of goods represents values that are often intangible and/or public goods. The intrinsic value of biodiversity is included as well as aesthetic and cultural values. In addition the value of natural assets in

1 See Young and Associates (2000)

2 The analysis of the services sector may be strengthened following the development of scenarios for the Catchment in the next phase of the study.

providing a broader range of options for the future is considered. As noted in Table 3, to date no estimate has been made of these values. This is for two reasons. First, the values are subjective and difficult to define. For example, what is the impact of a new housing development on scenic amenity? Second, techniques for placing values on non-market goods of this kind are controversial. A key priority for future stages of this project will be to more rigorously define and develop processes to account for the values of these goods in decision making.

The process of categorising goods has led to land-use and industry-based categorisations. For simplicity, ecosystem services are considered against these broad land-use and industry based headings in subsequent chapters of this report. However, we ask the reader to bear in mind the set of goods associated with these broad categories as indicated.

In Table 3, two estimates of the financial value of goods produced in the Catchment have been provided. The first is an estimate of the ***gross value of production*** which is a simple calculation of the market value of the goods produced. The second is an estimate of the ***value added*** by each land-use/industry which is the gross value of production minus the value of all inputs.

Estimates of the value added by each land-use/industry are important in understanding the relative importance of each industry to the regional economy. This is because they avoid double counting the value of inputs. For example, hay is an input to dairy farms that produce milk, which in turn is an input to dairy processing. Hence, the risk is that the value of hay will be counted three times. The further disaggregated the analysis becomes, the longer the product chains become and the greater the problem of double counting. This can be seen in the contrast between the gross value of production, approximately $6.5 billion, and the value-added estimate of approximately $3 billion.

Unfortunately estimates of the financial value added by industries and land-uses are difficult and costly to estimate as they require a detailed understanding of inputs to and outputs from all land-uses and industries as well as imports and exports from the region. The value-added estimates in Table 3 are extrapolated from an input-output study of the Shepparton Irrigation District completed in 1996 and must be treated with some caution.[3]

The gross value of each of the sets of goods identified in Table 3 has been derived from the best available data sources. It is important to note that the categorisation of goods was not undertaken on the basis of an analysis of traditional economic sectors. Rather goods were grouped on the basis of the links between land-uses and their potential impacts on key ecosystem services. This has meant that some unusual groupings of goods or production systems have emerged. For example pig and poultry production were combined because of the similarity of the production system: housed animals with significant waste management issues.

The approach taken to collecting the data and grouping industries means that a relatively wide number of data sources has been used. These are noted in Appendix 2. This raises a number of potential weaknesses in the data collection process:

- Different data sources may have used different methods for valuing production so comparisons of absolute values should be made with caution.
- In some cases extrapolations and estimates have needed to be made because the data sets available do not precisely cover the region or the category of goods.
- In some cases data for the base year (1996) were not available and data from other years were used.

In considering whether these potential weaknesses undermine the validity of the study, the purpose for which the data have been collected needs to be considered. For example, if the purpose were to precisely estimate Regional Gross Domestic Product (i.e. the sum of all value added in the region), the issues of double counting and inconsistent data sources would be significant and would need to be resolved through the construction of more robust input-output tables. However, our purpose has been to gauge the relative importance of different goods and land-uses at a fairly coarse scale. We are primarily interested in the overall significance of different production systems to the economy of the region on a scale of low, medium or high (see discussion of ranking). For this purpose the data collected would appear adequate.

3 Farmstats Australia Pty Ltd, *The Economic Impact of Irrigated Agriculture in the Shepparton Irrigation Region*, prepared for the Sustainable Regional Development Board (1996)

TABLE 3

Key Land-uses and Industries in the Catchment

Land-use	*ha*	*Quantity*	*Gross Value of Production*	*Value added*
PRIMARY INDUSTRIES				
Dairying – on farm	112,000	840 ML	$453,348	$148,937
Fruit & Grapes	11,000	269,813 tonnes	$173,553	$63,963
Vegetables – above ground	1,755	70,960 tonnes	$28,184	$10,387
Grazing	1,223,000	quantities can be found for wool and meat	$236,315	$123,157
Crops – Cereals	104,700	237,900 tonnes	$51,857	$33,138
Crops – Summer, Legumes, Oil seeds	18,100	32,800 tonnes	$5,743	$3,670
Hay and seed production	112,600 (all)	426,100 tonnes	$72,691	$37,883
Intensive animals – pigs, poultry, fish	200 (not including horses)		$42,614	$21,982
Apiculture	n.a.		$1,060	$530
Forests – Hardwood/Softwood	456,797	340,000m3	$85,500	$58,584
Mining – Land/Water based	n.a.		$1,000	$593
Alternative industries			No estimate available	
TOTAL PRIMARY INDUSTRIES			**$1,151,865**	**$502,824**
MANUFACTURING				
Dairy – processing	n.a.	n.a. – varied products	$1,562,000	$346,695
Fruit & Grapes – processing	n.a.		$798,000	$278,292
Vegetables – tomato processors	n.a.	55,452 tonnes	$159,600	$55,658
Timber Products	n.a.	-	$171,000	$68,698
Other Manufacturing			$236,000	$84,256
TOTAL FOR MANUFACTURING AND PROCESSING SECTOR			**$2,926,600**	**$833,601**
HOUSING AND CONSTRUCTION				
Building and Construction	73,266	-	$276,000	$151,189
TOTAL HOUSING AND CONSTRUCTION			**$276,000**	**$151, 189**
HOUSING AND CONSTRUCTION				
Electricity and gas			$118,000	$48,972
Water	2,431,654	3,400 GL	$80,000	$60,103
TOTAL ELECTRICITY, GAS AND WATER			**$198,000**	**$109,075**
SERVICES SECTOR				
Wholesale and retail trade	n.a.	estimates unavailable	$636,000	$387,422
Transport and Communication	n.a.	estimates unavailable	$310,000	$188,689
Finance, Housing and Business Services	n.a.	estimates unavailable	$428,000	$297,907
Public Administration and Community Services	n.a.	estimates unavailable	$468,000	$308,173
Entertainment and Recreation	n.a.	estimates unavailable	$158,000	$84,676
TOTAL SERVICES SECTOR	n.a.	estimates unavailable	**$2,000,000**	**$1,266,867**
ENVIRONMENTAL, CULTURAL AND AESTHETIC GOODS				
Biodiversity	n.a.		Significant non-financial value	
Aesthetic values	n.a.		Significant non-financial value	
Cultural values	n.a.		Significant non-financial value	
Option Values	n.a.		Significant non-financial value	
TOTALS – ALL SECTORS			**$6,552,465**	**$2,863,558**

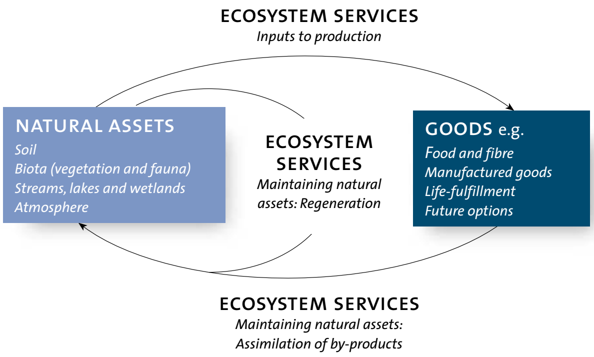
4.2 OVERVIEW OF ECOSYSTEM SERVICES AND THEIR ROLE IN THE CATCHMENT

Ecosystem services involved in the production of goods in the Catchment have been categorised on the basis of an assessment of the interaction between all goods produced in the Catchment and natural systems. The process of categorisation has involved a number of iterations between Catchment and scientific experts. However, the process of categorising ecosystem services is fraught with difficulty because of the interconnected nature of the services and because different people have different perceptions of the services they receive from ecosystems.

Below, the services are briefly introduced and defined while also outlining key issues associated with these services for the Goulburn Broken Catchment. The role of each service is discussed as both an input to production and its role in maintaining natural assets.

DIAGRAM 7

Ecosystem services conceptual framework



A more detailed discussion of each of these ecosystem services and the interactions between them is found in the specialists' papers in Chapter 7.

POLLINATION

Pollination is the service of fertilising flowers allowing for seed and fruit production. Pollination is critical to the regeneration of plants and to the production of fruits and seeds for consumption by animals and people.

Input to Production

Pollination is an essential input to the production of all plants and fruits. Plants dependent on wind pollination are secure (provided they have viable populations). However plants requiring insect pollination are dependent on an adequate number of pollinators. The dependence and sensitivity of each land-use on pollination is assessed.

With the important exception of the fruit industry, pollination services would generally appear to be secure within the Catchment. Introduced bees (hives) are used by fruit growers to ensure adequate pollination of trees. The key risk is dependence on European bees, which are at risk from the honey-bee mite.

Maintaining Natural Assets

Pollination is required to facilitate habitat regeneration. This issue is addressed under habitat regeneration.

LIFE-FULFILLMENT

Life-fulfilling services are defined as provision of aesthetic beauty, cultural, intellectual, and spiritual inspiration, sense of place, existence value, scientific discovery, and serenity.

Input to production

Life-fulfillment arises from the sense of place or enjoyment derived from our landscape. It is a key input to the housing, recreation and tourism industries.

Maintaining natural assets

Relates to the state of the landscape and its ongoing capacity to provide life-fulfilling services. The impact of different land-uses on landscape change is assessed. In considering this impact we recognise that landscape changes that please some people are not highly valued by others.

REGULATION OF CLIMATE

Regulation of climate relates to the services provided by plants, animals and other organisms, including those in soil, that regulate atmospheric composition and weather patterns, which in turn create the environment in which different plants and animals, including humans, live. The carbon cycle is a critical component of this process.

Input to production

Regulation of climate is a key input to production and variation in climate will lead to large fluctuations in agricultural yields from year to year. Variations are a normal part of the climatic cycle and are not addressed in this report. However, the capacity of land-uses and industries to adapt to changes in climate patterns is included.

Maintaining natural assets

Climate change is occurring at a global scale because of the increases in greenhouse gases (for example carbon dioxide and methane). The contribution of each land-use and industry to greenhouse targets is assessed.

PEST CONTROL

Pest control is the service of controlling organisms that are unwanted or cause damage to things that are of value to people.

Input to production

The importance of pest control in producing key goods in the Catchment is assessed. Pest control is of particular importance to the horticulture, vegetable, cropping and grazing industries, including issues surrounding the use of pesticides that represent a significant cost of production.

Maintaining natural assets

Pest control may be required to facilitate habitat regeneration, maintain soil biota or the health of water systems. These issues are addressed under other services and therefore are not considered under pest control.

MAINTENANCE AND PROVISION OF GENETIC RESOURCES

Genetic resources are part of biodiversity, which consists of genetic, species and ecosystem diversity. Genetic and species diversity (genetic variation) plays a role in both sustaining production systems and maintaining and regenerating natural habitat.

Input to production

This service is considered in terms of the contribution of genetic variation to the production of the good. For example, the capacity to develop different strains of crops, fruit trees and pastures to adapt to changing climate conditions is a key longer term service provided by genetic variation.

Maintaining natural assets

The role of genetic diversity is fundamental to maintaining natural assets. Genetic diversity is the foundation of biodiversity that supports all life. Genetic diversity is of particular importance in ensuring that ecosystems are resilient—that they have the capacity to bounce back from disturbance.

MAINTENANCE AND REGENERATION OF HABITAT

Maintenance and regeneration of habitat is the service of maintaining the biota through processes of regeneration, the maintenance of viable populations of fauna and the management of vegetation to facilitate production, dispersal and growth of seed.

Input to production

Habitat regeneration and maintenance is an important input to maintaining areas of native vegetation that are used for recreation, protection of biodiversity and through the growth of wood as an input to production of native forest products.

Maintaining natural assets

Habitat will degrade in the absence of regeneration. A range of processes can reduce the capacity of habitat to regenerate including, for example, grazing, clearing and weed invasions. The impact of land-uses and industries on habitat regeneration are assessed.

PROVISION OF SHADE AND SHELTER

Provision of shade and shelter is the service provided by vegetation that ameliorates extremes in weather and climate at a paddock scale. Shade and shelter are required for both plants (in the case of wind damage to crops) and animals.

Input to production

An assessment is made of the extent to which each land-use is dependent upon and sensitive to shade and shelter services. The provision of shade and shelter may be a significant issue in relation to animal health and fruit production.

Maintaining natural assets

The provision of shade and shelter is required for the regeneration of habitat and the maintenance of water systems. These issues are addressed under the services of habitat regeneration, water filtration and maintenance of healthy waterways.

WATER FILTRATION AND PREVENTION OF SOIL EROSION

Filtration and erosion control relates to the functions performed by soil components (including soil biodiversity) and vegetation in minimising soil loss and filtering sediments from water to improve water quality.

Input to production

Water filtration and prevention of soil erosion make a direct contribution to the production of clean water, which is a key input to many industries in the Catchment.

Maintaining natural assets (soil and water)

Water filtration and prevention of soil erosion contribute directly to the maintenance of soil and water resources both in their role as stabilising processes in native ecosystems and in the assimilation and stabilisation of additional sediments mobilised by human activities including agricultural production. The impacts of land-uses and industries on the capacity of natural assets to provide these services have been considered in relation to two key issues in the Catchment:

- **Sedimentation/Turbidity** The impact on turbidity and sediments in water systems (rivers, lakes and wetlands).
- **Soil loss** The impact on soil loss resulting in a reduced stock of fertile soils for future use. Soil loss through gully, sheet and wind erosion is an important longer-term issue in some grazing and cropping regions.

MAINTENANCE OF SOIL HEALTH

Maintenance of soil health is the service of: providing a physical medium for plants to grow in, providing moisture and nutrients to plants, maintaining soil biota that regenerate soils, supporting the growth of plants, and supporting the transport of water and nutrients in the landscape. In short, soil is a vital living system that is required to sustain biological productivity, promote air and water quality and maintain plant, animal and human health.

Input to production

Soil is integral to the growth of all plants. Soil fertility is considered as the key input to the production of plants and crops.

Maintaining natural assets

The impact of land-uses on soil structure, acidity, compaction and soil biota are considered in ranking the services. Soil health is a key issue for all agricultural land-uses within the Catchment with trends varying widely depending on individual farm management practices.

MAINTENANCE OF HEALTHY WATERWAYS

This service can be defined by a balance of fish, invertebrates, plants and algae in waterways, with the appropriate in-stream, riparian and floodplain habitats for these organisms to live in. Water quality relates to the chemical composition of water and the state of water bodies. Chemically it is desirable that water be free of artificial chemicals and contain only chemicals found in nature, for example phosphate, nitrate and trace metals.

Input to production

The dependence of each land-use/industry on healthy waterways is assessed. Healthy waterways is a significant input to the production of all goods dependent on water. However, water quality is generally sufficient for most agricultural purposes. Water quality is a more critical issue when considering the treatment of town water.

Maintaining natural assets

The contribution/impacts of each land-use/industry on the state of water systems is assessed. Linked issues including filtration, waste absorption and water flow are addressed under separate ecosystem services.

REGULATION OF RIVER FLOWS AND GROUND WATER LEVELS

This service relates to the service of collection and distribution of water through rivers, lakes, wetlands and groundwater systems.

Inputs to production

This service is integral to the production of all plants and animals and is also an important input to some manufacturing and processing industries. Water from off-site or water that is stored and used on-site has been considered an input in this study.[4] Water resulting from rain is addressed under climate stability.

Maintaining natural assets

Water is a resource that is involved in a complex range of flows and interactions between soils, plant growth, evaporation, groundwater systems, streams, and storages. Water is essential to life, but must also be kept in balance. The impact of land-uses on three issues of high significance to the Catchment in maintaining natural assets have been assessed.

- **Ground water tables.** Because of the removal of perennial vegetation (native trees, shrubs and grasses), increasing quantities of water are moving through the soil profile and reaching the groundwater table. As a result groundwater tables are rising and mobilising salt causing increased salt loads in waterways and loss of soils through salinisation.
- **Water flow.** Water flows are required to maintain the health of our water systems: their aquatic life and the

4 It is acknowledged that water collected and used on-farm will affect water flows within the Catchment.

flora and fauna dependent on stream and lake banks. The management of environmental flows from water storages is a key issue.

- **Flooding.** Flooding is a natural outcome of variation in climate and precipitation. Natural systems are adapted to this through the creation of floodplains and wetlands. However, if these are removed or land-uses changed, flooding may become more severe.

WASTE ABSORPTION AND BREAKDOWN

This service captures the role played by various organisms (terrestrial and aquatic) in absorbing and breaking down wastes.

Input to production

Waste absorption and breakdown do not generally make a direct contribution to the production of goods. An important exception, however, is in considering water production where waste absorption will work to improve water quality.

Maintaining natural assets

Waste absorption is a natural function played by ecosystems that have the capacity to assimilate wastes[5]. However, ecosystems can only absorb a certain quantity of waste before the wastes can no longer be assimilated resulting in undesirable outcomes. Nitrogen and phosphorous loads in waterways are considered at a Catchment scale with a number of on-site wastes including sodium, bacteria, biocides and heavy metals considered at a site scale. Waste management is a very important issue in the Catchment due to the size and scale of the intensive agriculture and the food processing industries. A key issue is the risk of algal blooms in waterways at times of low flow.

5 Some ecologists would argue there is no such thing as waste in a properly functioning ecosystem as every output is an input to another part of the system.

Chapter 5

Ranking and identifying priority ecosystem services

5.1 METHODS FOR IDENTIFYING PRIORITY ECOSYSTEM SERVICES

The major task undertaken in this inventory has been a first assessment of the relative importance of each ecosystem service to each land-use/industry in the Catchment. Because of the number of issues confronting the Catchment it is important to use a robust and consistent method to sort through the complexity and to identify those issues of highest importance to the sustainable management of the Catchment.

Drawing on the conceptual framework depicted on page 19 the relationship between each service and each land-use/industry has been ranked against the two key functions of ecosystem services:

- **Input to production.** Assessment of ecosystem services in this role was based on a combined weighting of the value of goods associated with each land-use/industry and the importance of the ecosystem service in producing those goods.
- **Maintaining natural assets.** Assessment of ecosystem services in this role was based on the impact of each land-use/industry on the capacity of natural assets to continue to provide ecosystem services.

Within these two functions three assessment criteria have been used:

- **Overall importance/impact.** First in relation to inputs, the overall importance of the service in relation to the production of goods; and second in relation to maintaining natural assets the impact of the land-use/industry on ecosystem service's capacity to maintain natural assets.
- **Importance at the margin.** The impact of a small change in a service on the production of a good or the maintenance of natural assets.
- **Manageability.** The capacity to manage the land-use/industry to ensure the ongoing delivery of the service (noting that a low ranking may imply a high priority for further effort).

These criteria have the capacity to identify priority services from a biophysical perspective. Assessment of current and potential management actions will be a key focus in the next phase of the study. Key management implications for the most highly ranked ecosystem services are discussed in this chapter.

The ranking process was highly iterative with regular revision and feedback. Rankings were initially undertaken within the Catchment based on local knowledge and then cross-checked by scientific experts. Draft rankings were then used to consult more widely within the Catchment and with specialists in the period between November 2000 and April 2001 (see Appendix 1 for a detailed breakdown of the consultative process).

Of course many gaps in our knowledge exist. Wherever possible these have been highlighted. Nevertheless the process has endeavoured to ensure that the best available knowledge was applied in a rigorous and transparent manner.

Table 4 provides a summary of the priority (most highly ranked) ecosystem services associated with each land-use/industry. These rankings are derived from the tables contained in Appendix 1. This appendix also includes a more detailed summary of the methodology used to derive the rankings.

TABLE 4

Highly ranked ecosystem services

Land-use	*Highly ranked ecosystem services*
Dairying – on farm	Regulation of climate Provision of shade and shelter Maintenance of soil health Maintaining healthy waterways Regulation of river flows and groundwater levels Waste absorption and breakdown (Phosphorus & Nitrogen)
Fruit & Grapes	Pollination Regulation of climate Pest control Maintenance and regeneration of habitat Provision of shade and shelter Maintenance of soil health Maintaining healthy waterways Regulation of river flows and groundwater levels Waste absorption and breakdown (P & N)
Vegetables	Pest control Maintenance and regeneration of habitat Maintenance of soil health Water filtration and erosion control Waste absorption and breakdown
Grazing	Life-fulfillment Pest control Maintenance and provision of genetic resources Maintenance and regeneration of habitat Provision of shade and shelter Maintenance of soil health Maintaining healthy waterways Water filtration and erosion control Waste absorption and breakdown
Crops (including hay and seed production)	Pest control Provision of shade and shelter Maintenance of soil health Water filtration and erosion control Regulation of river flows and groundwater Waste absorption and breakdown
Intensive animals: pigs, poultry and horses	Regulation of climate Waste absorption and breakdown
Forestry (Hardwood/Softwood)	Maintenance and regeneration of habitat Maintaining healthy waterways
Food Processing (e.g. tomatoes, fruit & grapes)	Regulation of climate Maintaining healthy waterways Waste absorption and breakdown
Housing	Life-fulfillment Maintenance and regeneration of habitat Provision of shade and shelter Waste absorption and breakdown (P&N)
Recreation (land & water based) (including other Public Land)	Maintenance and regeneration of habitat Maintaining healthy waterways Regulation of river flows and groundwater levels Waste absorption and breakdown (P, N & Carbon)
Water production	Water filtration and erosion control Regulation of river flows and groundwater levels Waste absorption and breakdown Maintaining healthy waterways
Areas of culture/future options	Life-fulfillment Maintenance and regeneration of habitat

5.2 KEY ISSUES FOR DIFFERENT LAND-USES AND INDUSTRIES IN THE CATCHMENT

This section of the report identifies key issues, pressures and causes of those issues, and potential management actions for those ecosystem services ranked highly against a land-use or industry. Issues are identified on an industry-by-industry basis as both the issues and management responses vary across industries.

Vegetables

Vegetable production is a relatively small land-user (1,755 ha of the Catchment in 1996/97), although this is growing. In the Catchment 70,000 tonnes of vegetables were produced, 63,000 tonnes being tomatoes, creating a GVP of $28 million. Since 1980 this GVP has only increased gradually from a little over $20 million. However, there has been a dramatic increase in production in the past few years. In 1999/2000, 380,000 tonnes of processing tomatoes were grown in the Catchment.

Although similar to fruit and grapes, the key management issue to emerge is chemical use and the link to soil health. Greater consideration of conservation bio-control and integrated pest management has the potential to reduce chemical usage and its negative impacts.

TABLE 5

Vegetables—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Pest control	Intensive use of pesticides	Cosmetic appearance of crop is significant to market	Employ conservation biocontrol and Integrated Pest Management Develop selective soil fumigation chemicals
Maintenance and regeneration of habitat	Clearing of endangered and vulnerable ecosystems	Land-use intensification	Design landscapes to include a representative range of threatened ecological communities
Maintenance of soil health	Excessive use of ammoniacal **fertilisers** in intensive vegetable production has, in some instances, caused severe topsoil and subsoil acidification and the leaching of potassium.	High nutrient input Intensive irrigation High energy cultivation Crop rotation	Do research to minimise negative impacts of tomato growing Apply ammoniacal fertilisers efficiently Use innovative rotations and inter-plantings (also encourages natural enemies) Manage soil health to minimise erosion
Water filtration and erosion control and Waste absorption and breakdown	Soil loss and nutrient run-off	Cultivation practices that leave bare and disturbed soil may allow excessive run-off and soil loss Lack of buffer areas between cropping areas and streams may result in direct transmission of sediment and associated pollutants	Minimum tillage practices Provide buffers between cropping areas and streams

Dairy Industry

Dairying occupies almost half a million hectares of irrigated land in northern Victoria and produces about a quarter of Australia's milk. Before and since deregulation of the industry, there has been a trend towards intensification, with larger and fewer farms and herds, and increased production per hectare and per cow. There are about 510,000 dairy cattle in the Catchment, which contribute in excess of $450 million dollars in revenue to the region (including all of the Shepparton Irrigation Region).

Other trends include a marked increase in nitrogen fertiliser application and irrigation water to pastures over the last 10 years. The industry claims that opportunities exist for increased production without compromising the natural resource base. This translates into adopting more efficient use of irrigation waters, nutrient management of pastures and a search for alternative pasture and fodder species.

Management issues for the highly ranked ecosystem services are primarily focussed on pasture management including: whole farm plans, drainage, irrigation practices, and nutrient management. The role of soil organisms is an issue of significant interest in pasture management.

TABLE 6

Dairy—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Regulation of climate	**Greenhouse gas emissions** The dairy industry is a major contributor to greenhouse gases within the Catchment	**Animals** Methane emissions equivalent to about 1480kt CO2-e	Increase efficiency of production to maximise production per unit emissions. Investigate use of new technologies to alter rumen function to reduce emissions
		Pasture An additional 340kt CO2-e/ year may be generated from associated nitrogen fertilisation, water logging and legume pastures	Improve pasture management to increase soil carbon stores, e.g. laser grading, drainage, whole farm planning in irrigated and high rainfall areas Apply fertilisers at rates and times that reduce nitrous oxide emissions and maximise the uptake by plants
		Wastes Nitrous oxide emissions of approximately 160kt CO2-e/year from the waste of animals including poundage of dairy shed effluent	Improve waste disposal methods including application of slurry on fields, methane biogas digesters to aerated pondages Apply denitrification inhibitors and new technologies
		Energy consumption Electricity usage in dairy farms is substantial and may produce emissions of up to 78kt CO2-e/year	Employ energy audits and improved technologies
Provision of shade and shelter	**Heat stress in animals** Heat stress has many adverse effects on livestock, including reduced reproductive efficiency, decreased liveweight gain, and reduced milk production	Clearing of native vegetation and an increasing prevalence of vegetation 'dieback'	Evaluate impact of heat stress on milk production in the region ▌ Plant shade trees that provide dense canopy cover ▌ Erect shade sheds/structures, although natural shade is generally much cooler, as plants do not store heat, but instead, contribute to further cooling through the evaporation and transpiration from their leaves

TABLE 6 CONTINUED

Dairy—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Maintenance of soil health	**Soil fertility** has been improved by increased nitrogen fertiliser over the last 10 years Compaction and water logging of soils	Application of fertiliser and improved nutrient management on-farm Irrigation, stock, farm machinery and cultivation all contribute to the compaction of soils and the decline of soil health	Evaluate the role of soil organisms in promoting the efficient cycling of nutrients on irrigated and dryland pastures to assess the potential for more effective use of fertilisers Manage stock rotations particularly on wet soils Improve irrigation practices for water use efficiency and water logging
Waste absorption and breakdown **and** **Maintenance of healthy waterways**	Nitrogen and phosphorous loads in waterways	Application of fertiliser and nutrient management on-farm Soil erosion associated with compacted laneways and stock tracks results in nutrient fertilisers	Improve nutrient management including: ▌Minimise soil erosion adjacent to streams though careful design of animal traffic ▌Improve treatment and use of wastes ▌Reduce fertiliser inputs to match outputs ▌Reduce chemical use in dairy wash down ▌Improve nutrient recycling through re-use of irrigation waters via laser grading and re-use dams ▌Vegetate, and regularly harvest, irrigation drains to allow uptake of up to 70% of nitrogen and phosphorus
Regulation of river flows and ground water levels	Water availability Salinity/ water tables most sensitive on light soils	Diversion of water for irrigation Accession water from rain and irrigation beyond the root zone and added to water tables	Improve efficiency in water use and management Change irrigation management with particular focus on light soils

Fruit and Grapes

The 11,000 ha irrigated fruit and grape industry is highly productive, due to both available water and soils. With 269,813 tonnes of horticultural products currently yielding a gross value of production of more than $173 million, this realises an increase of more than $55 million since 1980. One notable trend has been the three-fold increase in the gross value of production of grapes.

Most horticultural production systems in the Catchment are intensive operations, with heavy dependence on external inputs, and associated infrastructure. This is because producers of high-value crops, particularly those for export markets, have to meet exacting standards for fruit quality in order to remain competitive. There is very little organic horticultural production although there may be potential for this market niche to grow.

As a high input system, there are a number of key issues that emerge in the table below. Management of these is driven by:

- Vegetation management integrating pollination, shade and shelter, climate control and pest control.
- Water use efficiency for soil health, healthy waterways and groundwater levels.

TABLE 7

Fruit and Grapes—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Pollination	Some pollination- dependent crops, such as kiwi fruit, apples and pears are pollen limited and will produce higher yields when they receive extra pollination	Over reliance on a single bee species that is subject to disease Decline of native pollinators and introduced wild pollinators due to degradation of habitat	Bring in managed hives Develop alternative mite-resistant bee species for crop pollination Research alternative pollinators and role of native substitutes Enhance remnant vegetation to encourage European and native bees Manage pesticide use to reduce impact on pollinators
Regulation of climate	**Vernalisation** The reduced frequency of cool nights will affect the ability of trees to set fruit	Global climate change induced by increased concentrations of greenhouse gases in the atmosphere	Change to low chill varieties, change species or relocate the industry Establish breeding programs to deliver appropriate genotypes for climate in 10-30 years
Pest control	Grapevines, tomatoes, stonefruit, pomefruit and citrus have a range of pests that cause severe economic damage and pose a threat to the viability of these industries	Increased risk of pest outbreaks due to land-use intensification and development of monoculture crops Loss of natural enemies through inappropriate use of pesticides Spray-drift may cause off-site impacts	Make greater use of conservation biocontrol methods (e.g. habitat improvement for natural enemies) Use Integrated Pest Management including increased monitoring Manage biodiversity to maintain system resilience
Maintenance and regeneration of habitat	**Clearing** of endangered and vulnerable ecosystems	Land-use intensification	Design landscapes to include a representative range of threatened ecological communities
Provision of shade and shelter	Reductions in yield and fruit quality due to wind-induced rubbing and abrasion	Clearing of native vegetation and increased prevalence of vegetation 'dieback'	Establish 'permeable' windbreaks that allow almost half the wind to pass through. This optimises the benefits of reduced wind speed and turbulence

TABLE 7 CONTINUED

Fruit and Grapes—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Maintenance of soil health	**Acidification** is a critical issue, with 45% of orchard subsoils dropping below a pH 5 (calcium chloride). The pH is predicted to drop by about 3 units in 50 years	Intensive irrigation Application of nitrogen fertilisers	Apply lime ▪ Liming alone on clay loams does not improve the pH, and new orchards are now deep-ripped and ameliorated with lime and gypsum before planting Promote efficient fertiliser application Apply partial root zone drying
	Management of soil biota is essential for nutrient cycling	Management of soil biota by growers for enhancing the soil fertility is generally limited to slashing and mulching orchard grass	Manage orchard rows to maintain soil structure, thus minimising erosion Use filter strips and buffer zones adjacent to riparian zones to trap and arrest sediment Employ innovative soil management strategies that enhance populations of beneficial soil organisms
Regulation of river flows and groundwater levels	**Water tables and salinity** High water tables have threatened horticultural properties since the late 1960s.	Removal of perennial vegetation within recharge zones	Promote irrigation practices that are water efficient, such as drips and microsprays Establish targeted revegetation Remodel drains/channels Manage watertables so that they are more than 2m from the surface using groundwater pumps (pome fruit) and tile drains (vineyards)
Maintaining healthy waterways and Waste absorption and breakdown	Capacity to absorb **nutrients** (N and P) may be exceeded in both soil and water systems	Application of fertiliser	Promote efficient fertiliser application Employ better management and reuse of processing wastes

Grazing

About 50% of the Catchment area is used for grazing. GVP is currently $210 million which remains significant, although the relative importance of grazing to the regional economy is declining. An important trend, due to poor terms of trade, is the increase of off-farm income and lifestyle farming in grazing areas.

An opportunity for managing land-use change has been lost over the past 20 years where much land has been subdivided and lifestylers (hobby farmers) have replaced larger holdings. As the trend continues, there still remains an opportunity for future subdivisions or developments to have conditions that promote sustainability.

Many of the issues associated with grazing are well known (e.g. loss of native vegetation, breakdown of soil structure), and the assessment of ecosystem service based management actions indicates that most of these issues can be ameliorated by appropriate management of pastures and remnants.

TABLE 8

Grazing—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Life-fulfillment and Maintenance and regeneration of habitat	Decline of landscape aesthetics	Grazing of remnant vegetation has a significant impact on the health of native vegetation, which in the longer term, will have a negative impact on landscape aesthetics	Capture opportunities for improving land management as land ownership changes via planning process and appropriate sub-division Protect and enhance remnants, revegetate by natural regeneration, direct seeding, planting
Pest control	Competition for resources Limited capacity to manage issue	Foxes and dogs increase mortality rate of lambs Kangaroos and rabbits compete with stock for resources Proliferation of weeds Cost per unit area to manage pests can be expensive	Use biocontrol for vertebrate pests Increase habitat for predators of vertebrate pests (e.g. leaving dead trees for birds of prey) Increase habitat for weed controlling species
Maintenance and provision of genetic resources	Continuing loss of native grasslands	Loss through cultivation and land-use change due to poor economic returns to grazing enterprises Decline due to grazing pressure	Control grazing pressure
Provision of shade and shelter	The impact of shade and shelter are difficult to quantify ▌Sheep losses due to cold weather are not likely to be large because of the presence of hills (unlike Victoria's western district) ▌Cold weather will effect animal growth and feed requirements	Loss of native vegetation for shade and shelter	Plant shelterbelts and shade trees, preferably with links to remnant native vegetation

TABLE 8 CONTINUED

Grazing—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Maintenance of soil health	**Fertility** Loss of soil fertility is low at a site scale but is significant when aggregated at Catchment scale **Acidity and compaction** Caused by nitrification from clover	Rates of fertiliser application are lower because of poor economics Compaction of soils by stock and farm machinery Loss of calcium is occurring (as a result of "harvesting" via stock removal) Production of hay or over grazing may drive accelerated rates of soil acidification due to a higher proportion of clover in pasture composition	Fertilise (superphosphate) Improve nutrient cycling via rotational grazing Apply lime Grow perennial grasses with clover to take up nitrates (longer-term solution)
Water filtration and erosion control	Soil loss	Grazing pressure is causing accelerated soil loss, especially in the hill country in the south of the Catchment Impact is highest in times of drought	Manage stocking numbers, rotate stock and keep off wet soils Manage pasture cover and include perennial grasses (both native and introduced) Evaluate alternatives to continued grazing on fragile land during drought e.g. sacrificial areas, lot feeding, destocking
Maintaining healthy waterways and Waste absorption and breakdown	**Acidity** Acidity of major rivers is rising due to increases in soil acidification Soil erosion and stream-bank degradation Nutrient run-off Increased on farm water storages from subdivision	Acidity – As above Nutrient run-off is low on a per ha basis but may be large because of the broad-scale nature of the industry Cost of fencing all streams (including ephemeral streams) may be prohibitive in extensive grazing systems	As above Design watering points to minimise concentration of nutrients near streams Employ off-stream watering Improve efficiency of fertiliser management Fence streams where practical

Crops (including hay and seed production)

Various crops currently cover approximately 122,800 ha of the Catchment. Of this area, the most significant crops are the cereals, occupying 104,700 ha and making up more than three quarters of total crop production and 80% of GVP for crops. Between 1980 and 1995 there were significant decreases in GVP of cereal production, but prices have increased slightly since then. Legumes experienced significant fluctuations in GVP during the same period. Canola has grown significantly in area rising to 7,800 ha with a GVP of $4.5 million.

Hay production has also increased because of increased demand for feedstock to the dairy industry, which is intensifying and requiring more feed from off-site.

The key issue for cropping is management of soil health and minimising infiltration to groundwater. Minimum tillage and suitable cropping systems will help maintain soil structure. Use of deep-rooted perennials (e.g. agroforestry) and phase farming systems minimise infiltration to groundwater.

TABLE 9

Crops—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Pest control	**Weeds** are a significant issue on crop yields	Monocultures Leaving land fallow post-harvest may increase opportunities for weeds and seed banks Adoption of tillage practices that encourage weed growth	Alter tillage practices Integrate weed management Increase education
	Mouse plagues affect crops in the lighter soils along the north-western edge of the Catchment – less impact relative to the Mallee region to the west	Increased availability of food	Control food sources including grass, pasture and crop seed Improve sowing and harvesting practices Graze paddocks following harvest
	Fungal disease	Intensification of canola leading to yield declines Move towards no or minimum tillage (a problem with respect to fungal diseases) Lack of competitors and natural enemies for root pathogens in soil	Increase diversity of land-use options Adopt minimum tillage incrementally (e.g. via trash incorporation to encourage competitors and natural enemies of pathogens)
Provision of shade and shelter	Evaporation and transpiration losses from crops can be significant, especially when they are exposed to hot, drying winds	Clearing of native vegetation and increased prevalence of vegetation dieback	Establish permeable windbreaks to reduce soil moisture loss and enhance productivity

TABLE 9 CONTINUED

Crops—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Maintenance of soil health	Soil fertility and acidity	Nutrient levels are increasing in some cropping enterprises via significant fertiliser input Highly productive systems can result in increased soil acidity – difficult to deal with in areas where land-use profitability is low Possible loss of soil biodiversity (needs investigation)	As for fungal disease (above) Use of fertiliser formulations that minimise acidification Adopt systems that minimise soil acidity (e.g. phase farming)
	Degradation of soil structure	Stubble burned and not retained Cultivation leading to loss of organic matter, compaction and undesirable soil structure	Encourage stubble retention, minimum tillage and other soil conservation strategies
Regulation of river flows and ground water levels	Dryland salinity – rising water tables	Use of short rooted annual plants, thereby reducing transpiration and allowing leakage of water to watertables	Increase use of deep rooted perennials including agroforesty. Practice phase farming and possibly perennial cropping (intercropping)
Water filtration and erosion control **and** **Waste absorption and breakdown**	Soil loss and nutrient run-off	Cultivation practices that leave bare and disturbed soil may result in high sediment yields per unit volume of water	Practice minimum tillage

Intensive Animals – Pigs, Poultry and Horses

While these industries do not occupy much land they are significant due to their highly intensive nature. Their total GVP ($42 million—not including the thoroughbred and standard bred horse industries) is made up of pigs and poultry predominantly ($32 million) while a smaller but not insignificant contribution is made by trout ($10 million) and to lesser extent eels, where there is increasing demand. Pig production has remained relatively constant (240,000 pigs). There has been a significant decrease in poultry production since 1993. The breeding of thoroughbred and standard bred horses is also a very large and growing industry, second only to the Hunter Valley in Australia. Financial data from this industry have not yet been made available.

Dealing with wastes from intensive animals is the key management issue. Significant potential exists to promote the re-use of wastes for energy production, fertiliser and integrated production systems (e.g. pigs and mushrooms).

TABLE 10

Pigs, Poultry and Horses—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Regulation of climate	Emissions of greenhouse gases	Methane produced from 240,000 pigs is relatively large	Evaluate economics of co-generation in piggeries (i.e. capture and produce energy from methane produced from pig waste)
Waste absorption and breakdown	On-site management of high waste levels	Intensively housed animals	Promote re-use of pig wastes, such as in mushroom production, composting with organic matter to provide soil amendments for other industries Use wastes as a fertiliser in the cropping industries, apply only sufficient quantities to meet the plants' nutrient requirements At Euroa, efforts are being made to integrate mushroom and pig production to recycle wastes – although it seems that the waste generated by the pigs are far in excess of the capacity of the mushrooms to consume

Forestry

Hardwood and softwood forests in the Catchment cover approximately 440,000 ha and 17,500 ha respectively. There are 120,000 m^3 of hardwood are harvested annually in the Catchment; in 1996 this had a GVP of $7.5 million. The GVP for the 220,000 m^3 of softwood harvested in the same year was $78 million. Since 1996 wood produced for sawlogs has remained relatively stable under a sustainable harvesting system. However, there has been an increase in the demand for pulp.

Forests play a significant role in water management in terms of both quality and quantity. Investigations are needed to determine the impacts of current distribution of forests on managing issues such as nutrient loads and groundwater.

TABLE 11

Forestry (Hardwood and Softwood)—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Maintenance and regeneration of habitat	Decreased arboreal habitat Naturally fallen timber acts as terrestrial/aquatic habitat	Inappropriate harvesting	Apply ecologically appropriate fire regimes Leave habitat trees and supply nest boxes Plan for and maintain fallen timber in stream Compare with cost of artificial replacement
Maintaining healthy waterways	Sedimentation of waterways Reduced flows	Need for logging and access tracks for harvesting If area under forests increases (e.g. for salinity control) less water will flow to rivers	Design loading roads and tracks to protect in-stream water quality Implementation of appropriate streamside buffers Make whole-of-catchment assessment of water yield as part of the planning process

Food processing

The food processing sector is the single most important economic sector within the Catchment.

In the Catchment the dairy industry is the biggest producer in terms of GVP which currently exceeds $1.5 billion. Continuing growth in the industry can be expected following deregulation.

The fruit and grape industries are also large with a GVP of approximately $800 million. Wine makes up $64 million of that while horticultural products makes up approximately $734 million. The wine industry is enjoying considerable growth.

The GVP of tomatoes processed in the Catchment has increased dramatically over the last few years, in parallel with the increased quantity of processing tomatoes grown in the Catchment. Of Australia's tomatoes, 70% are processed in the Catchment, with a further 25% processed on the edge of the Catchment at Echuca. The estimated GVP for 1999/2000 is $160 million ($205 million including Echuca).

For the food processing industries that involve the intensified use of animals, waste management (both atmospheric and terrestrial) is the major issue to emerge. Current management is focussed on the further development of waste management practices.

TABLE 12

Food Processing—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Regulation of climate	Greenhouse gas emissions	Energy consumption associated with food processing	Energy audit and deployment of energy efficient technologies
		Breakdown of organic wastes	Dilute organic wastes within sewage treatment works Develop alternative products that use wastes (similar to dairy industry's use of whey) Minimise wastes (similar to dairy industry's osmotic processes)
Maintaining healthy waterways	**Water quality** is a significant input to production	At a Catchment scale land-use pressures may lead to a decline in water quality	Improve Catchment and waterway management Improve water treatment facilities
Waste absorption and breakdown	Food processing produces significant organic wastes that require treatment, generally through town sewerage systems Some waste materials are fed to stock although this may not be allowed to continue	Residues from food processing	Improve treatment of waste prior to application on land Continue development and application of best practice waste management strategies

Housing

There are 200,000 residents of the Catchment. The majority of houses are in the urban environments of Shepparton, Seymour, Kilmore, Benalla and smaller towns. The remaining people are housed in "rural areas". About 700 planning permits are issued each year in the Catchment for new dwellings. There is significant pressure for rural sub-division and lifestyle farming. The pressure on ecosystem services from new developments is relatively minor compared with other pressures in the Catchment, and compared with other Catchments, which are closer to the coast or larger cities.

Life-fulfillment and waste management were the only ecosystem services that ranked highly for housing. Management of the life-fulfillment issue is based on the use of vegetation for aesthetic appeal.

TABLE 13

Housing—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Life-fulfillment	**Subdivision and housing development** are having an impact on views and vegetation – there is debate about whether the impact is positive or negative or a mixture	Poor planning of rural subdivision	Capture opportunities for improving land management as land ownership changes via planning process and appropriate sub-division
Maintenance and regeneration of habitat	Decline in health of native vegetation	Grazing pressure and impact of pests and weeds within remnant vegetation are leading to decline of remnant vegetation with associated aesthetic impacts	Employ fencing and active ongoing management to control grazing pressure, weeds and pests Protect and enhance remnants, including revegetation by natural regeneration, direct seeding, planting
Provision of shade and shelter	Impact of wind and exposure on temperature regulation in houses	Loss of vegetation to provide shade and shelter	Use shade and shelter for dwellings, as studies show it can decrease heating and cooling costs
Waste absorption and breakdown	Housing can produce significant organic wastes that require treatment, generally through town sewerage systems and septics	Some septics don't function well resulting in leakage of organic wastes into waterways	Continue to develop and apply best-practice waste management strategies Carefully design and monitor septics, with placement of buffer strips to help cope with leakage

Water production

As a land-use, water production refers to the entire 2,431,654 ha of the Goulburn Broken Catchment and its role in capturing water. The Catchment "produces" 3,400 GL of water annually (what flows into the Murray at the base of the Catchment). The current value of that water production (the extracted component as distributed and sold by Goulburn Murray Water) is estimated at $40 million.

The flow-on value of that water is, however, considerably higher as it is the principle driver supporting the irrigation and associated food processing industries within the Catchment.

Given the complex nature of the land-use "water production" (i.e. the entire Catchment), it's difficult to add insight to current management actions. Management and rehabilitation of vegetation and riparian corridors is key, as are actions that reduce nutrient and sediment loads in streams.

TABLE 14

Water Production—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Maintaining healthy waterways	**Altered water regimes (flow and timing)** lead to changes in aquatic flora and fauna	Water storages and diversions affect flow regimes Water from large storages (Lake Eildon) may reduce water temperatures and hence impact on water ecosystems Reduced dissolved oxygen due to altered flow regimes Reduced photoelectric (solar) penetration Eutrophication (excess nutrient)	Determine water balance in Bulk Water Entitlement and Streamflow Management Plan to allow for appropriate environmental flows Revegetate and rehabilitate streamsides Manage water tables, allowing for appropriate base stream flow Increase retention of nutrients on-farm
Water filtration and erosion control	**Turbidity** The Goulburn River is a turbid river compared with others in the Murray Darling Basin – 52% of the sediment in the Murray River at Echuca is attributed to the Goulburn River **Physical aspects of aquatic habitat** High sediment loads have changed the nature of the stream bed and the habitats of organisms in the streams	Increased erosion and sedimentation caused by over grazing and trampling Instream watering points for stock Removal and degradation of streamside vegetation through clearing Coarse sediment loads are a result of historic stream degradation	Implement the Catchment Water Quality Strategy including ❙ Re-establish riparian zones- fence and protect riparian vegetation ❙ Protect soils through vegetation and other forms of cover – especially around gully and stream banks ❙ Establish buffer strips ❙ Establish wetlands ❙ Diversify land-use and improve tillage practices. ❙ Increase farm forestry ❙ Remove in-stream water points ❙ Decrease grazing pressure in sensitive areas

TABLE 14 CONTINUED

Water Production—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Regulation of river flows and groundwater levels	**Salinity vs water flow** There is a trade-off in Catchment management between outcomes of increasing quantity of water (water production) and managing groundwater level	Trees and other deep-rooted perennials take up water, which helps manage the water table, but this means there is less water flows and potentially increased salt concentration The extent of the impact of rehabilitation programs on water quantity production is not well understood	Evaluate the extent of impact of revegetation programs on water quantity production Afforest to prevent water logging and salinity Improve irrigation efficiency by ▌Laser grading and remodelling farm channels ▌Improving irrigation systems ▌Greater reuse of drainage water ▌Expanding drainage network ▌Using ground water pumps
	Flood mitigation Flooding causing significant damage to agricultural lands.	Inappropriate construction of levee banks Inappropriate development on land prone to flooding	Re-establish natural flood plains through strategic removal of levee banks Provide flood water storage capacity
Waste absorption and breakdown (phosphorus and nitrogen)	**Pesticides and nutrients** entering waterways and storages impact on water quality	Inappropriate construction of levee banks. Waste loads increased through fertilisers, pesticides, wastewaters, manure Inappropriate development on land prone to flooding	Reduce waste loads ▌Increase efficiency of chemical use ▌Use fertiliser formulations less susceptible to leaching ▌Increase on-farm recycling of nutrients ▌Manage soil structure to minimise leaching ▌Place buffer zones below septics

Recreation and tourism

While difficult to determine, the value of recreation in the Catchment has been estimated at over $100 million. With the close proximity to Melbourne, it is estimated that this value will steadily increase. Alpine recreation is a major contributor to regional gross value of production.

Given that a significant proportion of the recreation either directly uses water-bodies, or indirectly impacts on them, management is similar to that for water production. Enhancement of vegetation for greater aesthetic appeal needs consideration, although the return from this can be difficult to determine.

TABLE 15

Recreation and Tourism—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Maintenance and regeneration of habitat	Increasing fragmentation or loss of woodlands and subsequent loss of recreational opportunities and tourism dollars	Dieback of native vegetation Overgrazing of land Weed invasion preventing native vegetation from growing Rising water tables Lack of fire encouraging seed dispersal and regrowth Net gain rules not covering paddock trees	Reduce grazing Fence where appropriate Employ direct seeding – increasing stocks of native seeds Regenerate areas to combat rising water tables Mimic fire effects through heat and smoke or some grazing pressure (e.g. kangaroos) to encourage regeneration of native vegetation and control of weeds
Maintaining healthy waterways	Reduction in water quality resulting in decreases in tourism activity	Decreased water quality (e.g. algal blooms) limiting recreational activity Decreases in water quality negatively impacting on fish populations – thus affecting the recreational fishing industry	Place buffer zones more strategically (e.g. below camping sites) Design infrastructure (e.g. roads) with consideration of the possible impacts on water quality
Regulation of river flows and ground water levels	Low water levels may impact on tourism (especially at Lake Eildon)	Water diversions to irrigation and environment	Evaluate trade-offs in water allocation
Waste absorption and breakdown	**Primarily excess nutrients** entering waterways and storages impacting on water quality	Waste loads and bacterial levels in waterways increased through runoff of human wastes	Place buffer zones more strategically (e.g. below camping sites) Move campsites away from waterways and manage human wastes

Biodiversity, Culture, Heritage and Options

This category includes goods whose values are often intangible and/or public in nature. The intrinsic value of biodiversity is included as are aesthetic and cultural values. The values associated with these "goods" are many and varied. Given their strong link to the ecosystem service of life-fulfillment they are of course a key input to the recreation, tourism and housing industries. However, in addition these goods have considerable value in their own right. For example, the moral and ethical issues associated with decisions effecting biodiversity or cultural heritage are considerable.

It is difficult to tightly define the importance of these values, although few people would argue they are insignificant. However, as has been noted the values are subjective and difficult to precisely define, and techniques for placing values on non-market goods of this kind are controversial.

In our consultations with the Catchment community we have requested inputs as to what are the key intangible values in the Catchment and what management actions need to be taken to protect them. Protection of biodiversity and landscape amenity (through scattered trees) has consistently arisen as a key issue and is reflected in the table.

Other issues such as the impact of housing developments and rural subdivision are less clear cut as their impact is often a matter of opinion.

A key priority for future stages of this project will be to more rigorously define and develop processes to define and account for the values of these goods at a community wide scale. This will be a key focus for the future stages of the Ecosystem Services Project.

TABLE 16

Biodiversity, Culture, Heritage and Options—Key ecosystem service issues

Service	Issues	Pressures/Causes of Issue	Ecosystem Service Based Management Actions
Life-fulfillment	Loss of natural heritage and cultural identity due to land and water degradation	Loss of paddock trees Loss of roadside and streamside vegetation Lack of acknowledgement in planning process and regimes of the capacity of ecosystems to deliver life-fulfilling services Poor rural planning	Recognise culture and other values in planning processes Recognise multi-functionality of rural landscapes Use full range of policy instruments to protect the foundations of ecosystem services Improve planning of rural developments Ensure adequate buffer zones Recognise the importance of these services in the growth industries of recreation and tourism
Maintenance and regeneration of habitat	Degradation of fragmented native vegetation	Dieback of native vegetation Overgrazing of land Weed invasion preventing native vegetation from growing Rising water tables Lack of fire encouraging seed dispersal and regrowth	Reduce grazing Fence where appropriate Use direct seeding – increasing stocks of native seeds Regenerate areas to combat rising water tables Mimic fire effects through heat and smoke or some grazing pressure (e.g. kangaroos) to encourage regeneration of native vegetation and control of weeds

Chapter 6

Key findings and policy issues

To this point we have focussed on identifying those ecosystem services that are of highest priority to individual land-uses and industries. The issues are many and diverse. In this final Chapter of the report we draw together some of the key ecosystem service issues facing the Catchment.

Identifying key issues has involved grouping a number of individual ecosystem service challenges against key trends in the Catchment including the state of the Catchment's natural resources, current priority management issues and projected changes in land-use arising from continued economic growth and adjustment.

KEY ISSUE 1

Integrating management across ecosystem services

Natural systems are dynamic and self-organising. They are dependent on the full range of ecosystem services interacting with one another. This inventory has focussed on evaluating the relative importance of individual ecosystem services on an industry-by-industry basis. As a result the importance of the interactions between ecosystem services has been given insufficient attention.

A key area for future work is to assess how individual management actions or land-use changes will affect a range of ecosystem services. Priorities for further study include exploring the relative Catchment benefits of the following issues.

- **The proposed floodplain rehabilitation on the Lower Goulburn.** Aside from the value in flood mitigation, no assessment has been made of the potential ecosystem service benefits of the proposal to re-establish the floodplain on the Lower Goulburn River for both the Goulburn itself and the river downstream of Loch Garry. This could serve as a case study for the management of other floodplain wetlands and their linkages with irrigation infrastructure.
- **Value of alternative revegetation strategies.** The value and role of native vegetation and revegetation in meeting the Catchment's management objectives is well recognised. However, little work has been done to objectively evaluate the role of vegetation in providing the full suite of ecosystem services (see Key Issue 4). One specific example worthy of further evaluation is the interactions between reafforestation, water yield and salinity.
- **Implications of nutrient management.** The implications of management strategies for a specific ecosystem service issue will have implications for other ecosystem services. For example, nutrient management strategies will directly affect the health of soils and waterways but may also have indirect impacts such as providing added impetus for streamside rehabilitation and, hence, biodiversity conservation and life-fulfillment. Careful assessment of the full range of costs and benefits of different management strategies may reveal more integrated and cost effective strategies for the Catchment to pursue.

KEY ISSUE 2

Managing land-use intensification

Deregulation, micro-economic reform and the vertically integrated status of key industries in the Catchment (dairy, horticulture, wine, vegetables and timber) is placing considerable pressure on landholders to intensify production processes. Consultations with industry representatives have emphasised the need for their industries to continue to improve productivity and growth in order to achieve the economies of scale required to support the processing industry. The trend to land-use intensification is likely to remain the key driver of economic wealth within the region.

Land-use intensification is an issue in both the Shepparton Irrigation Region and the dryland. Key industries in the irrigation region include dairy, horticulture and vegetables. Here, the most significant issues relate to improving water use efficiency (to improve environmental flows and limit recharge to groundwater) and improving nutrient management (to stabilise and then reduce nitrogen and phosphorous levels in-stream). Management of these issues also has the potential to improve agricultural productivity. As noted, another key issue is the relationship between irrigation infrastructure and key environmental assets including floodplain wetlands.

In the dryland, land-use intensification is most intense in viticulture and other alternative agricultural industries. Here the key issues are the building of on-farm water storages (dams) that affect water flows in unregulated streams and the clearing of remnant vegetation.

Other key issues relate to soil, waste and pest management, contribution to greenhouse gas emissions, and loss of biodiversity from clearing of poorly represented ecological communities.

Analysis of the implications of land-use intensification will be essential to strategically plan for the ongoing growth and prosperity of intensive agriculture within the Catchment. Key issues include:

- **"Win-win" solutions.** Evaluating the potential for improvements in farm management practices to offset the environmental impacts associated with continued land-use intensification.
- **Limits to growth.** Assessment of how far land-use intensification can proceed before environmental thresholds are crossed.
- **Offsets.** The potential to offset impacts by encouraging land-use change in other less intensive and less profitable industries, for example, through nutrient trading between dryland and irrigated agriculture. This may lead to land-use becoming less intensive in some areas (see below).

KEY ISSUE 3

Managing transitions in land-use

There are a number of important transitions in land-use occurring in the Catchment. In the dryland some traditional agricultural industries (particularly broad-acre grazing) are being placed under pressure due to poor economic returns. This in turn is placing pressure on a range of ecosystem services including habitat regeneration, soil health (fertility, acidity and soil loss), pest control and the maintenance of healthy waterways.

In the irrigation region salinity, land-use intensification, pressure from water allocations and the need rehabilitate threatened ecological communities (types of native vegetation) are all leading to some areas of land being moved out of irrigated agriculture. The challenge here is to identify alternative land-uses that are viable.

These trends are leading to a number of pressures for land ownership and land-use change:

- Sub-division to meet a growing market for lifestyle properties (created for their high amenity value) within commuting distance to Melbourne.
- Farm consolidation and amalgamation as family farming increasingly takes on the characteristics of larger scale agribusiness in order to manage costs and return profitability.
- Diversification of farm businesses into alternative agricultural enterprises including viticulture and agroforestry.

The net result is that land prices are rising (as a result of increased capital and investment) thereby driving rapid changes in land ownership. Land prices often exceed the net present value of the productive capacity of the land. The process of land-use change carries with it a number of opportunities and risks related to key ecosystem services. For example, new rural sub-divisions have the potential to have both a positive and negative impact on environmental outcomes.

The Catchment is yet to fully harness a range of opportunities associated with land-use change including:

- **Local government.** Working with local government to ensure that all land-use change is consistent with Catchment management objectives and leads to a net gain to the environment.

- **Markets for ecosystem services.** Developing markets for ecosystem services that provide incentives that recognise the multiple public benefits of rehabilitation works and build upon existing cost sharing arrangements.
- **Rationalising assets.** Ensuring that proposals to refurbish or put in place new infrastructure (for example irrigation drains) is consistent with catchment objectives and will achieve full cost recovery.
- **Creating commercial opportunities.** Providing strong incentives and support in the development of new agricultural industries that have the potential to be profitable and return perennial vegetation to the landscape. This is a huge challenge given the limited range of options of newly developing industries.

KEY ISSUE 4

Managing vegetation—A hub in the landscape

As has been noted throughout this report, little work has been done to objectively evaluate the role of vegetation in providing the full suite of ecosystem services ranging from pollination to water filtration, salinity mitigation and carbon sequestration. It is unlikely the benefits for any individual ecosystem service will justify investment in revegetation. However, if the multiple-benefits of trees can be pooled, larger incentives and increased investment may be justified and built upon the innovative cost sharing arrangements already in place within the Catchment.

In this context, vegetation should be taken to include the full suite of vegetation from restoration of native ecosystems to commercial tree growing. It will also include the restoration of floodplains and wetlands.

Strategic re-establishment of trees and habitat is fundamental to restoring the full suite of ecosystem services.

- **Valuing the multiple benefits of vegetation.** An urgent task is to objectively evaluate and, where possible, quantify the multiple values of vegetation in providing the full suite of ecosystem services in order to further develop improved cost sharing arrangements including the potential for intensive industries to offset impacts off-farm.

KEY ISSUE 5

Managing cultural, heritage and option values

A socially vibrant and environmentally amenable region, the Goulburn Broken Catchment is a drawcard to people who want to live there or visit. Cultural, heritage and option values are difficult to manage because of their often intangible nature. Protection of heritage and amenity values is often interpreted as a call for no change and no growth. Indeed it is difficult to separate reactions to change from the core values that need to be retained and managed for.

Change is inevitable and must be managed in a way that takes account of these broader values. Key issues that have been identified to date include:

- **The intrinsic value of biodiversity.**[1] Including the commitment to protect, retain and rehabilitate remnant vegetation, as outlined in the Catchment's Native Vegetation Management Strategy.
- **Indigenous heritage.** The protection of key aboriginal sites and landscape features of significance to indigenous people.
- **Isolated and scattered trees.** The protection and recruitment of isolated standing trees in order to maintain landscape amenity (this is a huge challenge given the issues associated with dieback and no recruitment of paddock trees).

A key challenge will be to define other intangible values that require improved management of ecosystem services and to have these included in management strategies within the Catchment.

- **Local and Catchment planning.** Explicitly taking into account these values and incorporating strategies for sustaining these values in the landscape.

KEY ISSUE 6

Maintaining soil health

A key theme to emerge from all agricultural land-uses is the fundamental importance of soil health in maintaining the productivity of agricultural systems. Soil structure, chemical composition, soil biodiversity, and the water absorption and filtration capacities of soils are all key issues for the Catchment.

1 It is noted that biodiversity is also a key input to many of the other ecosystem services and goods in the Catchment and in this sense has very real and tangible values.

Soil management issues vary considerably around the Catchment. In intensive agriculture, the long-term impacts of high inputs and dramatically increased fertility must be considered. These industries can meet the costs of fertiliser, lime, pesticides and other inputs. The key question is the capacity of soils to sustain long-term changes to their structure and composition.

One important emerging issue in the irrigation region is soil sodicity, which is the build up of sodium levels in soils because of the domination of sodium chloride in subsoils and groundwater. Sodicity leads to soil structure decline and erosion, especially when accompanied by rainfall or freshwater irrigation on saline soils.

In cropping industries the impact of cultivation on soil structure, fertility and acidity must be carefully managed. Some farmers involved in broad-acre cropping have commented that the capacity to manage soil health issues has increased over the last 15 years, primarily through minimum tillage practices and more effective use of fertilisers and lime.

Grazing and other extensive land-uses are struggling to sustain investment in the inputs required to maintain soil health. Fertiliser and liming represent high costs per unit of production. As a result soil fertility is decreasing and acidity increasing in many areas of the Catchment.

Soil management is perhaps the single most significant on-farm ecosystem service issue in the Catchment and will require soil and water interactions to be managed on a systematic basis. Three groups of issues have consistently emerged as high priorities within the Catchment.

- **Acidification, sodicity and soil carbon.** The chemical structure of soils is a key driver in the productivity of soils. Agricultural practices are leading to changes in soil chemistry that need to be managed on a systematic basis.
- **Soil biodiversity.** The value of soil biodiversity, including soil fauna and invertebrates, in maintaining soil health and productivity is not well understood. Equally, the impacts of different management practices on soil biodiversity and the trade-offs involved are not well understood. However, evidence is emerging to suggest that opportunities exist for increased production with decreased input costs if the services provided by soil biodiversity are harnessed more effectively and sustainably. Careful evaluation of the value of soil biodiversity is a key priority for future empirical studies across different land-uses within the Catchment.
- **Soil loss.** The losses are inadequately recognised as a medium to long-term issue for farm enterprises in the Catchment.

KEY ISSUE 7

Accounting for the value of non-agricultural land and water-uses.

Non-agricultural land and water uses are growing in the Catchment. Recreation, tourism and lifestyle living are key growth industries within the Catchment with tourism alone estimated to be worth in excess of $100 million to the regional economy. Snow skiing, fishing, water sports and bushwalking are all established nature based recreation activities, focussed in the upper Catchment.

The relationships between these land-uses and different ecosystem services are clearly important. However, we are unclear how sensitive the tourism industry is to changes in the state of natural assets and the associated provision of ecosystem services. We have been told that impacts in water flow (water levels at Lake Eildon) and quality (fishing for native fish in the Broken River) will have a strong effect on established tourism industries. Management of human wastes in the upper Catchment is emerging as a significant issue with Giardia being recorded in many of the tributary creeks and streams in the upper Catchment.

A key issue is the extent to which the future needs of tourism, recreation and other lifestyle industries are taken into account in decision making. Key actions include:

- **The dependence of non-agricultural land and water use on natural assets.** A more rigorous analysis of the roles of non-agricultural industries in supporting prosperity in the Catchment and of positive and negative interactions with a range of ecosystem services is required.
- **Catchment planning.** Increasingly there is a need to take account of the value of non-agricultural industries as their importance to the regional economy.

KEY ISSUE 8

Management of water and salinity

The inventory has reaffirmed water management, including the full range of water based ecosystem services, as a critical ongoing issue in the Catchment.

The Catchment has put in place a range of complementary salinity management strategies including improved water-use efficiency to reduce accessions to groundwater, revegetation, and engineering based solutions (eg groundwater pumps). A key challenge here is to assess whether adoption of best practice will be sufficient to meet salinity targets.

Environmental flows and the management of aquatic biodiversity are also key issues. Environmental flows can, in part, be secured through improved water use efficiency to generate water savings in irrigated agriculture. The impact of land-use intensification on unregulated streams in the dryland is also emerging as a critical issue.

Nutrient and waste management and their impacts on water quality are also key issues as discussed elsewhere. The issue of water quality is particularly relevant to the provision of town water, water to the food processing industry and aquatic biodiversity.

The Catchment's approach to these issues has been to lead the implementation of best practice management on existing land-uses. However, there is growing evidence that these actions alone will not meet the Catchment's objectives for water quality and flow. The key issue is to evaluate in which parts of the Catchment best management practices will work and in which it will not.

- **Improved on-farm management.** Although much work has been done there are still considerable opportunities for improved farm-scale planning and design. A key issue is resolving financial constraints on farmers so they can invest in the adoption of best practice.
- **Recognising the need for fundamental land-use change.** The Catchment community generally recognises that more fundamental land-use change is required in some areas to meet its water management objectives. Challenges remain in identifying how much change is required, where precisely in the Catchment and over what timeframe. With this information the Catchment can begin the difficult task of developing strategies to manage the transition in a way that minimises adverse impacts—particularly on the plans of key agricultural industries that are the backbone of the wealth of the Catchment.

KEY ISSUE 9

Anticipating and adaptively managing emerging issues

The process of preparing this inventory has raised a number of emerging and/or longer-term issues for the management of the Catchment. These are briefly discussed below, with more detail provided in the specialist papers in Chapter 7.

- **Adaptation and responses to climate change.** Climate change is rapidly becoming a regional scale issue in addition to being a national and global issue. The Catchment will need to address adaptation issues as well as contributing to reducing greenhouse gases either through abatement or sink enhancement.
- **Impact of pollination services.** Pollination services appear adequate in general but some pollen-dependent fruits are likely being under-pollinated, and resilience of lucerne pastures may be increased through improved pollination. Further, pollination is at risk from the honey-bee mite that recently reached New Zealand.
- **The role of native insects and invertebrates.** Our lack of knowledge of the functional role and significance of insects and other invertebrates in providing the full suite of ecosystem services (particularly soil biodiversity) is a major impediment to more effectively using natural assets to sustain agricultural production.
- **Waste management.** Contamination of soil and water systems with heavy metals and the residual compounds of agro-chemicals will increasingly become an issue given the increasing awareness and demand for safe and healthy food.
- **Role, costs and benefits of shade and shelter.** There is much debate and contention over the value of shade and shelter given the temperate and undulating nature of the Goulburn Broken Catchment. There is a strong case for investment in empirical quantitative studies of the relative costs and benefits to different primary industries and land-uses.

Chapter 7

Specialists' commentary on ecosystem services

HOW ECOSYSTEM SERVICES RELATE TO ONE ANOTHER

Steve Cork
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Social scientists, like the Chilean economist Manfred Max-Neef, have identified a set of fundamental human needs, which includes subsistence, protection, affection, understanding, participation, leisure, creation, identity, and freedom. Natural ecosystems not only provide the food, fibre, shelter, water, liveable atmosphere and other raw materials and services necessary for subsistence, but they also contribute to protecting us from the elements, satisfying our need to understand our world, providing us with opportunities for creativity and leisure, and giving us a sense of identity. These contributions and more are discussed in the following essays. It was the realisation that ecosystems are so important in meeting the needs (and wants) of humans that led to the concept of ecosystem services as a new way to think about our relationship with nature.

The services provided by ecosystems to humans are products of the complex interactions among and between species and with the non-living components of the environment. For example, it is the diversity of species competing for resources and using one another as food that keeps population sizes in check and prevents most individual species becoming pests or weeds. A diversity of functions among animal, plant, fungal and microbial species in soil ecosystems leads to efficient release and use of nutrients and water for plant growth.

This complexity means that there is any number of ecosystem services that can be identified depending on how detailed one wants to be. Different research groups around the world are coming up with different classifications of ecosystem services to meet different needs. Categories like production, regulation, stabilisation, life-fulfilling and option-protecting services are emerging from these efforts.

In this report, our prime aim is to provide a framework to support thinking that will allow the full range of ecosystem services to be considered in decision making, for the benefit of the whole of society. To do this, we have taken the view that what is most important about ecosystem services is that human needs (and wants) are met. In our conceptual framework (see diagram on page 19), and in the tables throughout our report, we have focussed attention on a set of "things" (we have called them goods) that meet human needs and wants, and on a very broad set of natural assets that are the raw material for producing those goods. We have defined ecosystem services as the conditions and processes that maintain the natural assets and/or use those assets in some way to produce the goods.

Within this framework we have begun the process of classifying ecosystem services in relation to the connections they establish between natural assets and human needs. This process is far from complete. It is complicated by different perceptions among specialists about how ecological processes that underpin the services should be divided up, and by the difficulty that in any classification services can overlap or contribute to one another. For example, pollination of crops and native vegetation supports, directly or indirectly, production of food, provision of clean water, protection from floods, and provision of a range of life-fulfilling services.

In the following essays, various authors discuss the importance of individual ecosystem services flowing from natural assets in the Goulburn Broken Catchment. This is a convenient way to encourage dialogue about the roles of ecosystem services and to facilitate this first analysis of threats and importance. We have kept the number of services to a minimum, and you will notice that several could easily be divided into sub-services (indeed, this is done in some of the analyses).

It is important that we do not view individual ecosystem services in isolation from one another. Ecosystem services interact with one another in many ways. For example, vegetation regulates the composition of the atmosphere through the uptake of carbon dioxide and the production of oxygen while at the same time influencing ground water levels and the movement of water and wind across the landscape. These services are all valuable but can conflict with one another. Managing vegetation to lower water tables can reduce availability of water for other purposes. Retention of native vegetation can enhance soil structure and fertility, mitigate the effects of floods, control erosion by both wind and water, influence local weather patterns, provide protection from ultra-violet radiation and heat, and provide clean water to urban centres in a cost effective way. But it also occupies space that otherwise could be used for crops, buildings and recreation facilities, all of which are using ecosystem services to increase human welfare in some other way.

When assessing the aesthetic, cultural and spiritual values of ecosystems, we need to recognise that different people all see and value landscapes and landscape components differently. Studies of Swiss farmers asked to replant forests on their farms revealed that they thought this made the landscape unfamiliar and even ugly because they had grown up appreciating open spaces. In Australia too, studies are showing that increasing or decreasing vegetation cover beyond certain limits has a wide range of impacts on the comfort of different groups within society.

A key question for the later stages of this project is how to provide information on the interactions among ecosystem services, and on the merits of technological substitutes. Most discussions of natural resource management in Australia for decades have focused on only one or a few ecosystem services. It is important for the future that we provide a basis for considering the full range of important and sensitive ecosystem services. For the moment, however, we have focused on separate ecosystem goods and services, with consideration of interactions in general terms only. We believe this will lead to constructive dialogue about the issues we need to address in the next phases of the project so long as we do not forget the existence and importance of the interactions.

POLLINATION AS AN ECOSYSTEM SERVICE

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INTRODUCTION

People who live in the Goulburn Broken Catchment, and the goods that are produced there, rely on many services that are provided by local ecosystems. One of the key services provided to the fruit and vegetable and farming industries is the service of pollination. Pollination is the process of moving pollen from male flower parts to female plant parts. The pollen fertilises an egg cell in the flower, which then becomes a seed. Seeds are borne in fruits, so fruit formation also depends on pollination. For some plants, like grasses and cereal crops, the movement of pollen by wind is sufficient to pollinate flowers. For other plants pollination can happen automatically with the male flower parts contacting female parts of the same flower. However, the majority of plants need animals to visit their flowers to help move pollen, and so produce seeds. Birds, bats, and even small possums can pollinate some flowers, but the most important pollinators are insects, with the most significant being bees. Australia has a rich fauna of native bees, but the most common bee is the introduced European honeybee. This species is managed commercially by beekeepers, and there are also abundant wild European honeybee populations in the region.

Pollination as an ecosystem service is integral to both the ecological and economic health of the Goulburn Broken region. The existing service and the ability to provide this free service in the future, is increasingly under threat on a variety of fronts including over-reliance on a single bee species, pesticide use and lack of remnant vegetation. However, opportunities exist to secure this service to ensure that it can meet the needs of the Goulburn Broken Catchment now, and in years to come.

WHY IS POLLINATION IMPORTANT?

Economically speaking, pollination is a significant contributor to the gross regional product of the Goulburn Broken Catchment. This comes primarily from the contribution of pollination to a number of important crop species (table 17). There is also a substantial contribution through the pollination of nitrogen fixing legumes such as clovers and lucerne, which improve soil and fodder quality, thus maintaining healthier livestock with less fertiliser input to pastures. Lucerne, a pollination-dependent species brought into the Catchment as seed, is also important as a deep rooted species that lowers the water table, helping to reduce salinity. Finally, there are the values associated with sustained regeneration in native vegetation.

There is a wide range in pollinator-reliance among the crops grown in the Goulburn Broken Catchment, ranging from those that are very dependent on pollinators (such as almonds or blueberries) to those that will set fruit in the absence of pollinators (such as olives and soy beans). Growers say that for many of the multi-seeded fruits (such as pears and apples) there is more concern about maximising fruit quality with pollination, rather than fruit quantity. A well-pollinated flower will produce a bigger and better shaped fruit, with superior market value. Whereas for some single seeded fruits, like cherries and plums, pollination is important for the quantity and quality of yield.

Pollination of crops in the Goulburn Broken Catchment comes from three different sources:

- Managed European honeybees.
- Wild European honeybees.
- Native bees and other insects.

Growers of pollination-dependent crops will often pay for beekeepers to provide bees, because wild bees cannot provide a sufficient level of service. This is especially true for crops such as kiwi fruit, which in addition to being pollination-dependent are relatively unattractive to bees. In contrast, apples are very attractive to bees, such that although they benefit considerably from pollination, many growers are content with the level of pollination they get by attracting wild bees. Pears, which are one of the most important fruits in the area, benefit from pollination and many growers therefore bring in managed hives while other growers choose to make do with pollination provided by wild bees. Crops with low reliance on pollinators are not usually provided with managed bees. These crops may, nevertheless, have some value added by wild bees. For example, some research suggests that insect pollination is more reliable in producing good tomatoes than wind pollination, which is the only alternative in the absence of insects. Because the tomato growing industry is large in the Goulburn Broken, wild honeybees may be adding significant value in the tomato industry, even though the level of reliance on bees is low.

The following table shows the degree to which different crops rely on pollinators to produce fruits or seeds of good quality. A 100% reliance on pollination would produce no marketable fruits or seed without pollinators. A crop with 50% reliance on pollination would produce fruits or seeds without pollinators, but the crop would have half the value because of declines in the size, shape or number of fruits. To highlight some of the more productive crops in the area, we have put in bold those with yield greater than 4000 tonnes per year. Of course, some of the low tonnage crops have considerable market value nevertheless.

TABLE 17

Crop	*Pollinator reliance (%)*	*Tonnes per year*
Almond	100	1.4
Blueberry	100	29
Sunflower	100	300
Lucerne	**100**	**46,900**
Pumpkin	90	291
Cherry	90	518
Kiwi	90	428
Apple	**90**	**56,470**
Clover species	90	used in situ
Grapefruit	80	316
Plum	70	3,032
Apricot	**70**	**7,984**
Nectarine	60	2,055
Peach	**60**	**39,228**
Faba bean	50	1,100
Field pea	50	2,900
Nashi pear	**50**	**4,348**
Pear (not Nashi)	**50**	**141,011**
Strawberry	40	235
Mandarin	30	41
Orange	**30**	**5,373**
Lemon & Lime	20	1,383
Raspberry	10	17
Lupin	**10**	**10,700**
Canola	**10**	**10,900**
Grapes	**5**	**6,325**
Tomatoes (fresh)	**5**	**7,740**
Tomatoes (processing)	**5**	**55,452**
Olives	0	10
Soy bean	0	3,700

THREATS TO POLLINATION SERVICES

A. Honeybee populations at risk

The biggest threat to pollination services in the Catchment is the overwhelming reliance on one species, the European honeybee (*Apis mellifera*) to provide the vast majority of the pollination, both from managed hives and from wild populations. This is particularly risky in light of the threat posed by the honeybee mite (*Varroa destructor*). This pest kills honeybees, and has lead to substantial declines in wild and managed European honeybee populations elsewhere in the world. In the US, wild honeybee colonies are now drastically reduced in number, and the number of managed colonies declined 24% between 1995 and late 1996.

Since the arrival of the honeybee mite in New Zealand this year, Australia has become the only major beekeeping country free of the mite. Given its record of spread elsewhere in the world, it is likely the mite will eventually reach Australia. When it does, we too should expect to suffer dramatic declines in the level of pollination from wild European honeybees. This decline will cause yield declines in crops, and also those native plant species that are predominantly pollinated by honeybees. Concurrently, managed honeybee populations will be affected because the cost of maintaining a healthy hive will increase. Growers will be forced to compete for the limited services offered by beekeepers, which in turn will become more expensive.

It could take 10 years before European honeybees evolve resistance to this pest, thus causing long term damage to agricultural industries. While the *Varroa* mite is the most potent threat, the European honeybee is also vulnerable to a range of other diseases including tracheal mite and chalk brood. As long as we rely so much on one pollinator species, pollination services will be vulnerable.

B. Pesticides

Pesticides used to spray crops for pest species also pose a threat to honeybees, which can be killed by many commonly used chemicals. For example, in spring 1998, drift from aerial spraying with dimethoate in a Western Australian barley crop damaged populations in more than 100 beehives brought in to pollinate canola. Growers and chemical sellers in the Goulburn Broken acknowledge that the conflict between chemical use and pollination requires careful attention to the timing and method of chemical application and the choice of chemical. Managed hives can be moved to avoid pesticide problems, but wild populations of bees are more vulnerable. Excessive or incautious use of pesticides in the Goulburn Broken would have a negative impact on pollination services. Pesticide drift can also affect native bees and the plants they pollinate, but this phenomenon is little studied.

Even when pesticides do not lead to significant bee mortality, they can affect the livelihood of beekeepers. Australian beekeepers gain market advantage by offering honey that is free of pesticide residues. Careless use of pesticides introduces the risk the residues will appear in honey, thereby damaging the beekeeper's primary source of income.

C. Loss of remnant vegetation

Remnant vegetation is very important for the survival of wild populations of European honeybees as the vegetation provides hollows for colonies, and a diverse array of important food plants, especially *Eucalyptus* species. It also provides an essential food source for managed honeybees. A recent survey in the Goulburn Valley found that the majority of wild honeybee nests were in trees, rather than buildings or other human structures. The scale of their role in providing free pollination services is potentially great, with 0.8 to 7.8% (depending on the region) of trees occupied by wild honeybees. Clearing of remnant vegetation and dieback of *Eucalyptus* trees threatens the level of service from honeybees. Where there is insufficient remnant vegetation it is unlikely that wild bees will provide sufficient pollination to maximise yield. This is a particular problem when pollination-dependent crops are grown in large-scale monoculture. In these circumstances it is more likely to be necessary to bring in managed hives to supplement diminished access to wild bees. Native vegetation is also essential to healthy managed hives. The majority of crops do not provide a good resource for honeybees, so hives are maintained in good health on flowering plants found mostly in native vegetation.

D. Declining pollination of native plants

Studies from around the world and within Australia indicate that human induced landscape change has altered the pollination environment of many wild plant species. Fragmented vegetation may be particularly vulnerable, with some species showing depressed pollination when growing in smaller fragments. Because this problem is little researched, no data is available for pollination of native species in fragmented habitat in the Goulburn Broken.

However, on the lower slopes and plains native vegetation has been extremely fragmented, and surrounded by highly modified agricultural land. It is likely that some plant species in these remnants suffer reduced pollination rates that might affect the capacity of these plant populations to be sustained in the long term. This process threatens the biodiversity that is harboured by the remnant vegetation of the Goulburn Broken. Not only does this threaten native flora and fauna, but poor seed production also creates a challenge for government programs like Bushcare that use remnant vegetation as a source of seed to replant bushland.

ACTIONS AND OPPORTUNITIES FOR POLLINATION SERVICES

While there are a number of factors threatening pollination services, there also exist management tools to deal with these risks, and opportunities to bolster existing services.

A. Working with beekeepers

Growers in the Goulburn Broken currently get most of their pollination for free from wild bees. For a number of crop species there is evidence that yield would be improved by supplementing this free pollination with the service-managed hives. Currently most beekeepers make their income from honey, and get little income for pollination services. When pollination services are paid for, the cost is currently about $30 for one hive per acre, for a two-week flowering period. The value to the beekeeper of placing hives in a crop depends on the quality of the crop as a food source for bees (usually low), the availability of alternative floral resources, and the market price of honey. In these circumstances, growers are unlikely to get sufficient service from beekeepers unless they pay beekeepers for the pollination service. Paying for pollination is clearly a smart practice whenever the value of increased crop yield exceeds the cost of the service.

Farmers do pay for pollination when they purchase seeds, even if they are not aware of doing so. When a farmer buys seed of a pollination-dependent species (such as clover or lucerne for pasture, or carrots for a vegetable crop) part of the built-in cost of the seed is the management of pollination services by the seed producer, and for some seeds this cost can be significant. Any increase in pollination success of pasture species allows for less money to be spent on purchasing new seed.

B. New pollinator species

It will be extremely difficult to prevent the honeybee mite from entering Australia eventually, and when it does the cost of declining European honeybee populations will be very substantial. We can, however, prepare for the likely decline in the mite-sensitive honeybees by developing alternative mite-resistant bee species for crop pollination.

Australian scientists are currently working to improve pollination of lucerne by seed producers, by developing the imported leafcutter bee (*Megachile rotundata*) as an alternative pollinator. This species was chosen because in North America it does a better job of pollinating lucerne than the European honeybee. American experience suggests that if this introduced species can be successfully managed in Australian conditions, lucerne seed crops would increase two to three fold. Because this species is mite-resistant, it could also be an important pollinator to replace declining European honeybees as a pollinator of other crops. Research in the US, where honeybees have dramatically declined because of mites, has identified the potential of a number of bee species as commercially managed crop pollinators. A similar research effort should be developed in Australia.

Introducing non-native bees to Australia is not without its dangers. There is a risk that introduced species will negatively effect native pollinators or the plants they pollinate, or that they will become pests or vectors of insect or plant diseases. For these reasons we maintain strict quarantine, and the importation of a new species, such as the leafcutter bee, involves much preparation and research. Because of the need to be cautious about introduced species, future research should consider the potential of native bee species for commercial pollination services. The social native stingless bees (*Meliponinae*) show promise for tropical systems, but will probably not be able to service temperate areas such as the Goulburn Broken. There are native bees that aggregate in a manner that makes them potentially manageable for large-scale pollination, and these species deserve our attention.

C. Protecting and enhancing remnant vegetation

To maintain the free pollination service provided by wild bees, it is important that we preserve and enhance remnant vegetation. With good management, we can protect natural vegetation that provides food and shelter to European honeybees and native bees. At the same time we can manage fragmented vegetation to maximise the prospects of sustaining populations of native insects and the plants they pollinate. If growers want to minimise the cost of bringing in beekeepers, there may be value in providing habitat for wild bees around pollination-dependent crops. With good planning, species can be chosen that will flower at a different time to the crop, so that bee populations are sustained, and competition for pollinators is reduced.

D. Careful pesticide use

Pesticide use is an integral part of many production systems, but when pesticides have a negative impact on pollination service there is a hidden cost. It is important that impacts on pollinators are considered when choosing a pesticide and when designing an application system. This is especially true when applying pesticide during the flowering season in an area with pollination-dependent crops. Some chemicals are less dangerous to bees than others, and when these are available they should be considered. Where natural enemies are an alternative these offer a safer choice. Timing and method of application are also important in reducing off-site impacts, and communicating with local beekeepers can reduce impacts on managed hives. Growers are aware of the need to be cautious when their own crop is flowering, but it is also necessary to avoid impact on bees in neighbouring crops or remnant vegetation.

WHERE TO FROM HERE?

Our aim in the Goulburn Broken should be to ensure good crop yields at a reasonable price, healthy pastures with sufficient nitrogen fixing plants and sustainable reproduction by native species. Some actions can happen immediately. The protection of remnants and revegetation of excessively cleared areas are already underway in parts of the Goulburn Broken, and these actions will help pollination services. With careful design, revegetated areas could increase the security and availability of wild pollinators. We already know a lot about careful use of chemicals, and can learn from experience overseas with the same chemicals. Better management of pollination into the future will also require that we fill in some significant knowledge gaps. The most important are;

- Under what environmental and economic circumstances is it profitable for growers to pay for pollination services?
- To what extent do crops that are not usually supplied with managed bees currently benefit from wild bee pollination?
- Which bee species (native or introduced) are good candidates to be developed into mite-resistant commercially managed crop pollinators, as alternatives to the European honeybee?
- What kind of border or understorey vegetation would enhance the supply of free pollination from wild bees?
- How much more will farmers have to spend on seeds of nitrogen-fixing legumes (clovers and lucerne) if there is a decline in bee populations?
- Can we reduce the cost of seeds by better management of pollinators?
- How much crop pollination is done by native species of bees and other insects?
- What is the status of pollination services to native plants in fragmented environments?

LIFE-FULFILLING ECOSYSTEM SERVICES

Jason Alexandra
Alexandra and Associates

INTRODUCTION

While all ecosystem services are, by definition, life-fulfilling in some sense, life-fulfilling services are defined in this essay as provision of aesthetic beauty, cultural, intellectual, and spiritual inspiration, sense of place, existence value, scientific discovery and serenity.

Life-fulfilling services like "landscape aesthetics", "spiritual and cultural inspiration" and a "sense of *place*" are about being in the landscape, and the *landscape* being in us[1], as a shaper of our spirits, our values, our symbols, our culture and cultural icons, and our national or regional character.

A factory is an adequate analogy for the systems that deliver commodities and the physical services of ecosystems, but cathedrals, theatres, museums, universities or great art galleries are more appropriate analogies for the life-fulfilling services. It is important to acknowledge that landscape is already laced with culture—corroboree grounds, burial sites, dreaming trails and initiation sites—and that the nature of meaningful connections will continue to change.

The *place* we connect to is more than a mere location, it has *seasons*, and it has *meanings*, layers of *history, purpose, language* and public and private *symbolism*. *Place,* all places have layers of meaning, complex time scales and symbolism embedded in them. They are open for interpretation through the vast array of lenses that are human understanding and expression—history, politics, economics, geology, genealogy, the life sciences, the arts, religion etc.

The life-fulfilling ecosystem services are intricately bound up with culture, meaning and values and the relationship between peoples and the environment. The ecosystem service is the provision of the platform, the stage, the living auditorium for culture; and the culture the intricate rituals, dances that occur, that refreshes and that renew the connections and understandings. The environment provides the features—culture turns them into icons, symbols instilled with meaning that enable potent communication, powerful exchange. Symbols change over time—salt has become a powerful symbol of environmental damage for example.

For most Australians "landscape aesthetics", "cultural identity" and a "sense of *place*" are bound up in the physical and biological attributes of landscape, but they are more than the physical attributes alone. These services are also fundamentally important to all societies because over generations this is a service of *nature* helping to shape and define *culture*. The life-fulfilling ecosystem services support cultures' celebrations, reverence, curiosity, understanding and knowing—and in the process helps to shape the culture itself.

WHY ARE LIFE-FULFILLING SERVICES IMPORTANT?

Australia's landscapes and creatures are defining features our sense of identity, our culture and our values. They figure prominently in our history, our dreaming, and our stories, even our money and coat of arms display them. But it is in our visual arts that the life-fulfilling services of Australian ecosystems are most powerfully displayed. They have an impressive lineage: from ancient rock galleries at least 60,000 years old to the contemporary central desert dot painting; through Bouvelet and Von Guerard who celebrated nature's awesome grandeur to the Australian impressionist capturing fleeting moments and Australia's brilliant light. Albert Namatjira immortalised the outback. And after the war the modernists—Boyd, Tucker, Nolan, Percival, Williams and Olsen etc—helped Australians to reinterpret the landscape instilling it with meaning, richness deeper than mere appearance. In September 2000 our landscape symbolically featured in the Olympic ceremonies. Without a doubt it is a defining feature of who and what we are.

The landscapes of the Goulburn Broken Catchment are archetypal symbols embedded in the modern (southern) Australian psyche—the forested mountains, blue haze in summer, Buller with snow, the rivers snake across the plains, the pastoral scenes—red gums, box, merino and the transparent noon day light and so on...

The Goulburn Broken Catchment is a living example of some of Australia's most highly valued cultural treasures—it is the "*landscape"* painted by the Heidelberg school of Australian impressionists—Streeton, Roberts, McCubbin etc. Not the actual places painted, but the light, the scenes, the bio-region and its vegetation communities—the yellow box of Box Hill, the wetlands and red gums of the Yarra

1 "Landscape being in us" refers to idea that we imprint and are shaped by certain landscape images and ecosystem characteristics

floodplain still appear today throughout much of the Goulburn Broken Catchment as they did for the Australian impressionist late last century.

But these defining landscapes and cultural images are not a given, they are in fact a product of the natural ecosystems and the cultures—both black and white—that have worked with them and shaped them. They have changed over time and they will continue to change. Unmitigated environmental degradation will turn these images into relics—museum pieces.

In complex, multi cultural, modern Australia, culture is not homogeneous. The diverse relationships people have with landscapes, what they see, understand, interpret and value is dynamic, culturally, historically and often privately or personally determined[2]. It is experienced in different and in distinct personal ways, and it can be a lot of different things to lot of different people.

While sensations of connection, mourning, beauty, awe, spirituality and inspiration can be felt almost anywhere—some places are richer than others for a variety of reasons. Some conform to European ideals of beauty, others modern ideals of wilderness. There may even be power in landscapes that is yet to be explained, rationally, or in ways acceptable to the Baconian positivist tradition that dominates Western thinking. There is however, an ancient Chinese system of understanding landscapes—FengShui[3] which explains the powers of certain land-forms and which values some topographical patterns highly. According to FengShui theory, much of the Goulburn Broken Catchment is a very good place for humans.

Despite lacking a unifying theory comparable to FengShui, to explain what makes a landscape desirable, as a society we do recognise cultural and aesthetic factors. These have been codified in such processes and institutions as the Australian Heritage Commission with its Register of the National Estate (Heritage Places, landscapes) and other planning processes used by local and state governments. For example, view impact analysis has been a key feature of logging plans in Victoria forest management for more than a decade. These were used to minimise visual impacts of logging operations particularly from major roads.

There is no doubt that there are heritage values in many landscapes. Debates have raged inside the National Trust as to whether they were sufficiently addressing the issues of heritage that are tied up in Australia's rural landscapes as opposed to protecting historic buildings.

The life-fulfilling ecosystem services are less defined and harder to quantify than those services that result in production of goods, but they are none the less important. These services are important because the landscape is the web and waft of culture. Landscape—the place, has history, meaning and purpose. It requires due respect. Embedded in the landscape are the monuments and signposts, the relics and the images that support many of our culturally important stories, our myths and our dreaming trails. Along these trails there have been many journeys—journeys that are important for tribes, for nature and for individuals. Each has left marks and messages—some which are read like neon signs—the Hume and Hovell monuments on the side of Hume highway. Some are private and reside in diaries or have been inscribed on memories that will pass with the living, or may be handed down within families—sustaining the delicate threads of oral history.

2 It is the personal nature of these subjective relationships that make generalising difficult, however there is a range of techniques for determining what kinds of landscapes and images people prefer, including monitoring the kinds of landscapes people regard as beautiful and inspiring.

3 While this kind of thinking is poorly developed in western thought there are corresponding theories often referred to as geomancy with its ley-lines and a similar idea—Songlines—has been popularised in a recent novel of the same name.

THREATS TO LIFE-FULFILLING ECOSYSTEM SERVICES

The capacity of the ecosystem to deliver life-fulfilling services can be degraded and/or enhanced by our decisions, but first it must be acknowledged in the planning processes and management regimes. The Goulburn Broken Catchment is not simply a *factory* producing food, fibre, and water. A mechanistic approach to planning might suggest that we can simply tune up the Catchment so we get more of the products and services we want (clean water, crops, CO_2 absorption, conservation of biodiversity etc), and less of what we don't want (species extinction, loss of productivity, pollution etc) from the process. While each of these management issues are important in their own right, there is a need for explicit acknowledgment of the role of the ecosystems in providing life-fulfilling services.

Many processes of ecological decline expressing themselves as land and water degradation, species extinction etc threaten these services. In the Goulburn Broken Catchment loss of wide spaced paddock trees, loss of roadside and stream-side vegetation, poor planning of new rural residential subdivision, etc. will continue to threaten this service. The threats will manifest as controversy in community debates over a range of issues like rights to subdivide, and rights to build in places that have great views but will spoil the views of others.

OPPORTUNITIES AND ACTIONS FOR LIFE-FULFILLING ECOSYSTEM SERVICES

There are many specific possibilities for action on protecting these ecosystem services, and many of these will relate to other aspects of environmental management. However, most importantly there must be systemic appreciation that the life fulfilling values and services are important in their own right and because of their key role in supporting regional identity and prosperity. They play a large part in the economic prosperity of the region via tourism, recreation and life-style choices that collectively underpin the market in residential and rural and property markets and the service and building industry. Despite this importance they tend to be managed by default, as a consequence of other decisions and processes and there is a tendency not to recognise them as legitimate unless they lead directly to economic activity.

The following opportunities for action exist:

- Recognition of the cultural and other values in planning and management processes.
- Move from an instrumentalist, technocratic approach to planning and management to one which explicitly defines values in the landscape as a cultural and humanist challenge.
- Introduce public policy processes that aim to make qualitative values explicit.
- Move away from seeing primary industries as the dominant value in rural landscapes to one that recognises life-fulfilling ecosystems services.
- Acknowledge multi-functionality of rural landscapes. See lifestyle choice and real estate prices as surrogates for valuing the inspirational values of landscapes.
- Develop better planning and assessment processes that help make assumed values regarding the environment explicit and assist in bringing out the value of the life-fulfilling services to a region.
- Move from a reactive approach to policy to a pro-active one regarding these services.
- Use a full range of policy instruments to protect the foundations of these services, including if necessary the restricting or redefining of property rights—e.g. assumed rights regarding subdivision, clearing, construction, grazing etc.
- Recognise the richness and diversity of different systems of understanding and problem analysis—natural sciences analysis versus cultural socio-economic perspectives and ensure these link together in effective decision making.
- Develop a framework for understanding and protecting cultural values in landscapes and use decision making processes that use both cultural values and what the sciences tell us about risks, key processes, drivers etc.
- Use local and regional planning processes to help translate ideals (looking after the environment and what the community finds inspiring etc) into actions and explicitly assist in social and ecological trade-offs.
- Develop bioregionally appropriate equivalents to integrated Catchment management plans that address cultural values and attach these to the statutory planning processes.
- Ensure better planning of new rural residential developments and other developments e.g. use landscape overlays to protect views.
- Celebrate the landscape more explicitly in the form of events and festivals.
- Ensure adequate buffer zones, site and design guidelines that protect both function and visual aspects of key features and processes.
- Designation of special or significant features e.g. public land buffer zones, wetlands or other areas of critical ecosystem process.
- Introduce programs that use the landscape as a classroom—for education and lifetime learning.

- Explicit recognition of the importance of life-fulfilling ecosystem services for the growth industries of life style, education, recreation, and tourism.

LINKAGES TO OTHER ECOSYSTEM SERVICES

The close proximity of the Goulburn Broken Catchment to Melbourne has ensured that it is a favoured destination for recreational trips—skiing, camping, water sports, hunting and fishing, hobby farms, retirement etc. Many Melbourne families have made a traditional pilgrimage to the Goulburn Broken Catchment over Easter to contemplate lifes' great cycles of renewal—birth, death and rebirth—while bushwalking, or fishing and camping beside a stream.

The dryland parts of the Goulburn Broken Catchment are changing as a result of many people moving in for lifestyle reasons—these people are purchasing this ecosystem service when they buy the land and the right to occupy it. These buyers bring new financial capital, skills and values to the Catchment. New enterprises are likely to emerge and many older enterprises are increasingly servicing this growth industry, e.g. retailing, building and construction etc. For example, more road materials are required to upgrade country lanes and build tracks into houses dispersed across former farmland. Frequently, these new houses are located to take in inspirational views.

These ecosystem services are fundamental to much of the life style and recreation based industries. It is why many people want to live or holiday in the region.

In the dryland parts of Goulburn Broken Catchment life-fulfilling ecosystem services are critical to many industries—they underpin the real estate prices more than primary production. In fact due to the high aesthetic values much rural property is purchased for lifestyle reasons and therefore competes with those wanting the land for primary production. People want to live there because they like the landscape, the place, the sense of satisfaction they gain from the location.

The value of these services is increased by the ready access to Melbourne via the Hume, Melba and Maroondah Highways—for many of Melbourne's 3.8 million people the Goulburn Broken Catchment is a playground, a church and a school house. It is place of future dreams, inspiration and fun, it is place for learning and rejoicing, for retiring and for inspiring.

These services are linked to other services in many ways—they may be underpinning and inspiring much of the land repair work and the support given it by the nation. The importance of life-fulfilling ecosystem services in attracting nurses, doctors, teachers and workers in other service industries to the region has not been adequately assessed, but could be very important.

The life-fulfilling services are dependent on many functional aspects of the ecosystem continuing to perform—this service depends on physical aspects of the environment like water quality and scenic vistas. If the rivers and lakes are filled with algal bloom and the plains are covered in the carcasses of dead and dying trees then the sense of place and the value of this sense of place also changes.

If the biological aspects of the Goulburn Broken Catchment degraded further new stories of decline would permeate society. At present the ideal of landscape renewal and repair balances the stories of decline. Australian ecosystems' cycles of renewal can be both providers and formidable forces of destruction—fire, drought, flood.

WHERE TO FROM HERE?

Recognising and protecting the life-fulfilling services does not mean no change. Change can be a positive force but the change processes need to be informed by better understanding and clearer public policy and planning processes. Change options need to be assessed against some standard of landscape or ecosystem quality.

In short, we need to:

- Get a better handle on what is driving the economies of the Goulburn Broken Catchment and to what extent the landscape is the biggest natural assets.
- Address the knowledge gaps by developing a better understanding of the interplay between markets, scientific understanding and cultural values.
- Ensure successful adaptive management and encourage new ways of looking and learning.
- Foster a sense of place that taps and celebrates some of these ways of relating to the environment. It relies a lot on ecosystem processes to continue to deliver key features of *place*. These need to recognised and protected.
- Have more artist trails, community arts and environment programs.

REGULATION OF CLIMATE AS AN ECOSYSTEM SERVICE

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INTRODUCTION

While we often take climate stability for granted, it is a crucial aspect of our ecosystems. This is particularly demonstrated when a drought, flood, heatwave or severe frost occurs. There is increasing recognition that human activities may lead to significant global climate changes as well as altering climate on smaller scales. This has resulted in a focus on climate stability and the contributions that management of rural areas and industries make either to maintaining or disrupting that stability. Key contributions to climate stability include the potential of rural lands to act as a carbon sink through the growth of woody plants and increase in soil carbon while sources of the greenhouse gases methane, carbon dioxide and nitrous oxide from agricultural activities may contribute to climate change. More localised changes to climate may arise from large-scale changes in land cover as well.

The Goulburn Broken Catchment has a lot at stake in relation to climate change and stability. The region's primary industries—agriculture, fruit growing and the dairy industry would suffer negative impacts in terms of climate change. Concurrently, the region is both a positive and negative contributor to climate stability. Contributions to greenhouse gas emissions are made through intensive dairy, cattle and sheep farming, while carbon sinks are provided in the Catchment through existing vegetation and revegetation efforts.

WHY IS THE SERVICE IMPORTANT?

Prior to agricultural development, the climate stability services the Catchment used to provide included acting as a store for carbon through biomass and soil organic matter, a sink for methane via the action of micro-organisms and a source of methane and oxides of nitrogen from natural wetlands, fires, grazing macropods and invertebrates. When aggregated with emissions/sinks from other similar regions, this resulted in relative stability of concentrations of greenhouse gases in the atmosphere and thus maintenance of gross climate patterns. However, human activities have increased the concentrations of greenhouse gases in the atmosphere, leading to commitments to reduce emissions under the Kyoto Protocol. The Goulburn Broken Catchment could be expected to contribute to greenhouse abatement in order for Australia to meet national targets.

The Catchment would have also provided significant feedbacks between the land and the atmosphere. Low levels of subsoil drainage and surface runoff would have meant high proportions of rainfall being transpired—assisted by the high levels of vegetative cover and surface roughness provided by the native vegetation. Higher transpiration would tend to cool the days, warm the nights and probably contributed to regional rainfall via recycling. Changes in vegetation cover over the past 150 years may have subtly altered these effects.

Climate affects all ecosystem functions either directly or indirectly and thus will impact on ecosystem services. These impacts include amongst many others, rainfall that provides soil water for plant growth and runoff for streams, temperature regimes that allow extended growth of highly productive pastures and vernalise fruit trees, humidity that affects water use efficiency, cloud cover that affects how much sunshine reaches the ground and snowfall that affects spring river flows. Changes in climate will thus particularly impact on horticulture, intensive and extensive livestock industries, industries that rely on irrigation, cropping industries and biodiversity.

THREATS TO THE ECOSYSTEM SERVICE

A. Impacts from changes in climate stability

There is increasing expectation that global climate change may occur as a result of increasing atmospheric concentration of greenhouse gases. Because of the pervasive effects of climate on ecosystem services, impacts of climate change will also be pervasive. Potential impacts that have been identified for the Goulburn Broken Catchment or for Victoria more generally include:

- Reduced frequency of vernalisation of fruit trees requiring either changes to low chill varieties, changes species or relocation of the industry. Given the significant amount of infrastructure associated with the horticultural industry, the latter adaptation will have significant impacts.
- Reduced streamflows, particularly increased frequency of low flows. This may have significant implications for water allocation between industry and environmental flows.
- Increased water demand by irrigated pastures and other systems.

- A 5 to 10% increase in wheat yields by year 2100 due to the enhanced growth from higher CO_2 levels, but this benefit will be offset by a 6-8% decline in grain protein content requiring more effective management of nutrients.
- Increased pressure on biodiversity conservation with species progressively being isolated outside their preferred climatic zone. These pressures will be in addition to those already existing from habitat change, feral animals, pest plants, diseases and changed fire regimes.
- Increased heat stress for intensively kept livestock requiring increased attention to cooling systems.

B. Goulburn Broken Catchment contribution to national emissions

As accumulating atmospheric concentrations are the causal factor behind human-induced climate change, an assessment of the emissions from the Catchment may be useful. The emission estimates below are based on data from a variety of sources and generally use the Australian National Greenhouse Gas Inventory (NGGI) approach to quantifying emissions. Activity data to calculate total emissions were unavailable for most livestock and for fertiliser application.

C. Agriculture

Dairy Cattle

A recent CSIRO study identified the Catchment as one of the highest emitters of methane from livestock per hectare in Australia. Much of this arises from the intensive, irrigated pastures in the north of the Catchment. There are about 510,000 dairy cattle in the Catchment, with methane emissions equivalent to about 1,480kt CO_2-e/year and nitrous oxide emissions of 160kt CO_2-e/year from their waste. An additional 340kt CO_2-e/year may be generated from associated nitrogen fertilisation and legume pastures. Electricity usage in dairy farms is substantial and may produce emissions of up to 78kt CO_2-e/year.

Beef cattle

These produce on average methane equivalent to 1400kg CO_2-e/head/year plus nitrous oxide equivalent to 80kg CO_2-e/head/year. Cattle in feedlots produce about 8% higher emissions than pasture based cattle.

Sheep

These produce on average methane equivalent to 155kg CO_2-e/head/year plus nitrous oxide equivalent to 11kg CO_2-e /head/year.

Pigs and poultry

Pigs produce on average methane equivalent to 400kg CO_2-e/head/year plus nitrous oxide equivalent to 63 CO_2-e kg/head/year. Poultry produce about 1.7kg CO_2-e/head/year from nitrous oxide from their waste.

Cropping

About 1.25 ± 1% of the nitrogen applied in fertiliser to these areas is emitted as N_2O.

D. Clearing and revegetation

Clearing of land can result in release of carbon from both biomass and soil pools and is a significant source across the nation. However, clearing is now restricted in Victoria and if it is still ongoing in the Catchment, it is probably not a major emitter. In contrast, there are many farms that are actively revegetating and this will tend to store carbon in both biomass and soil. Figures for areas of revegetation and rates of carbon accumulation were unavailable.

Forested areas in the Catchment have been considerably reduced since European settlement with some 2.4Mha of forest originally but only 0.74Mha remaining. Studies in other locations suggest that large-scale clearance can affect climate. At small paddock scales, removal of trees tends to raise daily maximum temperatures and reduce nighttime low temperatures. It can also increase frost frequency and severity. At larger regional scales, it may also affect climatic factors such as rainfall and windspeed although these are more difficult to demonstrate.

E. Fossil fuel emissions and other emissions

Greenhouse emissions from fossil fuels are predominantly CO_2 but also contain trace amounts of gases such as methane and nitrous oxide. Disaggregated figures of fuel consumption for the Catchment were unavailable, however, they would be small compared with those in major metropolitan centres. There are also greenhouse emissions that arise from waste water treatment plants, landfills and abattoirs.

F. Total Catchment emissions

Net Catchment emissions were unavailable due to limitations in data availability.

OPPORTUNITIES AND ACTIONS FOR THE ECOSYSTEM SERVICE

The aim in the Goulburn Broken should be to maintain agricultural production whilst cost-effectively reducing greenhouse gas emissions and encouraging maintenance and development of carbon sinks.

There is a range of activities that could be undertaken to reduce emissions:

A. Animal production systems. Ensure they are operating effectively (i.e. good husbandry practices) as by maximising efficiency, emissions per unit productivity can be minimised. New technologies which can reduce methane emissions may be available over the next few years—adoption may be useful as most will have productivity gains as well as reducing emissions. Improved pasture management can also increase soil carbon stores in some situations.

B. Fertilisers. Apply nitrogenous fertilisers at rates and times which tend to reduce nitrous oxide emissions and maximise the uptake by plants. Some fertiliser formulations sold overseas have denitrification inhibitors and new technologies such as waxed calcium carbide may also be worth evaluating as these may have economic benefits from increasing efficiency of uptake.

C. Waste disposal. For intensively kept livestock there are waste disposal methods which can reduce emissions of greenhouse gases. These range from appropriate application of slurry on fields and methane biogas digestors to aerated pondages.

D. Vegetation. The protection of remnant vegetation and revegetation of excessively cleared areas are already underway in parts of the Goulburn Broken, and these actions will help reduce net emissions. Minimising further clearing or establishing clearing offsets may also be involved.

WHERE TO FROM HERE?

In the longer-term there is an array of adaptations that may need to be considered as climate changes continue. For cropping and horticultural industries, these involve continued assessment of the varieties used and the establishment of breeding programs that will deliver appropriate genotypes for the climate one to three decades ahead. Increased attention to management of nutrients will be needed as may a focus on pests and diseases. The dairy and horticultural industries will be crucially affected by changes in the availability of irrigation water and increasing water use efficiency will probably be needed. Increasing heat stress management may be needed by the dairy industry. The other livestock industries will probably be less affected in the medium term but if increased drought frequency occurs as suggested by some climate analyses, then changes in pasture and stock management will be needed. Crucially in all the above, an adaptive management approach will help these industries make timely and effective adjustments.

INSECT PEST CONTROL AS AN ECOSYSTEM SERVICE

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INTRODUCTION

The soil and above-ground vegetation provides the habitat for a complex and diverse community of invertebrate animals. The most common interactions these organisms have is that they eat each other. The resulting food web represents a model of the interactions between predators and prey. The greater the biological diversity of the community, the more complex are the linkages in the food web, and, in general, the more resilient the system is against incursions of species which are likely to become pests. There is a relationship between the structural complexity of the higher plant communities of an agroecosystem (and any adjoining remnant natural vegetation) and the amount and quality of available habitat it provides to invertebrates. Thus, orchards are structurally more complex than wheatfields and insect diversity is many times higher.

In the Goulburn Broken Catchment the horticulture industry has a series of pests that cause severe economic damage and pose a continual threat to the viability of these industries. The adoption of sustainable production systems, the role of conservation biocontrol and integrated pest management and working closely with farmers and growers will all work towards a sustainable solution to pest insects.

IMPORTANCE OF INSECT PEST CONTROL AS AN ECOSYSTEM SERVICE

Gross farm gate Value of Production (GVP) of the Goulburn Broken Catchment is approximately $1 billion. For the purposes of this overview the following aggregations have been made;

1 **Horticulture**, including stonefruit and pomefruit, citrus, fresh and processing tomatoes and vegetables (approx. 20% of GVP)

2 **Livestock and dairy**, including cattle (beef and dairy), sheep (meat and wool), pigs and poultry (approx. 58% of GVP);

3 **Broadacre crops**, including, cereals, pasture seeds and fodder crops (approx. 11%)

4 **Timber and minor industries** 11% GVP

This review concentrates predominantly on horticulture, the industry most affected by insect pests (dicotyledonous crop plants have more resources that are attractive to insects than monocotyledonous crop plants which are mostly affected by fungal root pathogens rather than insects). This overview does not cover fungal pests.

Most horticultural production systems in the Goulburn Broken Catchment are relatively high-tech. operations, with heavy dependence on artificial inputs, irrigation, and associated infrastructure. We found little awareness amongst growers of natural pest control as an ecosystem service, and no evidence of deliberate management of the agroecosystem to enhance pest control using natural enemies. However, growers were well aware of integrated pest management (IPM) and the role of biological control in IPM.

In the Goulburn Broken Catchment, grapevines, tomatoes, stonefruit, pomefruit, vegetables and citrus have a series of pests which cause severe economic damage and pose a continual threat to the viability of these industries.

Grapes

Grape Phylloxera is the major insect pest of vines and has been widespread and most destructive in Victoria. An aphid, it causes galls on roots and leaves leading to root rot, which kills vines and will eventually wipe out a vineyard. The only effective management is by strict quarantine (e.g. the quarantine zone in Northern Victoria around Rutherglen) and replanting vines with Phylloxera-resistant rootstock. Other pests of lesser importance include Two-Spotted Mite, Bunch Mite, Blister Mite, and Rust Mite. Conservation biocontrol of these mites has been developed in Sunraysia, the Murray Irrigation Area and the Riverland, using the natural enemies in the form of two native predatory mites, *Amblyseius victoriensis* and *Typhlodromus dooreenae*.

Tomatoes and Vegetables

Western Flower Thrips (WFT), Onion Thrips and Tomato Thrips all transmits Tomato and Spotted Wilt Virus (TSWV), which affects tomatoes, strawberries, and various vegetables. If TSWV becomes established in the Goulburn Broken Catchment, crop losses are likely to be severe. WFT has been found in parts of Northern Victoria and in the horticultural districts of the Melbourne metropolitan area. Last year saw severe outbreaks of TSVW on strawberries and vegetables. There is no integrated pest management commercially developed for WFT. Control is by insecticides such as methamidophos and fipronil.

Stone and Pomefruit

Codling Moth is the most damaging insect pest of apples and pears. It can tunnel into every fruit on a tree, rendering it unsaleable. To minimise codling moth damage, growers have used frequent sprayings of broad spectrum insecticides, with detriment to beneficial insects, as well as residue problems and considerable cost. The use of insecticides to control the Codling Moth has also resulted in secondary pest problems, particularly with the two-spotted mite. Codling Moths prefer apples, but they will also attack pears, nashi, quince and crab apples. Biocontrol has been developed for Codling Moth using a predatory mite, which is resistant to broad spectrum insecticides used for Codling Moth control, but it is not in widespread use. Other natural biocontrol agents include various parasitic wasps. Broad spectrum insecticides are currently used to control the Oriental Fruit Moth which is a major pest of peaches. Control in the canning peach industry has been partially replaced in the Murray Irrigation Area by the use of synthetic pheromones to disrupt mating. This technique is also used in the Goulburn Broken Catchment, especially by larger, high-tech. growers. The Lightbrown Apple Moth does serious damage to fruit and leaves, to apples, other pomefruit and citrus (cf. below). It has a variety of natural enemies including several parasitic wasps. Spraying for Codling Moth also controls Light Brown Apple Moth.

Citrus

Citricola Scale is a sap-sucking insect that produces honeydew, encouraging growth of Sooty Mould Fungus, which leads to downgrading of fruit quality. Red Scale does not produce honeydew, but causes fruit blemish and leaf drop. Moreover they inject toxins that can kill trees. Biocontrol is by the use of parasitic wasps.

Dairy and Pasture

Dairying occupies almost half a million hectares of irrigated land in northern Victoria and produces about a quarter of Australian milk. The major invertebrate pest affecting pastures is Red-Legged Earth Mite. The only method for control is spraying with insecticides such as dimethoate. The efficacy of spraying has recently been greatly increased by development of a predicitive information package (Timerite®) for farmers, who can now achieve good control with a single spray in spring.

CURRENT STATE OF PEST CONTROL; THREATS AND STRESSES

A. Integrated Pest Management (IPM)

Integrated pest management combines chemical spraying and biological control to reduce pest populations to minimum acceptable levels. Considerable reductions in pesticide usage can be achieved, and the methodology usually requires continual monitoring for pests. Mating disruption and other pheromone-based pest management for orchard moths is becoming more widespread, as are control methods with predators and parasitoids. Nearly all of these methods are introduced commercially to crops as needed. In the Goulburn Broken Catchment there has been a recent trend towards chemical companies to provide comprehensive IPM services in addition to selling insecticides. They carry out monitoring of pest populations, provide information on pest life cycles, and introduce commercially reared natural enemies.

B. Overspraying, Pesticide Residues and Resistance

Pesticide residues are a major issue in the horticultural and livestock industries. Apart from the damage that overspraying does to the beneficial fauna of orchards and paddocks, it can also encourage development of resistance and increase outbreaks of secondary pests. Spray drift may also cause damage to adjacent areas of natural vegetation. Because of regulations relating to pesticide residues in meat, livestock are rarely grazed in orchards, or fed using forage from orchard alley cropping. Use of slow-release anthelminthic drugs such as the milbemycins represents a threat to increased pasture fouling and decreased productivity by disrupting the activities of the dung-degrading fauna and flora.

C. Shifting Cultivation

The Goulburn Broken Catchment contains one, if not the only, example in Australia of shifting cultivation. Some growers in the fresh tomato industry practise this method. The fresh tomato industry produces a high-value crop, intensively cultivated, and where market emphasis on external appearance is crucial. Consequently, inputs of pesticides are very high, and yield decline commences in 2-3 years. Growers will then shift to a new site, often to land that has been bought from dairy farmers. Currently, fresh tomato production occupies only around 1,000 ha, but is expanding rapidly.

D. Loss of Natural Vegetation

Remnant vegetation provides a reservoir of potential natural enemies of pests. Though their services are largely untried and unrecognised by farmers and growers, the removal or degradation of natural vegetation represents the loss of habitat for a resource of considerable ecological and economic potential.

ACTIONS AND OPPORTUNITIES

A. Adoption of Sustainable Production Systems

A major constraint on adoption of sustainable production systems in horticulture is that the system is quality-driven and growers are reluctant to change to practices that they perceive may have an impact on appearance and value of their produce. Ironically, the emphasis on cosmetic quality may be a constraint on the adoption of sustainable production and may be at odds with community attitudes and certain market access requirements. However, the willingness of major growers to adopt IPM shows some promising prospects for the development of ecosystem services based on conservation biocontrol. Interestingly, the reasons most cited by growers for reduction of pesticide use is the health of themselves and their workers and not the risks to agricultural and natural ecosystems.

B. Conservation Biocontrol and its Role in IPM

There are a number of examples of success stories in conservation biocontrol in the citrus and grape industries in Southern NSW and in SA, but little has yet been achieved in Northern Victoria. Orchard ecosystems, being perennial cropping systems with an existing high degree of spatial structural complexity and habitat diversity, are particularly amenable to management for encouragement of natural enemies.

C. Education of Farmers and Growers

Working more with farmers and growers is critical to increase understanding about the effects of pesticides on non-target beneficials, and upon ecosystem services both directly relevant to their systems and to those in other industries. The concept of conservation biocontrol and habitat enhancement to encourage natural enemies has yet to gain much of a foothold.

D. Role of Department of Natural Resources and Environment and Agriculture Victoria

Agriculture Victoria, through its research stations in the Goulburn Broken at Tatura, Kyabram Cobram and Rutherglen, provides a key role in research on sustainable production systems. They are looking at methods of promoting conservation biocontrol and use of natural enemies, but have no major programs at present.

WHERE TO FROM HERE?

More quantitative research is needed on the nature and value of pest control ecosystem services, based on empirical studies. Such studies will address the relative contribution of natural vegetation and role of structural complexity in terms of realising ecosystem-derived pest control.

MAINTENANCE AND PROVISION OF GENETIC RESOURCES

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INTRODUCTION

Genes are the basic units of inheritance. They are embodied in the chemical code associated with the deoxyribonucleic acid (DNA) molecules packed away inside all living cells.

Each gene controls a different characteristic and no two products of sexual reproduction have the same combination of genes. We can see this in looking at two people but it applies equally to a field of seemingly identical wildflowers. Each plant in the field has its unique DNA, its unique set of genetic instructions, and therefore its distinctive set of characteristics. One plant may have more flowers, and the next flowering put more energy into growing roots.

Such tiny variations are important as they enable species and ecosystems to work out how best to perpetuate themselves. With genetic diversity they can evolve to secure their future in an ever-changing environment.

Biodiversity, or biological diversity, is the variety of life at all levels of resolution: ecosystem, species and genetic. Biodiversity is underpinned by and utterly reliant upon genetic diversity. At species level the consequences of loss of genetic diversity can be seen in the cheetah and the North American bison where entire wild populations are vulnerable to disease or radical changes to their environment. In Victoria we have the critically endangered brush-tailed rock wallaby (genetically distinct from its NSW cousins).

In sartorial terms we need a full wardrobe of genes—jeans (many styles, colours, weights, fabrics—maybe even a few different sizes) in order to be 'all dressed up with lots of places to go'.

WHY ARE GENETIC RESOURCES IMPORTANT?

A. Intrinsic Value

Life should be valued in all its complexity. When we marvel at the wonder and variety of nature, we assign it not only current value but also future value—the right of the great journey of evolution to continue.

B. Resilience

Diverse systems are better able to recover from disturbances, shocks or any changes imposed from outside. Think of the benefits of being a multiskilled worker or of having a diverse spread of investments. Likewise natural and agricultural systems with a complex array of genetic resources at their command are best equipped to weather 'storms' ranging from species-specific disease to global warming.

C. Improving Existing Crops

The world's most important crops, for example the cereals, owe more to the efforts of crop breeders than to the application of fertilisers and pesticides. Productivity is sustained through constant infusions of fresh genetic material. This topping up of a crop's hereditary constitution relies on healthy wild sources of genetic material. These sources are often threatened and many remain unknown. Ninety-five percent of Greece's native wheats are extinct; the situation is much the same in Turkey and the Middle East. Asian rice crops have been saved several times from deadly viruses by eleventh-hour discoveries of resistant genes in wild rice.

D. New Foods

Humans have only ever used about 3,000 plant species for food, only 150 of which have been cultivated on a large scale. Yet there are at least another 75,000 edible plants in the wild. Our modern crops thrive in a limited range of favourable environments. Incursions into marginal areas meet with failure of the enterprise and devastating environmental impacts. What if we were to expand our tastes by looking into nature's genetic storehouse for plants adapted to dry or saline conditions? We know there are untried wild relatives of barley wheat, rice, millet, sugarbeet, tomato, date palm, pistachio and others. In Israel sea water irrigates sorghum, soybean and avocado specially adapted from salt tolerant wild relatives.

E. Medicines and Pharmaceuticals

One quarter of our medicines and pharmaceuticals are derived from plants, another quarter from animals. New drugs are being identified all the time with tropical forest plants attracting most attention to date. When comparing the number of rainforest species that have yielded drugs with the number yet to be investigated, we arrive at the sobering conclusion that only 12% of the potential has been realised. Even less is known of other ecosystems.

F. Industrial Uses

We are much less aware of the use of plants and animals for purposes other than food and medicine. And yet our daily lives are supported by a myriad of products derived from gums, exudates, oils, resins, dyes, tannins, vegetables fats and waxes, insecticides, and many other biodynamic compounds. A person would be brave (foolhardy?) to assume industry has made full use of the Earth's genetic resources for our current needs let alone future ones.

G. Research Models

Genetic resources have medical and industrial uses even when not put to direct use. The molecular structure of natural rubber provides a blueprint for synthetic rubber. The hollow unpigmented hairs on a polar bear provide a model for cold-weather clothing and may one day drive radical new designs in solar collectors. Squids supply neuroscientists with crucial insights into our own nervous system.

H. Biotechnology

Biotechnology relies absolutely on a diverse supply of genetic resources. Genetically engineered organisms hold the promise of feeding the world's billions, controlling pests, breaking down toxic chemicals—even countering global warming. There are risks however. Australians know too well the potential consequences of releasing untested organisms into the environment.
Market forces may deny ecologically sustainable outcomes in biotechnology. For example, current genetic engineering for agriculture is concentrating on pesticide and herbicide resistant crops rather than fertiliser-free and pest-free varieties.

THREATS TO GENETIC RESOURCES

Processes that threaten biodiversity at ecosystem level or species level, whether in aquatic or terrestrial environments, will threaten genetic resources.

- **Loss of remnant native vegetation** may harbour restricted genetic material. It may also harbour organisms which keep pests in check.
- **Declining pollination of native plants.**
- **Changed fire regimes** may deny fire to species requiring fire for germination, or may be too frequent to allow species to set seed.
- **Uncontrolled pest species** threaten native species directly or by altering habitat.
- **Threats to aquatic ecosystems** that include low river flows, barriers to fish movement, low temperatures downstream of large dams, and pollution.
- **Overuse of agricultural chemicals** threatens non-target species directly or via residues.
- **Rising water tables** threaten vegetation with water logging and salinity.
- **Threats to the soil** include the impacts on soil biota as well as all vegetation dependent upon soil fertility and health, as described in other essays in this Chapter.
- **Loss of habitat** which can be the result of any of the above threats.

OPPORTUNITIES AND ACTIONS

- Maintain a register of local genetic resources as research data comes to light.
- Investigate the use of genes from native relatives (local, regional and national) in established crops.
- Promote the use of native plants (and more controversially—animals) for new agricultural products.
- Revegetate areas strategically. Tie together remnant patches to improve genetic flow. Provide habitat for pollinators, especially near crops.
- Undertake research into the fire ecology of local species/communities and apply ecological considerations to fire regimes.
- Target traditional pest control programs more effectively, research and apply biological controls, and engineer crops to be pest-resistant rather than chemical-resistant.
- Many of these actions are described in more detail in other papers in this chapter that describe complementary ecosystem services.

LINKAGES TO OTHER ECOSYSTEM SERVICES

Every ecosystem service is reliant on life forms in one way or another, whether they be soil biota (e.g. Water Filtration and Prevention of Soil Erosion) or forests (e.g. Regulation of Climate). As such genetic resources underpin all ecosystem services as they do all life.

WHERE TO FROM HERE?

The way forward demands that we value and embrace Australia's genetic resources. We must treat them as we do our most valued possessions and information. They must be secure. We must study them and learn as much as we can. We must apply our knowledge to the benefit of society, economy and environment. With regard to agriculture, farmer Bruce Milne of Coleraine in Victoria's Western District offers this view of the future:

"I look forward to a method of ecosystem farming in Australia which recognises, and reconciles, the native potential of this country. We need to farm with, not in opposition to, Australian native flora and fauna and in that way enhance biodiversity."

MAINTENANCE AND REGENERATION OF HABITAT AS AN ECOSYSTEM SERVICE

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INTRODUCTION

The regeneration of habitat is an ecosystem service maintaining the natural asset that supports biodiversity, which is important to humans in a range of ways. Habitat is the environment in which organisms live and reproduce, and it includes the space, water, atmosphere, and nutrients or solar energy that an organism requires to survive. Habitat occurs at all levels and scales from the microscopic scale of a plant particle to which a bacteria adheres in the gut of a possum, to the massive old red gum in which the possum finds shelter and the landscape in which the possum searches for food. Habitat is also very fluid and it ebbs and flows with life—growing old and decaying but still providing habitat for other creatures. This regeneration must continue otherwise life would eventually cease.

The woodland habitat of the Goulburn Broken is the focus for this paper and in particular the regeneration of eucalypt woodlands. These woodlands provide habitat for a range of unique plants and animals as well as contributing to other ecosystem services including reducing ground water discharge and providing shade and shelter for farm animals. However, in the Goulburn Broken Catchment, these woodlands are disappearing which in turn affects the ecosystem services that they provide. Various stresses such as dieback, over grazing, weeds, rising water tables and lack of fire are all contributing to the decrease in this habitat. The Goulburn Broken Catchment Management Authority and the Victorian Government also recognise the need to maintain habitat and have in place a strategic framework with re-vegetation goals for the Catchment. The will, knowledge and capacity to regenerate these shrinking woodlands are building, as recognition grows that we all ultimately depend on the regeneration of habitat for our own well-being.

THE IMPORTANCE OF HABITAT MAINTENANCE AND REGENERATION

The woodland habitats in the Goulburn Broken are home to a plethora of creatures including birds, bats, bees, frogs, lizards and a wide range of plants and fungi. Over two-thirds of the birds of the Goulburn Broken Catchment rely on tree hollows in woodland habitats for shelter and nests. They live in the trees and the understorey of shrubs and tussock grasses. Similarly, up to eight species of bats also live in the woodlands. Both the birds and the bats feed on the diverse load of insects found on trees and can also feed beyond the trees into the crops and pastures thus reducing the need for chemical pest control. Tree hollows are also home to native and European honeybees, which in turn are essential for the pollination of some crops and pasture.

Branches from eucalypts that have been pruned off by termites, lightening and wind-storms also provide very essential ground cover for species of small, mostly insectivorous marsupials such as the yellow-footed antechinus. This 'litter' is also home to at least 16 species of lizards and five frogs.

Woodlands are the only habitat for a wide range of plants and fungi. There are over six species of beautiful orchids that are unique to eucalypt woodlands in northern Victoria, and many species of hypogeous fungi (most of them undescribed by taxonomists) also live in the woodlands. These fungi have a mutually beneficial relationship with the eucalypts and are reliant on the roots of eucalypts to provide them with carbohydrates, which are produced in the leaves far above. In turn, these fungi effectively increase the area of the tree's roots thousands of fold, greatly increasing the tree's ability to gather water and nutrients from the soil. All of these habitats and services would soon cease if the trees and shrubs within the woodlands do not regenerate.

The importance of habitat in the Goulburn Broken has been recognised by the Goulburn Broken Catchment Management Authority, and the Victorian government.

The *Native Vegetation Plan* for the region sets out priorities and goals in relation to the management of native vegetation. Specifically, the plan aims to:

- Maintain or increase the extent of all native vegetation types, using 1999 extent as the base, in keeping with the goal of Net Gain listed In Victoria's Biodiversity Strategy 1997.
- Enhance the quality of existing native vegetation by managing 90% of native vegetation cover according to Best Management Practices by 2010. (This goal applies to both private and public land).
- Increase the cover of all 'Endangered' and applicable 'Vulnerable' Ecological Vegetation classes to at least 15% of their pre-European vegetation cover by 2030.
- Increase the viability of threatened species and the extent and quality of threatened ecological communities.

The *Native Vegetation Plan* provides a framework within which effective decision making can occur on issues relating to clearing native vegetation and direct investment for the protection and enhancement of habitat.

THREATS TO WOODLAND REGENERATION

Eucalypt die-back is a complex problem that occurs in the Goulburn Broken, but more insidious is the lack of regeneration which is caused by continuous grazing, weed invasion, rising water tables and altered fire regimes. Die-back would be much less a problem if the dying trees were being rapidly replaced at little cost by the ecosystem service of natural regeneration.

A. Grazing

The combined grazing and browsing by livestock, kangaroos and rabbits generally kill trees and shrub seedlings before they can grow tall enough and produce thick enough bark needed to survive such attack. Grazing is a natural part of these systems, but the high intensity and prolonged duration is new. The dramatic increase in the regeneration of Callitris pines following reduction in rabbit numbers is a well documented example of the impact of browsing on regeneration.

B. Weeds

Native trees, shrubs, grass and forb seedlings are being out competed by the dense swards of weeds such as barley grass phalaris and thistles. Weed competition is enhanced by the soil nutrients imported into woodlands through a century or more of dung and urine deposition by livestock seeking the shade and wind protection of trees, which are slowly dying. Few native plants can survive in these high nutrient environments, having evolved to live in low nutrient soils. This over-fertilisation is worsened by further nutrient inputs of drift from cropping and pasture improvement activities.

C. Rising water tables

The long-term regenerative capacity of woodlands is further threatened by rising water tables. Prolonged water logging is killing some species, others are killed or stunted by salinity. Resistant trees such as some varieties of river red gums can rapidly grow on these shallow water tables, but then may collapse from water stress as they draw-down the water table below their roots.

D. Elimination of fire

Controlled fire is now eliminated from these landscapes to avoid damage to crops, pastures and livestock. But fire is an integral part of the evolutionary history of eucalypt woodlands. Without it, regeneration
can be suppressed, particularly of some Acacia understorey species that are hard-seeded and only freely germinate after fire, or heat treatment prior to mechanical planting.

OPPORTUNITIES AND ACTIONS

There are ways of conserving and restoring the regenerative capacity of woodland habitat, and these are outlined below.

A. Grazing Control

Undesirable grazing can be reduced through fencing, rabbit control and kangaroo management. Grazing does not need to be permanently removed for regeneration to occur, it only needs to be significantly reduced when seedlings are becoming established. Some timely grazing is also needed in certain places to enhance the patchiness of woodland understorey so that no one species such as kangaroo grass comes to dominate. The fencing off of remnant woodlands by Landcare activities is often funded through fencing incentive schemes, and is the essential first step in conserving regenerative services.

B. Weed Control, Fire and Re-seeding

Competition by weeds usually needs to be reduced as well. One of the most effective means of enhancing natural regeneration on deep soils, as exemplified by work done in the central tablelands of NSW, is to 'scalp' the topsoil to one side. This involves using a small grader or blade behind a tractor to scrape aside the top 10-15 cm of soil exposing a less fertile and relatively weed free layer suitable for the germination of seed from existing trees.

Where a shrubby understory has been lost due to chronic grazing and browsing, direct seeding of local provenance shrubs is often necessary. The biggest constraint to direct seeding, which is otherwise inexpensive, is finding and harvesting sufficient quantities of seed. There are so few shrubby remnants left, and what plants are left produce so little viable seed, often due to lack of sufficient native pollinators, that the current demand for seed greatly outstrips the meagre supply. Establishment of local provenance seed nurseries should be a priority.

Re-introduction of fire into these remnant woodlands, as an ecosystem service, is generally no longer feasible. The landscape is now so fragmented that species that are damaged or killed by fire can no longer move back in from areas not burned. Mimics of fire are now needed for those species that require fire to persist in the landscape. Heat or smoke treatment of some shrub species to break their dormancy is one means of providing the service fire used to deliver. Intense grazing by a mob of livestock for a day or two can also mimic fire by rapidly consuming a build-up of exotic and native grasses that can choke out native broad-leaf forbs and orchids.

The capacity for the natural regeneration of native grassy understorey has also been lost in many areas. However, relatively low-cost technology has now been developed to gently harvest these fluffy grass seeds and sow them by modifying air-seeders routinely used for crops. Again, sources of quality local provenance seed is a constraint, but patches still exist along roadsides, travelling stock routes and semi-natural pastures on low-input farms.

C. Rising water tables

Various strategies are being implemented to fight rising water tables in the Goulburn Broken. These often involve re-vegetation of parts of the landscape. In addition to enhancing maintenance of existing habitat by lowering water tables, these strategies can add new habitat if appropriate mixes of native plant species are used. Patches of revegetation need to be large and wide enough to provide habitat for those species that need large areas of woodland. For example, 95% of the small insectivorous woodland birds in the Southern Tablelands of NSW are only found in woodland patches at least 10 ha in size.

LINKAGE TO OTHER ECOSYSTEM SERVICES

Regeneration of habitat has many connections to the delivery of other equally important services. Soil is habitat for all the crops we consume, and the maintenance of soil fertility ensures the regeneration of soil habitat. Similarly, maintenance of fresh water supplies ensures the regeneration of habitat for all those life-forms that cannot survive in salty or polluted water. Habitat also provides a desirable landscape that provides beauty and recreation to many people's lives. Regeneration of habitat underpins the production and maintenance of biodiversity, which is important to humans in its own right and because of its role in ecosystem services like water filtration, flood mitigation, maintenance of soil fertility, natural pest control and pollination.

WHERE TO FROM HERE?

There are three ingredients needed to maintain or restore natural regeneration of native woodland habitat: will, knowledge and capacity. A will is needed from individual farmers with support from their families, neighbours and communities to modify land-use practices to allow woodland trees, shrubs, grasses and forbs to seed, grow and set seed again. A will is needed now to regenerate hollow bearing trees that take over 150 years to develop. The will of landowners will be enhanced by better evidence of the multiple values of native vegetation to all of society and increased interest by society in supporting land ownership in maintaining those values.

Better knowledge is needed to understand the most effective ways of restoring regenerative capacity. But all new knowledge is essentially gained through trial and error, whether it be conducted by scientists with their hypotheses and replicated experiments, or by farmers continuously trying out new ideas. The critical element in gaining new knowledge is not so much the good idea, but monitoring and communicating our successes and failures.

Finally, individual land managers and communities need the capacity to act on their will and knowledge. Capacity is built through profitable enterprises, incentive schemes and new technologies that reduce costs.

This will, knowledge and capacity is building but needs to be accelerated through sustained support from all levels of society. We all ultimately depend on the regeneration of habitat for our own well-being.

PROVISION OF SHADE AND SHELTER AS AN ECOSYSTEM SERVICE

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INTRODUCTION

The dual ecosystem services of providing shade and shelter are derived primarily from the ability of structurally complex vegetation such as trees and shrubs (natural assets) to ameliorate extremes in local weather and climate. In the Goulburn Broken Catchment, these types of vegetation are commonly arranged in the form of windbreak and woodlot plantings, or as native vegetation remnants and individually scattered paddock trees. The value landholders place on the provision of these services varies considerably throughout the Catchment, depending largely on the susceptibility of their enterprise to extremes in weather and climate, but also the topography and shelter requirements of their particular property.

In a survey of trees on farms conducted by the Australian Bureau of Agricultural and Resource Economics (ABARE) during 1994, over 50% of farmers surveyed from Victoria had planted trees in the past three years. Of these farmers, 95% listed the provision of shade and shelter as one of three main functions of their plantings. The other two main functions were the rehabilitation of degraded land and protection from future degradation (44%) and conservation of native vegetation and wildlife (32%). These results provide a strong indication of the value Victorian farmers place on shade and shelter services.

From a scientific viewpoint, research conducted over the past 50 years has shown that windbreaks, through the provision of shade and shelter, may significantly improve the productivity of livestock, pasture and crops. The main reason for this improvement is the ability of trees and shrubs to create a more benign and productive microclimate.

The biggest threat to the continued provision of shade and shelter services is any factor that can influence the establishment and sustainability of windbreak plantings as well as the management of existing native vegetation. In the Goulburn Broken Catchment, these factors may include the loss of native vegetation, increasing dryland salinisation, and any reduction in government support and tree planting incentives.

WHY ARE SHADE AND SHELTER IMPORTANT?

Shade and shelter services are important for many enterprises in the Goulburn Broken Catchment. Industries with the most to gain are grazing and on-farm dairying, which produce agricultural product with a farmgate value of $236,315,000 and $453,348,000, respectively. However, the provision of shade and shelter services in other industries that involve crop and pasture production is likely to be important as well. This is because unlike livestock, plants cannot move and hence are unable to actively seek out shade and shelter during inclement weather and climate. For this reason, industries in the Goulburn Broken that involve crop and pasture have the potential to increase their production through the benefits of shelter such as reduced wind damage and moisture stress.

A. Enhancing Livestock Production

Shade and shelter services can increase livestock production either indirectly through increased pasture production or directly through the alleviation of environmental stresses such as extreme heat and cold. Only the latter is discussed here.

Heat Stress and Shade

Trees and shrubs provide shade for livestock during extreme hot weather. They do this by intercepting the sun's rays, which is either deflected into the atmosphere or used as energy for photosynthesis. The result is a shading effect under the vegetation canopy that can lead to lower maximum air temperatures during the day, and obviously greater thermal comfort for livestock.

Heat stress has many effects on livestock, including reduced reproductive efficiency, decreased liveweight gain, and reduced milk production. Heat stress is unlikely to be a major problem in the Goulburn Broken Catchment, but may occur periodically with the onset of extreme hot weather.

The most probable effect of periodic heat stress to livestock in the Goulburn Broken will be a temporary drop in sheep fertility and the well-being and size of calves. Mortality in potentially sensitive stock such as newborn lambs and calves may also occur because it can take several days before these young animals can properly regulate their own body temperature. Milk production will not be significantly affected, as heat stress in dairy cows is related to a combination of high humidity and temperature. For this reason, lack of shade is a larger problem for dairy cows located in the tropics and subtopics. But nevertheless, it is fair to assume that dairy cows in the

Goulburn Broken will derive benefit from shade in one form or another during periods of extreme hot weather, particularly those with a high percentage of black coat. These benefits could include not only higher milk yields, but also higher milk fat yields and lower mastitis test scores. The cows with shade are also likely to need less water to drink. The relative merits of shading dairy cows is a hotly debated issue in the Catchment.

Cold Stress and Shelter

The provision of shelter to reduce cold stress in the Goulburn Broken Catchment is likely to be more important than for alleviating heat stress. Cold stress occurs when increasing wind speeds cause an increase in the rate of heat loss from the animal's body. To compensate for this heat loss, the animal needs to either eat more feed or use its fat reserves to maintain an equivalent body temperature. The end result is a reduction in livestock productivity as energy is diverted from producing wool, meat or milk, towards activities that involve keeping warm.

Reports from a dairy farm in Auckland, New Zealand, state that the complete removal of an existing windbreak caused an 11% fall in on-farm milk production, despite a district increase of 5%. This research suggests that dairy cows in the Goulburn Broken could potentially benefit from the provision of shelter during extreme wind and rain, especially when combined with cold temperatures. But it is unclear whether this shelter would lead to a significant increase in milk production.

Newborn lambs and shorn sheep will be the most susceptible to cold stress in the Goulburn Broken Catchment. Again, it is the periodic events of extreme wind, rain and cold that are likely to have the largest impact. This is because the combined effects of wind and rain both act to raise the animal's lower critical temperature. For example, newborn lambs can die from heat loss with only moderately cold air temperatures (9 degrees C) when this is combined with a wind speed of 30 km/h. Research undertaken in south-western Victoria has shown that shelter from the wind can reduce lamb mortality by over 10% for single lambs, but these figures can be as high as 30% during prolonged periods of cold, wet and windy weather. Shorn sheep are also susceptible to these inclement weather conditions, and losses in Victoria as high as a 100,000 have been reported for a single extreme event. However, no large losses of shorn sheep have occurred in the Goulburn Broken Catchment and this could be due to the undulating nature of much of the grazing country, which provides some opportunity for seeking natural shelter.

B Enhancing Pasture and Crop Production

Another way shelter can influence microclimate is through the ability of windbreaks to influence atmospheric turbulence, which not only effects evaporation and transpiration processes, but also reduces the likelihood of plant damage through the mechanical effects of wind. Evaporation and transpiration losses from crops and pastures can be significant, especially when they are exposed to hot, drying winds. In a dryland situation, the provision of shelter can reduce soil evaporation rates leaving more water available for pasture growth or grain-filling later in the season. However, these benefits may be negated somewhat if the shelter also increases photosynthetic activity and hence growth rates and biomass production, which can lead to increased transpiration and water use. Under an irrigated situation, shelter will allow greater vegetative growth to occur and this could result in increased pasture and enhanced crop yields, without a major change in water use.

Few studies have investigated the role of windbreaks in enhancing pasture and crop production in Australia. Of the few that have, a sheep grazing study was conducted at Armidale NSW, which showed that windbreaks can increase wool production at high stocking rates by as much as 35% and live weight gain by 21% when compared to unsheltered sheep. Another study at Rutherglen Victoria, showed that wheat yields in the maximum area of shelter could be increased by 20-25% and oat yields by 0-47% depending on the orientation of the windbreak. While these results show considerable promise, further research needs to be undertaken to assess the plant competition effect and opportunity cost of dedicating productive land to a windbreak system.

The productivity of certain high value vegetable and horticultural crops can be increased by the protection from physical plant damage that shelter provides. In the Goulburn Broken Catchment, Kiwi fruit in particular, require shelter from the wind because they are easily damaged by rubbing and abrasion.

THREATS TO THE PROVISION OF SHADE AND SHELTER

A. Loss of Remnant Native Vegetation

Many properties in the Goulburn Broken rely on remnant native vegetation for the provision of shade and shelter services, particularly those that involve grazing. However, much of this remnant vegetation is in the form of linear roadside corridors, individually scattered paddock trees, or small and fragmented blocks. The sustainability of this native vegetation is questionable. For instance, the linear roadside corridors are subject to considerable pest and weed invasion. The isolated paddock trees are succumbing to a number of ailments collectively known as dieback. Small blocks of remnant native vegetation are often in various states of decline.

B. Increasing Salinisation of Catchment

Rising saline water tables in many parts of the Goulburn Broken are threatening the sustainability of low-lying native vegetation remnants, as well as various tree and shrub plantings. Evaporation and transpiration processes increase the salt concentrations in the groundwater until eventually it exceeds the plant's salt tolerance. This leads to plant death and obviously the cessation of any shade and shelter benefits. Salinisation may not be seen as a serious threat to shade and shelter services in the Goulburn Broken at present, but predictions regarding its future spread suggest that it will be of increasing concern in the years to come.

C. Reduction in Tree Planting Incentives

Reductions in government support for farm tree planting schemes are a major threat to the continued provision of shade and shelter services. For instance, the ABARE trees on farms survey conducted in 1994 revealed that 34% of Victorian farmers surveyed had used assistance schemes in the past three years to plant trees. This level of participation combined with the community infrastructure that has been developed over the past decade through a range of government policies and programs, means that any reduction in the level of funding or support could have significant consequences for the provision of shade and shelter services.

D. Poor Windbreak Management and Design

Another threat to shade and shelter services is windbreak management and design. As the remnant native vegetation in the Catchment continues to degrade, it is critical that new windbreak plantings are designed and managed correctly. Mostly importantly, this means ensuring they are correctly positioned in relation to the prevailing winds, but also that the spacing between breaks, height, width, length and permeability is appropriate for the shade and shelter benefit that is desired. For instance, if the objective is to maximise the area of wind protection for pasture and crop production, then the windbreak should be designed to allow almost half the wind to pass through it. Whereas if the objective is to provide cold weather protection for livestock, without the need for optimising pasture growth, then a dense windbreak would be preferred. This latter style of windbreak needs to be carefully managed to ensure that stock browsing does not create low-level gaps in the windbreak, which will allow wind to accelerate through the gap at stock height.

ACTIONS AND OPPORTUNITIES FOR THE PROVISION OF SHADE AND SHELTER

A. Protecting and Enhancing Remnant Vegetation

The continued supply of shade and shelter services from remnant vegetation will depend on the adoption of more sustainable management practices, coupled with rehabilitation practices that increase both remnant size and quality. Initiatives such as the 'Goulburn Broken Native Vegetation Management Strategy' are a good start and will help to protect and enhance remnant native vegetation in the Catchment by prioritising those areas that are in most need of attention.

B. Moving Towards New Markets and Incentives

Shade and shelter services could be valued more highly in the future, as the demand by both international and domestic agricultural markets for proof of greater environmental stewardship increases. These market trends are the catalyst for considerable recent interest in the development of Environmental Management Systems (EMS) and other green accreditation systems. The idea is that these systems provide a mechanism for linking environmental responsibility with market processes.
The multiple environmental benefits that windbreaks deliver may see an increase in the area of land in the Goulburn Broken that is set aside for windbreak establishment if a competitive market advantage can be realised.

WHERE TO FROM HERE?

Evidence regarding the benefit of shade and shelter to livestock enterprises are well documented. Less well known is the role of shade and shelter on dairying enterprises in temperate Australia. Previous research into the potential for increased pasture and crop production has shown promise, but has also highlighted the considerable complexities of climate, soil and plant interactions.

Current knowledge gaps surround the translation of these paddock-scale benefits to the enterprise or industry scale within the Goulburn Broken Catchment. This requires greater investigation of the opportunity cost of dedicating productive land to windbreak systems, as well as determining competition effects and other negative interactions. Research is already being undertaken to address certain aspects of these gaps, but if it is to be of any use to the Goulburn Broken, then it must be conducted within analogous agricultural ecosystems—similar mixes of soil, weather, and farm enterprises.

Another major knowledge gap is the role of shade and shelter services in urban areas. For instance, studies from overseas have shown that carefully designed tree and shrub plantings in urban environments can reduce energy consumption for air-conditioning by 10 to 50%, depending on the level of building insulation. This cooling service is created when water vapour is released from the plant's leaf surfaces through evaporation and transpiration. This water vapour cools the surrounding air and the temperature difference can be considerable.

The monitoring of shade and shelter services is not commonplace, but is important if landholders want to assess the performance of their windbreaks and also quantify the production benefit that they derive. A series of simple qualitative indicators could be developed to monitor the current state of these services, as well as to identify any pressures or threats that may arise. These indicators could include the use of 'tatter flags'—strips of calico attached to a post—which could be set up at various locations around the property to assess the protection afforded by shelter as well as other areas that are in need of shelter services. Other indicators could include a rapid measure of vegetation condition or health and a 'before and after' assessment of the change in agricultural productivity.

THE PREVENTION OF SOIL EROSION AS AN ECOSYSTEM SERVICE

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INTRODUCTION

Soil provides an essential physical and biological component of most terrestrial ecosystems. Soils form from parent materials over time scales of thousands of years. It is widely recognised that soil erosion in human impacted landscapes is effectively mining soil at unsustainable rates. Prevention of soil erosion by ecosystems serves to preserve this vital resource and stop downstream impacts of eroded soil.

Soil erosion is widespread in Australian landscapes. It has many forms including sheet and rill erosion of hillslopes, gullies, tunnels, streambank erosion and wind erosion. Water and wind, as the agents of erosion, are supplied to the Australian landscape in a highly variable, sometimes erratic, manner. An important feature of the erosion processes in the Australian landscape is that erosive episodes are frequently linked with the prolonged dry periods. At these times soils are frequently exposed to the water and wind erosion because of relatively low protection by vegetation and other components of ecosystems.

The resistance of soil to erosive agents is largely determined by the protection to soil provided by vegetation, plant litter and other organisms such as moss and lichens. For erosion by water, protection is provided by a number of factors. First, plants and animals that live in and on the soil improve soil structure, so that surface runoff is less frequent and less intense. Vegetation and other forms of cover reduce the incidence of degradation features at the soil surface including soil crusts and hard setting. Biological activity at the soil surface, such as worm burrows and insect galleries, provide enhanced infiltration thereby reducing surface runoff and associated sheet and rill erosion. Secondly, vegetation also provides resistance to overland flow by slowing and spreading it. In many incidences this results in the energy of flow being below the threshold for erosion to occur. Finally, protection by vegetation provides a shield against raindrop impact that drives splash erosion and enhances the erosive ability of overland flow.

Gullies are a major feature of Australian rural landscapes and their occurrence is largely determined by low levels of cover during periods of overland flow. Cropping and grazing patterns have historically paid little attention to the fragility of drainage depressions. In the southeastern Murray Darling Basin including the Goulburn Broken Catchment, the majority of drainage depressions are incised with gullies. Gullies continue to yield high levels of sediment after they have formed. In many parts of Australia, stabilisation of gullies is problematic because vegetation finds it difficult to establish itself in the gully's micro-environment.

The stability of streambanks, both for permanent and short-lived streams, is strongly influenced by vegetation. The combined forces of scour by streamflow, gravity through mass slumping and the impact of raindrops act upon streambanks. For vegetation to be effective in protecting stream banks the vegetation must be present at the point of failure. For instance, scour frequently occurs at the bottom of the stream bank and mass failure occurs at depth within the stream bank where only deep-rooted vegetation exerts an influence. The re-establishment of riparian vegetation is a major issue facing rural Australia. Grazing and cropping of stream banks is still widespread.

The upland streams of the Goulburn Broken Catchment can be broadly divided into two types of Catchments, each with characteristic erosion features. Those in forested areas with low levels of land clearing have low levels of in-stream turbidity. In these sub Catchments all forms of erosion are generally low, and although local areas of high erosion may occur (eg forest roads), they are well buffered from the streams. Those areas in cleared landscapes normally have moderate to very high levels of turbidity. Gully erosion and local areas of sheet and rill erosion are the predominant forms of erosion in these sub-Catchments.

The Goulburn Broken Catchment is a contained within a climatic zone characterised by moderate rainfall intensities, frontal weather systems and occasional thunderstorms. Also it is an environment where gully erosion is prevalent due to the combination of land disturbance, soil types and temporal cycles of vegetation cover. In such a setting the importance of vegetation in stabilising gully and stream bank environments is relatively important compared with the role of vegetation in minimising sheet and rill erosion.

Farm dam surveys within the southeastern portion of the Murray Darling Basin for small Catchments (<10km^2) have established that sediment yield is of the order of 50 m^3 km^{-2} yr^{-1} for frequently tilled Catchments, 20 m^3 km^{-2} yr^{-1} for areas

with improved pastures and 10 m^3 km^{-2} yr^{-1} for small Catchments with native pastures. The same researchers note that in this region, sediment yield increases approximately eight-fold when gullies are present in the Catchment of the farm dams. These findings would be similar if observations were made within the Goulburn Broken Catchment.

WHY IS THE SERVICE IMPORTANT?

The benefits and costs of this ecosystem service can be broadly divided into the categories of on-site and off-site.

On-site services The rate of soil formation is so small that soil is effectively a finite resource. Maintaining soil in its place of formation provides benefits to the ecosystem based upon those soils, including growth of natural and human-managed plants. Eroded soil carries with it valuable soil nutrients, which clearly have productive benefits by remaining in the uneroded soil. Furthermore, eroded soil may also carry potential pollutants, including many pesticides, which would otherwise breakdown if left attached to uneroded soil. There have been many attempts to quantify the impact of soil erosion of land productivity. These studies are confined to consideration of sheet and rill erosion by water and wind erosion of hillslopes. All of these studies show that as the depth of soil eroded increases so do the impacts on plant production. Small amounts of erosion generally have modest impacts on productivity but large cumulative soil erosion depths result in overwhelming reductions in plant productivity. It appears that plants have thresholds within the soil physical and chemical environments whereby plant-available water, nutrients and the physical environment of roots become limiting as the depth of remaining soil decreases.

Other important onsite costs are the loss of land associated with streambank migration, the loss of riparian zone habitat and the costs associated with gullies dividing land areas into smaller accessible units.

Off-site services Eroded soil is transported and deposited downstream. The distance that eroded sediment is carried varies from a few centimetres to many kilometres. Deposition may occur on footslopes, riparian zones, streambeds, wetlands, estuaries and the sea bed, and behind human-made structures including soil conservation banks, filter strips, farm dams and reservoirs. The costs associated with transported sediment include the removal of sediment and associated pollutants from drinking water, and reductions to productivity of domestic animals that drink sediment-laden water. The benefits are few but do included reduced penetration of light into water bodies that may moderate growth of water organisms including algae. Costs associated with sediment deposition include the desilting of structures such as roads, dams and wetlands, and the release of sediment-attached pollutants to water systems. Benefits to deposition are few but locally there may be benefit if nutrient-rich sediment is deposited on a productive area such as a floodplain. In the Goulburn Broken Catchment off-site impacts are particularly important because of the intensity of downstream water use, including irrigation and industry.

THREATS TO THE PREVENTION OF SOIL EROSION

A. land-use practices

Soil erosion is a cumulative form of degradation. Soil conservation has been a prominent issue in rural Australia for the last twenty years. However, erosion continues on much of the land surface at unsustainable rates. There is little or no evidence that the current range of land-use practices will result in erosion rates decreasing to rates comparable with soil formation rates. In short, the status quo is resulting in a gradual run down of the soil resource. Restoration practices that have been applied to small parts of the landscape do result in dramatically decreased rates of soil erosion but the cumulative historical loss of soil remains. These general conclusions hold across the various forms of soil erosion.

There are trends in land-use that may result in changes to the current soil erosion rates. In the southeastern Murray Darling Basin including the dryland portions of the

Goulburn Broken Catchment, there is a clear trend toward the intensification of grazing industries with the use of improved pastures and fertiliser becoming more widespread. Such enterprises offer the prospect of increased pasture growth which, if well managed, can reduce the rates of soil erosion. Increasing stocking rates have some ramifications for the degradation of unfenced riparian zones and heavy traffic areas such as gateways and watering points.

B. Salinity

Soil erosion may increase as a result of dryland salinity, though little is known about this issue. Salt scalds are subject to very high soil erosion rates and their impact is increased by the proximity of scalds to drainage lines. On footslopes and in landscape hollows there is a clear potential for existing vegetation to be lost through salinisation leading to more erosion. With the massive projected increases in areas of dryland salinity this area warrants further investigation.

C. Diminished vegetation

Gully and stream bank erosion may diminish the value of remnant and restored riparian vegetation. There are many examples of small areas of riparian vegetation which have been removed or degraded as a result of channel instability in the area immediately upstream and downstream of the vegetation.

OPPORTUNITIES AND ACTIONS FOR THE PREVENTION OF SOIL EROSION

A. Revegetation

Protection of soils by vegetation and other forms of cover is recognised as the major management tool for wind erosion management. Such cover shields the soil from erosion stresses of wind and absorbs the impact of soil particles that have been mobilised upwind.

There are clear opportunities for erosion rates to be substantially reduced by community and commercially-based revegetation. Community-based revegetation around gully and streambank environments is a clear priority. There is a clear need to identify and address the impediments to the fencing of these key parts of the landscape.

With the trend towards farm forestry and plantation forestry in the southeastern Murray Darling Basin, there are opportunities for providing more permanent vegetation cover to soils and some possibilities for restoring soil structure. Innovative practices and product diversification offer the ability of mimicking natural ecosystem behaviour while maintaining farm incomes. An example of such innovative practices is alley farming where conventional cropping or grazing is carried out in alleys at 20 to 100 metre spacing formed by belts of trees. In cropping environments the degree of protection provided by such cover varies rapidly through phases of the cropping cycle. In grazing lands the cover varies more slowly as pastures respond to the combined processes of growth and grazing. In streambank environments deep-rooted vegetation declines or is reestablished over time scales of years to decades.

B. Diversification of land-use

There is an increasing trend for the diversification of land-use in southern Australia and in the Goulburn Broken in particular. The growth of intensive land-uses, such as vineyards, may enable enterprises to invest in local restoration works including fencing of streams and the provision of off-stream watering for domestic stock.

LINKAGES TO OTHER ECOSYSTEM SERVICES

There are some firm linkages of soil erosion control to other ecosystem services. The first is to soil structure and the strong influence structure has on moderating soil erosion by water. The second is to water filtration. The downstream impact of eroded soil can be strongly moderated by filtration downstream. Many of Australia's natural ecosystems are characterised by erosion-deposition sequences where patterns of vegetation result in the redistribution of water, sediment and nutrient in a banded or patchy spatial arrangement. There are clear benefits to mimicking such patterns in agricultural landscapes. Systems such as alley farming have the potential to do this.

A further link to other ecosystem services is the provision of a stable channel network that conveys flow and provides other river users with an environment that provide their needs. Streams, rivers and estuaries that are unstable, and have large dynamic deposits of sediment may inhibit navigation and recreational use of such zones. Furthermore unstable streams result in the erosion of remnant or restored habitat in the near-stream zone.

WHERE TO FROM HERE?

What more do we need to know?

There is a clear technical need in supporting revegetation strategies. Guidance is required as to where revegetation should be targeted for best effect and so that successful progressive revegetation can be achieved. This advice must be informed by knowledge of all degrading processes including erosion and dryland salinity.

As mentioned above, our knowledge base is very poor on the interrelationship between soil erosion and dryland salinity. There is a clear need for field based monitoring and experimentation concerning this issue.

In extensive grazing systems there remains the difficult issue of the provision of off-stream watering so that grazing and trampling of stream environments is minimised. An examination of the economics and other constraints of such measures in these enterprises is required.

How do we address the knowledge gaps?

Following the National Land and Water Resources Audit of 2000 there is a need to convert the knowledge of spatial distribution of the various forms of erosion into a priority map for management action. This will require input of regional knowledge concerning industries and their ability to take up such measures.

A study concerning other specific issues should be initiated by the rural industries' research funding agencies.

How/what do we monitor to ensure successful adaptive management?

The planned periodic audit of key measures of erosion in its various forms should be an appropriate measure. There need to be measures that specifically examine riparian zones of both perennial and ephemeral streams, as well as gully networks and erosion associated with dryland salinity.

MAINTENANCE OF SOIL FERTILITY AS AN ECOSYSTEM SERVICE

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INTRODUCTION

Soil interacts with plants and the environment to effect the transformation, flow and accumulation of energy and matter. As such, a primary ecosystem function, or service, is the supply of nutrients to plants through the major biogeochemical processes and elemental cycles (Carbon, Nitrogen, Phosphorous and Sulphur). Thus, soil provides, through the physiological activity of the soil biota, the foundation for all terrestrial ecosystems involving plants. Other functions of soil are discussed in other sections of this report.

Healthy soil is essential for the major industries within the Goulburn Broken Catchment including horticulture, dairy and livestock. However, soil fertility is decreasing due to a number of factors including acidification, leaching, overuse of fertilisers, salinity, loss of biodiversity, overstocking and grazing pressure and generally unsustainable farming practices. A movement towards more sustainable land practices is essential for the health of the soil, and in turn the key economic drivers within the Goulburn Broken Catchment and will only be achieved through working closely with the farming community and with key agencies such as the Department of Natural Resources and Environment and Agriculture Victoria.

IMPORTANCE OF MAINTENANCE OF SOIL FERTILITY AS AN ECOSYSTEM SERVICE

Soil fertility underpins the primary economic drivers of the Goulburn Broken Catchment and influences the output of these major industries. Gross farm gate Value of Production (GVP) of the Goulburn Broken Catchment is approximately $1 billion. For the purposes of this overview the following aggregations have been made;

- **Horticulture** including stonefruit and pomefruit, citrus, fresh and processing tomatoes and vegetables (approx. 20% of GVP)
- **Livestock and dairy** including cattle (beef and dairy), sheep (meat and wool), pigs and poultry (approx. 58% of GVP);
- **Broadacre crops** including, cereals, pasture seeds and fodder crops (approx. 11%)
- **Timber and minor industries** 11% GVP

This review concentrates on Horticulture and Livestock/Dairy.

Horticulture

The above valuing of horticulture above does not include winegrapes, plantings of which have increased to nearly 2,000 ha., and currently represent about 10% of horticulture GVP, without value-adding. Most horticultural production systems in the Goulburn Broken Catchment are relatively high-tech operations, with heavy dependence on artificial inputs, and associated infrastructure. The awareness levels among growers in the Catchment regarding soil fertility as an ecosystem services is low, and there exists no evidence of deliberate management of the soil biota to enhance soil fertility, apart from slashing and mulching with orchard grass sward.

There is very little organic horticultural production within the Catchment. Producers of high-value crops such as fresh tomatoes, stone and pomefruit, particularly those for export markets, have to meet exacting industry standards for fruit quality in order to remain competitive. They rely heavily on artificial fertiliser inputs, timings and quantities which are sometimes, but not always, determined by annual foliar nutrient analysis.

Livestock and Dairy

Dairying occupies almost half a million hectares of irrigated land in northern Victoria and produces about a quarter of Australian milk. Before and since de-regulation of the industry, there has been a trend towards intensification, with larger and fewer farms and herds, increased production per hectare and per cow. Other trends include a marked increase in irrigation water use and nitrogen fertiliser application to pasture soils over the last 10 years. The industry claims that opportunities exist for increased production without compromising soil fertility and water quality. It remains to be seen whether potential detrimental effects to soil and water resources of increases in stocking rate can be offset by adopting more efficient use of irrigation water, nutrient management of pastures, and a search for alternative pasture and fodder species.

CURRENT STATE OF SOIL FERTILITY; THREATS AND STRESSES

A. Acidification, Leaching and Overuse of Fertilisers

Agriculturally induced soil acidification is caused by leaching of nitrate nitrogen, released by the nitrification of ammonium fertilisers and from the mineralisation of organic matter. Nitrate nitrogen is the main form of nitrogen that plants absorb through their roots. It is highly watersoluble, and if it is leached to below the root zone before uptake by plant roots, it then contributes to soil acidification. The main effect of acidification is decreased plant growth; aluminium and manganese become available to plants at increased levels, which become toxic, whilst the availability of other nutrients (calcium, magnesium, molybdenum and phosphorous) decreases. Soil acidification can be neutralised by liming, and minimised by efficient water use and application of fertiliser with low acidifying effect.

Acidification is a huge issue for the horticulture industry in the Goulburn Broken Catchment. Most plantings are on duplex clay loams with less than 1.5% organic matter. The subsoil of red clay in and around Shepparton has a natural pH of about 8.2. In a survey of orchards by the Institute of Sustainable Irrigated Agriculture (ISSIA), Tatura, 45% of orchards had soil pH below 5 (CaCl). pH has dropped by an estimated 3 units in 50 years. This drop occurs at a depth of about 40-50 cm. Liming alone on clay loams does not improve the pH, and new orchards are now deep-ripped and applied with lime and gypsum before planting.

Excessive use of ammoniacal fertilisers in intensive vegetable production has, in some instances, caused severe topsoil and subsoil acidification and the leaching of potassium. Over application of fertiliser is widespread on farms within the Catchment. The often-held assumption that high-yielding fruit crops result in removal of large quantities of soil nutrients is an oversimplification (at least 80% of the crop tonnage is water) and leads to the erroneous assumption that fertiliser applications are a limiting factor in production. The problem is often too much fertilizer, not too little. An average yield of about 60 tonnes of peaches per hectare removes about 35-50 kg of nitrogen, yet would receive an application of about 200 kg/ha of nitrogen fertiliser. Much of this excess is leached to groundwater depths, contributing to acidification and nitrate pollution.

B. Salinity

Water tables in the Goulburn Broken Catchment are shallow and saline. The August 1999 Watertable Map of the Shepparton Irrigation Region (published by the Goulburn Broken Catchment Management Authority) indicates depths of:

- >3m on 48% of the land
- 2-3 m on 25% of the land
- 1-2 m on 25% of the land
- 0-1m on 2% of the land

In the last 10 years, the August average for the 0-1 m category has varied from 2-25% of total land area. Water tables appear to be shallowest in areas of irrigated dairy production around Kyabram. Short-term increases in water table depth have been due to drought and groundwater pumping, and the region is generally highly reactive to seasonal rainfall. The long term trend, however, is towards shallower and saltier water tables.

C. Loss of Biodiversity and Fertility through Unsustainable Farming Practices

The Goulburn Broken Catchment contains one, if not the only, example in Australia of shifting cultivation. Some growers in the fresh tomato industry practise this method. The fresh tomato industry produces a high-value crop, intensively cultivated, and where market emphasis on external appearance is crucial. Consequently, inputs of pesticides are very high, and yield decline commences in 2-3 years. Growers will then shift to a new site, often to land that has been bought from dairy farmers. Currently, fresh tomato production occupies only ca. 1,000 ha, but is expanding rapidly.

Pesticide residues are an issue in the horticultural and livestock industries. Because of regulations relating to pesticide residues in meat, livestock are rarely grazed in orchards, or fed using forage from orchard alley cropping. Administration of slow-release antiparasitic drugs for cattle and sheep, such as the bolus formulations of the milbemycins, represents a threat to increased pasture fouling and decreased productivity by disrupting the activities of the dung-degrading fauna and flora.

D. Overgrazing/overstocking

Consequences of overstocking, especially due to grazing in wet conditions, includes degradation of soil physical properties, fouling of pastures and riparian zones with mud and manure and lower pasture production. The trend towards higher stocking rates also puts pressure on remnant vegetation and there has been an emergence of new pasture weeds such as Carpet Grass and Mullumbilly Couch.

ACTIONS AND OPPORTUNITIES FOR SOIL FERTILITY SERVICES

A. Adoption of Sustainable Production Systems

A major constraint on adoption of sustainable production systems in horticulture is that the system is quality-driven, where quality equates with cosmetic characteristics and external appearance, rather than with innate quality.

Thus, growers are reluctant to change practices that they perceive may have an impact on appearance and value of their produce. A flavour-lacking Packham pear of perfect dimensions is worth more than a flavourful but distorted one. It is significant that the processing tomato industry in the Goulburn Broken Catchment, where fruit appearance is not a major issue, is one of the most forward-thinking on sustainability issues. Constraints on sustainable production in dairy include a drive towards greater intensification and herd size and market imperatives such as squeezed margins for dairy farmers.

Ironically, the emphasis on cosmetic quality as a constraint on the adoption of sustainable production may be at odds with community attitudes and certain market access requirements. The constraints intensify with the drive of growers to improve performance in export markets. This is a global phenomenon in the horticulture industry, and has simply not been adequately addressed in national policy on sustainable agricultural production.

B. Education of Farmers and Growers

Working more with farmers and growers to increase understanding about the effects of their industries on the Catchment as a whole (e.g. eutrophication from nutrient runoff from pastures), and upon ecosystem services both directly relevant to their systems and to those in other industries represents a good opportunity to increase sustainable land practices.

C. Role of Department of Natural Resources and Environment and Agriculture Victoria

Agriculture Victoria, through its research stations in the Goulburn Broken at Tatura, Kyabram Cobram and Rutherglen, provides a key role in research on sustainable production systems, particularly in soil, water and nutrient management. Their success in working with growers and in achieving adoption is considerable. Most of the work is still focussed on making agricultural production systems more 'efficient', especially in terms of nutrient and water use. The exploration of potential benefits of ecosystem goods and services has yet to be explored in any detail. However, the chances of successful adoption of such a program would be high, bearing in mind the considerable influence they have had on agricultural production in the Catchment.

LINKS TO OTHER ECOSYSTEM SERVICES

Clearly, there are interrelationships between all biogeochemical processes within an ecosystem. It follows therefore that perturbation of those processes that contribute to soil fertility will have knock-on effects for other ecosystem services, most notably, habitat, water quality, waste absorption and breakdown, and pest control under circumstances involving natural enemies resident in soils.

WHERE TO FROM HERE?

What is the relative contribution of artificial fertilizer inputs versus soil biotic activity to crop biomass in different production systems? The answer to this question requires measures of plant biomass production due to fertiliser inputs in the absence of any biotic activity. Such a study would provide an estimate of the value of the ecosystem service of soil fertility provided by the soil biota.

MAINTENANCE OF SOIL HEALTH AND FUNCTION AS ECOSYSTEM SERVICES

John Williams
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INTRODUCTION

All terrestrial life ultimately depends on soil and water. Soil health can be defined as 'the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health'.

Soil is a seething foundry in which matter and energy are in constant flux as it provides the support services for ecosystem primary production. A rich mix of mineral particles, biota, organic matter, gases, water and nutrients, soil constitutes a self-regulating biological factory essential for initiation and maintenance of life. Soil determines the partitioning of rainfall, snowmelt or irrigation into overland flow, infiltration, storage, deep drainage, and in turn groundwater recharge. The way soil accepts, stores, and transmits water and associated solute strongly influences the nature of rivers, springs, lakes and wetlands. Ecological function has a strong dependency on soil biotic activity and processes which decompose, transform, transport and store nutrients and carbon in the soil profile for use by plants and other primary producers. The development of sustainable ecosystems depends on the ability to manage the soil biota to optimise its beneficial role in maintaining the "health" of the ecosystem and productivity of the land-use.

There is now increasing awareness that ecologically sustainable land and water management requires a shift to addressing agricultural production in the agro-ecosystem in which it is cast.

WHY IS THE SERVICE IMPORTANT?

The ecosystem services provided by soil heath are very important to the productive industries of the Goulburn Broken Catchment. The most important industries that benefit from the services of soil health are:

- The pasture-based industries of dairy, cattle, sheep and horse operations.
- The fruit and grape industries.
- The hay and seed production industry and the softwood forestry industries are of a similar order of importance followed by.
- Crops including cereals, legumes and summer, vegetable production as well as the supply of water.

These relative values in terms of GVP are set out in Table 18.

TABLE 18

The approximate value of productive industries that are strongly dependent on ecosystem services provided by soil health.

land-use GVP	*$,000*
Softwood Forests	78,000
Crops	53,100
Fruit & Grape	173,553
Dairy	453,348
Hay & Seed	72,691
Grazing	236,315
Vegetables	28,184
Water Supply	80,000

Animal Industries. Services of soil heath that underpin the productive function of pastures and fodder crops under both dryland and irrigation are clearly of paramount importance to the region. This is true for both the animal based industries and the pasture and fodder crops that produce hay and pasture seed.

Fruit and grape industries. Key processes supported by soil health and function are nutrient retention and availability; supply of effective gas exchange; and water entry, storage and transmission through stable soil structure as reflected in effective soil hydraulic properties.

Hay and fodder crop production. Hay and fodder crop production are very dependent on services provided by healthy soil.

Softwood forestry. Ecosystem services provided by soil health to softwood production will be important in supply, retention and cycling of nutrient. Maintenance of soil functions which facilitate litter turn-over and high infiltration rates will also be important.

Cereal, legume & summer crops. Annual crops draw heavily on the services provided by soil health. The nutrient storage, cycling, transformation and movement to the root are all functions provided by healthy soil.

Intensive vegetable production. This industry with very short rotations can minimize dependency on the ecosystems services provided by healthy soil. High nutrient input, intensive irrigation and frequent high energy cultivation all put the soil functions at risk and damage soil structure. The high input systems over the short term can compensate for soil services but over the long term, to move towards sustainability, these intensive industries will need to foster soil health. The need to manage soil health so as to minimise erosion and thus sediment transport to streams is most important in these vegetable production industries. Use of filter strips and buffer zones adjacent to riparian zones to trap and arrest sediment entering streams is an important issue for this industry.

Water supply. The soil health is expressed at the landscape scale in the rates and magnitude of the storage, transport, transformation of water, chemicals and sediments which impact on the form and nature of streams, lakes, reservoirs and wetlands. The quality of water is determined to a very large extent by the nature of the interactions with soil chemistry and biota as it enters, moves through and over the soil towards waterways, lakes and reservoirs. Soil health reflected in soil structure that is stable with high rates of infiltration facilitates the filtration services that are so important to water quality. The soil health is important in partitioning the water between infiltration and overland flow, thus the water quantity as well as water quality is impacted by the quality of the soil health ecosystem service. Managing to retain soil in good health will be critical to water yield and quality in the Goulburn Broken.

THREATS TO THE ECOSYSTEM SERVICE

A. Rural Production

Playing a key role in Australia's economic development, rural production has also had a profoundly detrimental impact on the quality of the land and water resources. This impact is most often delivered via damage to soil properties and soil biophysical function. Australian rural production systems have been built by drastically changing the nature and seasonal patterns in the hydrological and nutrient cycles of the native ecosystems.

Consequently, the exotic agricultural production systems of Australia's rural industries all face a common core of resource and environmental problems. These settle about the management of soil processes that determine the match between the sinks and the sources of water, carbon and nutrients in the ecosystem. Most of our current plant production systems leak water, carbon and nutrients, and are therefore not ecologically sustainable in the long term. The match between the seasonal pattern of supply and demand for nutrient and water in our agro-ecosystem is poor with the consequence that the systems leak into the broader landscape. This mis-match results in water-logging and movement of salt through the landscape, resulting in salinity as well as leaching of nutrients to generate soil acidification and leakage of nutrients and carbon to water bodies.

B. Loss of soil organic matter

Maintenance of soil organic matter levels is vital to soil health. Organic matter improves aggregation and structure, nutrient cycling and retention, water retention and is a major carbon sink. There is strong evidence that our more intensive agricultural practices have reduced the carbon store, particularly the humic forms, in soils in south eastern Australia. As organic matter decreases, soil structure tends to breakdown, water infiltration declines and run-off and erosion increase. There are a range of conservation farming practices that can alleviate and even improve soil carbon and soil health, but adoption has been sporadic.

C. Compaction of soils

Compaction of soils by stock, farm machinery and intensive cultivation practices, particularly under poor drainage associated with water-logging and irrigation, have a very significant negative impact on soil health. This is to the detriment of both productivity and ecosystem function. Damage to soil health through compaction is an important issue in the Goulburn Broken Catchment.

D. Contamination of soils

An emerging issue that will grow in importance is contamination of soil with heavy metal associated with fertilizers and the residual compounds from agro-chemicals. While there is increasing concern with the movement of agro-chemicals and heavy metal contaminants, either in solution or adhering to sediment particles, into watercourses and groundwater, the retention of these in soil and their subsequent bio-availability and impact on soil biota and the health of soil will become increasingly important. These contaminants will have both environmental quality and consumptive use impacts on water supplies and the products produced from them.

These can be from point sources that are relatively easy to manage and control (e.g. sewage effluent points, intensive livestock production and cattle and sheep dip sites). Or they can be from diffuse sources that are far more difficult to control in terms of potential offsite impacts (e.g. effects of broadacre fertiliser, pesticide and herbicide applications). The ultimate impact of practices on the environment and human health is that there may be significant amounts of organic, inorganic and heavy metal pollutants moving across landscapes and into the air and water.

Environmental contaminants are and will be of increasing concern to the management of our agricultural enterprises for many years to come given the increasing public awareness and demand for safe and healthy food. The impact of these contaminants is usually mitigated though soil properties and processes with major impacts on soil health. In the Goulburn Broken Catchment there is a long history of intensive fertiliser and agro-chemical use and the contaminant of soil and the impacts of this on soil health will need to be fully explored. It would appear that this could be a significant threat to the ecosystem services provided to industry and natural heritage by soil health and function in this region.

E. Soil Acidification

Following on from the hydrological imbalances established in the pasture and fodder crop industries in the region and the extensive production of hay, there will be significant leaching of nitrate beneath the root zone of most shallow annual pastures coupled with loss of bases with the harvest of hay. This results in soil acidification of surface soils with serious negative impacts on soil health. The use of nitrogen fertilizers in fodder and other cropping industries will further drive the acidification process given the major hydrological imbalance following initial land clearing.

OPPORTUNITIES AND ACTIONS FOR THE ECOSYSTEM SERVICE

A. Increase Knowledge About Soil

To better understand how to describe the services arising from soil health will be most important for progress in valuing and managing this ecosystem service. This task will be assisted by getting soil science knowledge in forms that can inform and aid those involved with policy development and implementation including tactical land managers such as Landcare facilitators and private rural consultants.

It is vital that policy tools and instruments are underpinned by sound scientific data and knowledge and that they support holistic, ecosystem-based approaches to land and water management. The availability of data on the condition of the natural resource base is critical for us to understand the state of our natural resources, the extent and rate of degradation, the impacts of human activity on rural landscapes, and to design new farming systems. This data needs to be assembled at various levels—the farm, local, Catchment and region—together with appropriate linkages to facilitate access. It provides a basis for future decisions on policy directions, funding priorities, on-ground management practices, and for performance benchmarking.

B. Better Soil Management

We need to develop systems that make full use of available water, carbon and nutrients, so that they may be both more productive and more ecologically sustainable.

The better management of soil and maintenance of healthy function will ensure that this fundamental ecosystem service continues to benefit food and fibre production as well as the broader ecosystems and landscape.

It is therefore imperative that the Goulburn Broken Catchment community moves its attention to increasing knowledge and understanding of these life-sustaining processes in the soil and value the services provided.

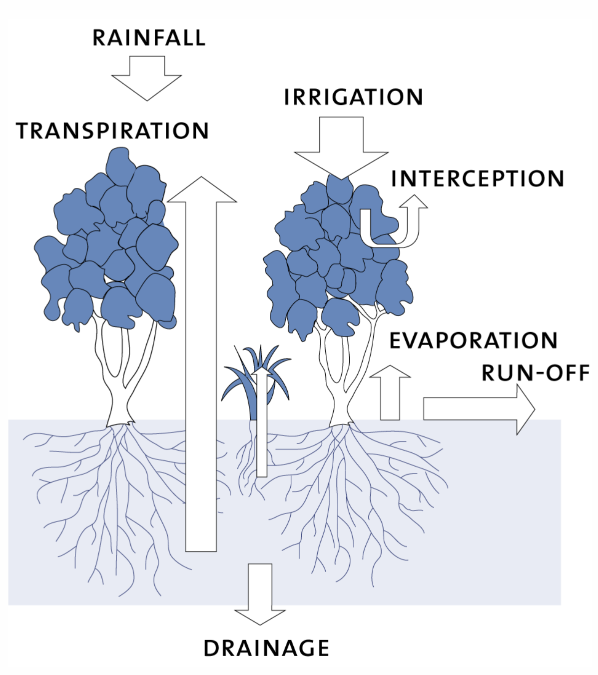
To achieve this the Goulburn Broken Catchment communities will need to challenge soil scientists to direct thinking and effort to the processes in the soil which are critical to ecosystem function and begin to value the ecosystem services provided by a healthy soil as reflected in soil structure and fertility.

LINKAGES TO OTHER ECOSYSTEM SERVICES

Soil health can be seen to be central to water, carbon and nutrient management, and therefore tightly linked to many other ecosystem services. The entry, storage, transformation and transport, of water and chemicals, particularly carbon and nutrients, in the root-zone of vegetation are soil processes critical to the functioning of ecosystems and the landscape as a whole. This is set out below.

DIAGRAM 9

The terms of the hydrological cycle.



The way in which native vegetation captures, recycles and manages scarce nutrient and water is in strong contrast to the generally leaky nature of most agro-ecosystems. The matching of sources and sinks of water and nutrient in both space and time in Australian ecosystems both native and managed requires critical analysis. The biological soil processes which drive decomposition, transformation and influence how nutrients, carbon and contaminants are stored in soils is critical to soil health and function. These are all important ecosystem services provided by soil health and function. To be comprehensive, soil health ecosystem services will need to consider the soil properties and processes that deal with organic and inorganic inputs of fertilisers, pesticides, associated contaminants and residuals. Quantifying these interactions and the factors affecting the mobility of nutrients and pollutants, with a view to identifying the absorption, storage, transformation, and transport mechanisms for movement of these materials over and through the soil profile to water bodies would be essential. These ecosystem services, while important parts of soil health ecosystem services, are also addressed as services that provide waste absorption and breakdown and will be discussed elsewhere.

WHERE TO FROM HERE

We lack reliable, extensive and consistent data on the soil, vegetation and water resources in the Goulburn Broken Catchment despite investment over long time. We need to improve our knowledge of different land types, their distribution and biophysical resources—climate, geology, topography, soils, fauna and flora. We have little understanding on how to build reliable indicators of soil health that are practical and that could be used to describe and value soil health services. We also need to increase our understanding of inter-relationships between these land characteristics and their properties, which together determine the functioning of the nutrient and hydrological cycles that underpin the system.

MAINTAINING HEALTHY WATERWAYS

Gary Jones
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INTRODUCTION

In recent years, the terms 'waterway or river health' and 'water quality' have almost become synonymous. The terms have been used in an increasingly broad way to cover many of the beneficial environmental and aesthetic 'values', 'attributes' or 'qualities' of water. These values or attributes may be *chemical* in nature—traditionally good water quality meant an absence of artificial chemicals and pollutants, and a 'natural' (typically low) level of chemicals and compounds found in nature (e.g. nutrients such as phosphate, nitrate, ammonia, trace metals, etc.). This chemical definition still applies but there are other important attributes to water quality. For example, good water quality is taken to describe a healthy water body with a near-natural balance of fish, invertebrates, plants and algae, with the appropriate in-stream, riparian and flood plain habitats for these organisms to live in.

A modern description of good water quality is also invariably linked to the purpose for which the water is used, or the societal and aesthetic values which we attach to it. For example, good quality water used for irrigation might imply low salt content and low contaminant levels; water for environmental (river health) protection may also need to have low levels of nutrients and a temperature suitable for the survival of native fish, whereas with water for human drinking purposes temperature may not be so important but low turbidity and very low levels of water-borne pathogens may be critical. In other words, there is no single definition of "good" water quality—it depends on the purpose the water is being used for, or more generally, our expectations of what benefits it should provide to us and the environment. These societal expectations may change from one river catchment to another, moving from upstream to downstream along a river system, or even in the same reach of a river or in one lake, depending on the interests and expectations of the local community.

This multi-faceted view of river health and water quality is essentially that which philosophically underpins the National Water Quality Management Strategy and associated National Water Quality Guidelines.

So what condition of a waterway can be described as 'healthy', indeed, what exactly do we mean by a waterway? The term waterway is best used in very broad sense to refer to any part of the landscape where water flows over or under the land, or pools on it to form a lake or wetland. A waterway can be permanent or temporary, and freshwater brackish, or estuarine. A healthy waterway is one that has: a balanced population of aquatic biota—fish, aquatic mammals, insects, plankton, bacteria and plants; natural levels of sediment, nutrients and trace metals; an absence or only very low levels of anthropogenic pollutants; good habitat condition; and a hydrological regime that has not been sufficiently changed by human activity to have a detrimental effect on the aquatic biota.

WHY ARE HEALTHY WATERWAYS IMPORTANT?

Healthy waterways with good water quality have multiple benefits for Australian industry and the broad community. These ecosystem services can be described under the following headings:

Agriculture. The transport of water from upper catchments to irrigated cropping and live stock production enterprises downstream, and its temporary storage, is a major ecosystem service provided by rivers, lakes and wetlands. Without these natural waterways, artificial canals and pipelines must be built to transfer water from one point on the landscape to another. However, the use of rivers as artificial conduits comes with an environmental cost. To improve the engineering efficiency of rainfall runoff capture and storage by waterways, thousands of dams and weirs have been built on waterways throughout Australia. Downstream flow patterns are often dramatically altered in many rivers and can have dire consequences for in-stream biota. Whilst these engineering changes are of great benefit to the agricultural and urban industry, and their communities, it is also a threat to other ecosystem services provided by waterways (see below).

Drinking water. As well as transporting and storing water for potable use, natural, healthy waterways provide an important service in improving the quality of drinking water. In turn, this reduces the cost of treating the water prior to human consumption. For example, human bacterial and protozoan pathogens (natural and human) from catchments may be removed during their passage downstream in rivers, or can be consumed by natural predators that live in water. Natural organic matter found in catchment rainfall run-off is also degraded and metabolised by river biota. This is an important function, or service, provided by waterways—natural organics

when chlorinated in drinking water treatment plants produce carcinogenic by-products. The lower the levels of organic matter in raw water the better the quality of the subsequent treated drinking water.

Recreation fishing and aquaculture. Fishing is Australia's most popular past time, and it is the basis for an industry worth tens of millions of dollars annually to the Australian economy. Healthy waterways support populations of native fish species that are highly sought after by anglers in different parts of the country—Murray Cod, Golden Perch, Australian Bass, Barramundi, etc. Supporting sustainable stocks of native and sometimes introduced species (e.g. brown trout) is a highly desirable service provided by Australian waterways.

Aquaculture is a rapidly growing industry in Australia and throughout the world, with many high value fish, crustaceans and shellfish being amenable to high turnover production by aquaculture enterprises. Healthy waterways provide the brood stock and genetic diversity of animals required to support a robust aquaculture industry. They also usually transport and provide the water required by the industry to sustain production in arid regions where such high level production would otherwise be impossible.

Other recreational uses and aesthetics. The use of waterways for recreation and for tourism is also an important service. These activities include swimming, water skiing, canoeing, sailing, power boating, and house boating.

The general aesthetic value of a healthy waterway—its floodplain and riparian trees, shady water holes, and great expanses of open water, touch the Australian psyche and form a central place in the lives of most Australians, especially those in inland Australia.

THREATS TO HEALTHY WATERWAYS

The issues of river health degradation and rehabilitation sit squarely on the natural resources management agenda of all Australian states. Under Council of Australian Governments (COAG), the need for water resources reform has been highlighted as a primary requirement for ecologically sustainable development as we move into the 21st century. At the national, state and regional levels, management plans are in place or being development to arrest the degradation of our waterways. Some of the major threats that have been identified include:

- Over allocation of water for consumptive uses resulting in rivers with impoverished flow regimes.
- Inappropriate methods and practices of river regulation management.
- Unsustainable development and inappropriate management of catchment, riparian and floodplain lands.
- Introduction and expansion of exotic pest species (e.g. carp).
- Loss of key native fish and animal species, partly due to construction of barriers to fish movement (weirs and dams).
- Loss of in-stream vegetation—which plays both an important role in nutrient filtering and providing habitat in a healthy waterway.
- Major depression in water temperature down stream of large dams causing impacts on native fish and animals.
- Potentially damaging discharges of agricultural and urban pollutants and toxins.

OPPORTUNITIES AND ACTIONS

There are many remedial and rehabilitation actions that must be carried out to restore Australia's waterways to a point that even approaches what they once were. Clearly they will never be pristine again—we cannot totally turn back the clock on two centuries of European development and degradation. The challenge is to make our agricultural and urban industries and developments ecologically sustainable. In the case of healthy waterways this means the provision of environmental flow allocations and regimes for rivers, the provision of fish passages in dams and weirs, the revegetation and conservation of catchment, riparian and floodplain lands, the reuse and/or improved treatment of domestic and industrial wastes, and a smarter and more environmentally sensitive use of agricultural chemicals.

The opportunities to do these things are now upon us. Major national policy agreements such as the COAG water reform policy, the National Heritage Trust, and the very recent PM's Action Plan on Salinity and Water Quality provide both the political will and financial backing to commence or continue the process of improved environmental management. At the local and regional level, collaborative community catchment management committees, and action groups such as Landcare and Waterwatch, have important roles to play in managing our waterways and catchment lands.

Under the COAG water reforms, all states are now implementing strategic planning and action programs to provide environmental flow allocations and regimes for rivers. The National Water Quality Guidelines have very recently been revised and updated to provide a robust and scientifically sound basis for protecting water quality. Finally, the concept of environmental stewardship of our land and water resources is beginning to be developed and this holds out a great opportunity for all members of the community to take a long term view of waterway and water quality protection.

WHERE TO FROM HERE?

There are knowledge gaps that need to be filled but new knowledge is only a part of the solution. Having the political will and social empowerment to undertake the changes in land and water management that are required is a big part of what we now need to do to improve the health of waterways.

Environmental flows, as a broad ecological study area, is where much research is needed and is being directed. How much water do rivers need, at what times of year, and how should it be released from storages for the greatest benefit or least damage? How do key native fish species respond to flow? How important is organic matter input from flood plains to the healthy functioning of a large, low land river? These are just some of the scientific questions that must be addressed.

In many of these areas there is already good quantitative or semi-quantitative knowledge, but this knowledge needs to be refined and quantified so that volumetric environmental water allocations and environmental flow rules can be enshrined in river management and operational plans.

Finally, we are still uncertain as to what are the best indicators of a healthy water way. How will we know if rivers are improving in response to our management actions? Some indicators have been developed and are being used throughout the country. These include the national AUSRIVAS program, which uses benthic macroinvertebrates (aquatic insects) as indicators of river condition. In Victoria, the "Index of Stream Condition" is being developed and refined to be used as a state-wide assessment method.

The problem with many of the biological and chemical indicators we now monitor is that they are either very slow to respond to environmental change (e.g. fish populations which may take 10, 20, 30 years or more to improve their condition, or otherwise the link to waterway health is not as explicit as was once thought). Good examples of this are nutrients and turbidity. We now realise that many waterways can naturally have elevated levels of both, but this does not make them unhealthy. Further work is certainly required in this and related areas if we are to have robust and sensitive techniques of river health assessment.

WATER FILTRATION AS AN ECOSYSTEM SERVICE

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INTRODUCTION

When sediment moves with water through the landscape there are many opportunities for this sediment to be captured and returned to the soil surface to become soil again. Examples of such filtering are buffer strips, grass swales, farm dams, floodplains and wetlands. The performance of such filters is wide ranging. For example, in one study near-natural riparian zones have been reported to trap greater than ninety percent of incoming sediment. Trapping efficiencies as low as twenty percent have been recorded in other environments.

Sediment carried by water usually contains a large number of attached substances including nutrients, organic matter and often pesticides. Therefore capturing sediment can have multiple benefits for downstream water quality and other off-site impacts such as the smothering of in-stream habitats associated with soil erosion.

The filtration of water occurs by three processes. First, adherence is the process by which sediment particles "stick" to surfaces, usually the surface of vegetation. This process appears to be especially important in wetlands where fine sediment is captured out of high water flows. Second, deposition by settling is the most commonly observed method by which water is filtered. For this mechanism the water velocity is reduced by the roughness of the vegetation or litter, so that the capacity of the water to carry sediment is reduced. The deposition by this mechanism occurs preferentially for the coarser fraction of the sediment load. Frequently coarse particles contain relatively low concentrations of attached pollutants compared with fine sediment. This is because fine particles, containing clay and organic material, have far more surface area per gram of sediment on which to absorb pollutants. Thus sediment that passes through zones of settling may contain a disproportionate fraction of the incoming attached pollutant load.

Finally the process of infiltration is very important for the filtration of sediment loads. Here the volume of overland flow is reduced by the infiltration of some of the water into the soil. This mechanism relies on patchy infiltration properties along a flow path. A common example is when runoff from a road surface passes onto a soil surface where the diffuse flow is infiltrated before linking with the stream. Infiltration captures all sediment sizes and is particularly useful because of its ability to trap very fine sediment.

Filtration can occur at a range of spatial scales. The landscape can be considered as a sequence of erosion and deposition patches. As water flows from the point where it originally became runoff to the sea it passes through a series of these alternating patches. The smallest patches may be tussock vegetation that separates bare ground. The largest patches may be reaches of a river flowing steeply or gently through the lower landscape. The effectiveness of filtering is strongly influenced by the relative size of the patches. For example a road on a ridge top in a forest may generate a large volume of runoff and sediment but it will be well buffered from the stream because the down slope forest filters the runoff. The same road running along the stream bank has little opportunity for buffering because the deposition patch below it is small relative to the size of the road.

These observations about the spatial size and arrangement of filter areas are the chief reason for the contrast in sediment loads emerging from forested and agricultural environments. Catchments with forestry operations normally only have a small portion of the landscape disturbed at any one time. It is normal for land below the harvested or trafficked land to act as a filter and minimise off-site sediment delivery. In contrast many agricultural lands have a very large portion of the land surface disturbed simultaneously enabling sediment generated to reach the stream network. As forestry operations become more intensive such as in short rotation plantations with high reading densities their behaviour becomes more like agricultural landscapes.

There is considerable discussion about the sustainability of filters. Filters by their nature accumulate sediment and this may effect their performance. For instance, grass filter strips accumulate sediment upslope and within the grass strip. This sediment buries part of the grass making the path smoother and less resistant to overland flow. Grass will normally recover so that the filter's resistive roughness is restored. The sediment accumulation also results in a locally-changed land surface slope. This may result in water flowing to the side of the accumulated fan. In extreme cases, filter strips result in a terrace being built.

The various forms of filters operate differently for differing magnitudes of runoff events. Filters that rely on infiltration will work best for small and moderate events, whereas floodplains only begin to operate in larger runoff events where floodwater inundates floodplains. It is possible that some filters will act to deposit sediment in small and medium events and this material is remobilised in very high flows.

WHY IS THE SERVICE IMPORTANT?

The reality of most Australian rural landscapes is that they will continue to generate sediment through soil erosion by a variety of processes. The constraints of enterprises and the enormity of the task of revegetation ensure that we will have sediment moving in our landscapes at above-natural rates for many decades to come. Filtering is an efficient way of diminishing the downstream impacts of soil erosion within the above constraints. Filters normally occupy a relatively small area of land and may be more acceptable to land owners as a result.

Capturing sediment has many benefits to the environment associated with decreasing downstream impacts. However, such capture does not normally result in the same level of benefits as if the soil had remained at its original location.

The costs associated with transported sediment include the removal of sediment and associated pollutants from drinking water, and reductions of productivity of domestic animals that drink sediment-laden water. The benefits are few but do include reduced penetration of light into water bodies that may moderate growth of water organisms including algae. Costs associated with sediment deposition include the desalting of structures such as roads, dams and wetlands, and the release of sediment-attached pollutants to the water system. Benefits of deposition are few but locally there may be benefit if nutrient-rich sediment is deposited on a productive area such as a floodplain. In the Goulburn Broken Catchment off-site impacts are particularly important because of the intensity of downstream water use.

THREATS TO THE ECOSYSTEM SERVICE

A. Landscape Change

Many of our natural systems have filtering built into their function. For instance much of the southern highlands of New South Wales had swampy meadows in the drainage lines in pre-European times. The post-European development of the Australian landscape has resulting in the removal of many of these filters through the homogenisation of land cover and the generation of massive gully networks that bypass remaining filters. In some parts of Australia we continue to develop the landscape with the above consequences. Clearing of native vegetation and the use of in-stream watering points for domestic stock are specific threats.

B. Salinity

The emerging dryland salinity in large parts of the Australian landscape may have consequences for the operation of current and future filters. Elevated salinity levels in our soils and streams will result in the change in vegetation species able to occupy many of the filtering parts of the landscape.

OPPORTUNITIES AND ACTIONS FOR THE ECOSYSTEM SERVICE

A. Water filtration restoration

There is increasing awareness in the Australian community about the role of filtering areas such as wetlands and riparian zones. In the coming years there is an opportunity to convert this awareness into a large number of restored filter areas. Also the water engineering community is increasingly viewing such areas as cost effective ways of managing water quality.

B. Technical expertise

There is a considerable amount of technical knowledge available for Australian landscapes about the design filter-related restored areas. Incentives for the uptake of these measures need to be carefully designed and implemented.

LINKAGES TO OTHER ECOSYSTEM SERVICES

Filtering of water as a service is strongly coupled to the erosion of sediment. It is a key step in planning the restoration of filters to identify major sediment sources and place filters in their pathway. This principle has been considered a trivial step by many agencies and land-use managers—frequently it is not. Sources of sediment such as gullies, roads and stock watering points may be larger than the sediment moving from agricultural hillslopes. In this case the use of hillslope filter strips may result in only a small reduction of downstream impacts.

There is also a strong link to the ecological function of wetlands and riparian zones. It is widely recognised that these areas have several functions in ecosystems. Designs for restoration or preservation of such zones may consider only one or a subset of these functions. For instance riparian zones will be restored only on stream banks if bank stability and water temperature moderation are the sole considerations. If filtering were to be considered then riparian zones would be extended to occupy more of the hollows through which overland flow enters the stream.

WHERE TO FROM HERE?

On a practical level there is a clear need to understand the constraints to the uptake of riparian zone and wetland management. The awareness in the community needs to be converted into action. Knowledge of the effectiveness of incentives in a range of physical and economic settings is required.

In restoring the natural filtering of landscapes Catchment managers need well guided plans of step-by-step restoration. Our understanding must guide the reestablishment of filter-areas so that systems do not fail part way through the process. As ecosystems reestablish themselves in filter areas, we need sufficient understanding to predict how this function will change through time.

We need more knowledge about filter function and design in salinised landscapes.

Research projects that address the above issues need to be funded and managed by the rural industries' research funding agencies. This research needs to be based around demonstration sites in a range of environments across Australia.

The uptake of filter-based land management measures can only be assessed through surveys of land managers and in-stream water managers. Direct measures of water quality are inappropriate, as there is insufficient knowledge of the magnitude and timing of the impact of individual measures at the whole-of-catchment scale.

REGULATION OF RIVER FLOWS AND GROUNDWATER LEVELS PROVIDED BY ECOSYSTEM SERVICES

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INTRODUCTION

As rain falls from the sky, it forms part of the water cycle that we rely on in so many ways—for agriculture, vegetation, drinking water, recreation and many other uses. When the rain reaches the ground surface it may either infiltrate into the soil or run over the soil surface. Infiltration will occur if the soil is not saturated, and surface runoff will occur if the soil is saturated or if the intensity of rainfall exceeds the infiltration capacity of the soil. Once rainfall has entered the soil it will drain down through the soil profile, perhaps beyond the plant root zone to an underlying groundwater system. From there, the water will flow laterally through the landscape, possibly to a stream or river. However, much of the infiltrating rainfall is simply stored in the soil profile, and is later taken up by plants in the process of transpiration. Some soil water is also evaporated directly through the soil surface. The term *water balance* refers to the accounting of water inputs to and outputs from catchments. Input is mostly rainfall, but may include river flow diversions and groundwater inflows from beyond the Catchment boundary. Outputs include river flows, groundwater outflow, evaporation from open water bodies, soil evaporation, plant transpiration, and rainfall interception by plant canopies. Change in storage may occur in the unsaturated soil, the groundwater system and in dams.

The regulation of river flows and groundwater within limits that sustain and fulfil human life are two key services provided by the living and non-living components of ecosystems in the Goulburn Broken Catchment. There are important interdependencies between river flows, groundwater and land-use. land-use affects rates of groundwater recharge (and thus groundwater levels in the Catchment), and evapotranspiration rates (and thus the amount of water yielded from the Catchment). Groundwater levels affect rates of baseflow input to rivers and the extent of saturated areas within Catchments. Both of these affect the flood response of Catchments to major rainfall events. Groundwater discharge affects the sustainability of land-use, as does the yield and quality of river flows.

River flows and groundwater dynamics fluctuate through the Catchment due to variation in relief, soils, climate and land-use. Mean annual rainfall, in particular, varies considerably across the Catchment, with less than 450 mm falling in the north and more than 1,600 mm falling in the south-east. Although the Catchment covers only 2% of the Murray Darling Basin, it contributes some 11% of the flow. The Catchment yields a pre-regulated flow of about 3.4 million ML, most of this arising from forested areas in the upper Catchment. Flows through the Catchment have been modified by Lake Eildon (3.4 million ML storage), Goulburn Weir, Lake Mokoan (0.36 million ML storage) and Lake Nillahcootie (0.04 million ML storage).

About two thirds of the runoff from the Catchment is diverted to support irrigated agriculture which takes place in the Shepparton Irrigation Region where over 2,800 km^2 of land is irrigated.

Whilst river regulation smoothes out the effects of climate variability on seasonal flows, annual river flows still vary significantly in the Catchment. For instance, in the Broken River, annual flow has varied between 5,000 ML in the drought year of 1943, and over 1 million ML in the flood years of 1917 and 1956.

WHY IS THE SERVICE IMPORTANT?

The term 'river flows' is a collective one, denoting a variety of hydrologic services that have varying importance to different Catchment functions. It embraces water yield, low flows and peak flows, definitions for each of which are provided below.

The bulk river flow, referred to as *water yield*, affects the water storage volume which in turn dictates the amount of water that can be allocated to irrigated agriculture, other consumptive uses and the environment in the lower parts of the Catchment. Catchment water yield varies as a function of the annual rainfall and land cover. Yield increases with rainfall, and forested catchments yield less water than grassed catchments. The differences in yield between grassed and forested catchments increases with rainfall. River flows in the Goulburn Broken Catchment are heavily allocated to consumptive uses and the environment. Hence, reductions in water yield caused by climate or land-use change will present problems for catchment managers.

River flows vary in time and the term *flow regime* is used to denote the frequency of flows of particular magnitudes. In hydrologic practice, these flows are ranked in order of their magnitude; the terms *peak flows* and *low flows* are used to denote those flows in the lower and upper percentiles of these rankings respectively. Maintenance of low flows is particularly important for certain aquatic and terrestrial ecologic complexes, as these may be threatened if flows persist below a particular magnitude threshold. Peak flows also serve an important ecological function in terms of flushing and/or re-working of river sediments. However, if peak flows are too great they may cause flood damage or lead to adverse channel erosion. There is an important link between groundwater and flow regime. As groundwater levels rise, river low flows are increased. At the same time, Catchment moisture deficits decrease, leading to larger and more rapid Catchment run off responses to rainfall. Hence, peak flows are also increased by rising groundwater.

Rising groundwater and associated salinisation is probably the biggest threat to ecosystem services in the Goulburn Broken Catchment. The combination of these threats lead to land degradation and losses in agricultural production and native vegetation. Salinising groundwater also degrades the quality of river flows which further impacts on agricultural production (via degraded irrigation water) and native vegetation (via stream salinisation).

There is another important link between groundwater and river flows; dilution flows. In the Goulburn Broken Catchment most of the river flows are yielded from the wetter upland regions which are mainly forested. These produce large volumes of fresh water which dilute the saline waters which leak into the lowland sections of the river network from groundwater. If the quantity of fresh water input to the river system is reduced (say by climate or land-use change), then the quality of river flows may be degraded via enhanced salt concentrations.

The importance of the role of ecosystem components in regulating river flows and ground water lies in its efficiency compared with human-engineered alternatives. Totally replacing this regulation with technology not possible because of cost and limits to our understanding. Imagining the extent of technological substitution necessary indicates how important the contribution of ecosystems to human welfare is. Even replacing partly lost regulation, such as that lost when native vegetation was cleared from our landscapes, is a complex and expensive exercise. Decisions to change ecosystem components further need to include consideration of the efficiency and cost of technological substitution for regulation of river flows and ground water.

THREATS TO THE ECOSYSTEM SERVICE

Salinity

At present, 45% of the land in the Shepparton Irrigation Region (SIR) is underlain by shallow watertables (<2m depth), and this

area is projected to rise to 60% by 2020 if no remedial action is undertaken. A major cause of rising watertables in the SIR has been the loss of remnant native vegetation, which now covers less than 4% of the area. Over half of the shallow seasonal wetlands (>1 ha in area) have been lost from the SIR, and most of those remaining are severely degraded.

Waterlogging and salinity are by no means confined to the irrigated areas; 45 km^2 of land in the Catchment is subject to dryland salinity and the area is expanding at 5% per year to an expected maximum affected area of 380 km^2 if nothing is done. These dryland areas currently yield about 180,000 tonnes of salt per year to the irrigated areas and the River Murray, representing about 45% of the Catchment total. This dryland salt load is expected to double in the next 50 years if no remedial action is undertaken.

Afforestation

Afforestation is proposed as a key element in the fight against waterlogging and salinity in the Goulburn Broken Catchment. If conducted on a broad enough scale and implemented in the right areas, afforestation will reduce these forms of land degradation, but it may take many years before the full effects are felt. For these reasons, tree planting should be regarded as an adjunct to other forms of remediation. One of the binds faced by Catchment managers is that by improving one ecosystem service (say groundwater condition), they may harm another (river flows).

One unwelcome consequence of afforestation is reduced water yields. It is possible to deduce the reduction in mean annual water yield that would result from afforestation of grassland. Yield reductions would be greatest in high rainfall areas, and would be greatest for pine plantations. For areas with 800mm mean annual rainfall, grassland catchments yield about 210mm of runoff per year. After complete afforestation of these areas mean annual yield may reduce by up to 165mm under eucalypt forest and up to 210mm under pine plantations (equating to yield reductions of 79 and 100%, respectively). For areas with mean annual rainfall of 1200mm, grassland catchments yield about 493mm of runoff per year. After complete afforestation these areas, the mean annual runoff reductions may be as great as 265 and 350mm (equating to yield reductions of 54 and 71%, respectively).

In addition to reducing catchment yields, afforestation will reduce low flows and high flows. Some streams that are currently perennial will become intermittent and may thus threaten the viability of certain terrestrial and aquatic ecological complexes. These may also be adversely affected by reductions in peak flows (e.g. reduced flushing of salts in floodplains, reduced transport and re-working of sediments in channels). Floods of low to intermediate magnitudes will be reduced though it is unlikely that major ones will be and these are the ones that cause most infrastructure damage.

OPPORTUNITIES AND ACTIONS FOR THE ECOSYSTEM SERVICE

Tree Planting

The growing waterlogging and salinity problem can be addressed by tree planting if this is conducted on a broad enough scale. Recharge rates under trees are negligible compared to that under pastures and crops. There is ample evidence to show that tree planting can lead to significant lowering of watertables in local and some intermediate scale groundwater systems, though it is unlikely to have much impact on regional groundwater systems. Where possible, afforestation should be focussed on areas receiving less than 800mm of annual rainfall. These are the areas most at risk from salinity. Water yield reductions in the Catchment will also be less if these areas are afforested in preference to wetter sites.

Improved Irrigation

Improvements in irrigation efficiency (via laser grading of land, remodelling of farm channels and drains, and improved methods of application) can lead to reductions in groundwater recharge and slow the rate of groundwater rise in irrigation areas. Re-use of drainage water can help keep salt in the system longer and thus reduce salt export to the river network. However, agricultural productivity will be reduced once irrigation water exceeds a particular salinity threshold.

Expand Drainage Network

Expanding the already extensive drainage network in the Catchment will help to reduce watertable levels and enhance agricultural productivity, but will also probably increase the export of salts to the river network. In 1997, some 1,830 km^2 of land in the Shepparton Irrigation Region was drained. The Goulburn Broken Catchment Management Authority (GBCMA) *Catchment Management Strategy* seeks to increase this area to 2,680 km^2 by the year 2020. Increasingly, the surface drainage network is being co-designed and co-funded by community groups.

Ground Water Pumps

Groundwater pumps and evaporation basins are increasingly being used to manage groundwater rise and salinisation in the Goulburn Broken Catchment. In 1997, some 365 groundwater pumps were in operation in the Catchment. The GBCMA *Catchment Management Strategy* seeks to install a further 365 pumps in the near future.

A significant aspect of river flow management in Victoria is the bulk water entitlements process that seeks to implement an equitable distribution of water to users, including the environment.

WHERE TO FROM HERE?

As we have discussed above, the challenges in managing groundwater and river flows in the Goulburn Broken Catchment are immense. Valuable ecosystem services are under threat by rising groundwater and salinisation, yet the management options available to counter these problems are not problem-free. Because of the interdependencies between land-use, groundwater and river flows, it is necessary to take a holistic view of catchment function. In managing for any one of these there will be tradeoffs against the others. For instance, attacking the rising groundwater problem by reducing irrigation and afforesting cleared dryland areas will probably lead to reductions in agricultural production and reduced river flows. Whether or not these changes improve the net worth of ecosystem services in the Catchment depends on one's point of view. Because such choices are ultimately subjective, it is imperative that Catchment managers and stakeholders are equipped with the tools to analyse the tradeoffs which different land and water management strategies present. Future research and development programs should focus on the development and application of such tools.

WASTE ABSORPTION AND BREAKDOWN

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INTRODUCTION

The absorption and breakdown of wastes is an essential ecosystem service provided by the soil to many industries in the Goulburn Broken Catchment. These wastes include the wastewaters, effluents and solid wastes which are deliberately applied to the soil, and also the chemicals found in leachate and runoff from the land which are inadvertently and unavoidably applied to the soil. If the surface and ground waters of the Catchment are to be protected, the loading of these wastes must be limited to that which can be absorbed or broken down in the soil and used sustainably in the soil/plant system.

Many of the industries in the Goulburn Broken generate wastes containing carbon, macronutrients, salt, bacteria, and biocides. These are treated by the soil through a variety of mechanisms including incorporation into the soil organic matter, conversion to carbon dioxide and water, and retention and storage until being taken up into the vegetation. These mechanisms are mediated by the soil micro-organisms and good functioning of this treatment depends on the maintenance of a healthy environment for the microbes. In turn, a healthy environment for the soil micro-organisms requires that there is a good soil structure, that the soil is not so wet as to prevent adequate aeration of the soil, and that the organisms are not exposed to excessive amounts of toxic materials, including salts, biocides, and heavy metals.

Other wastes produced in the Goulburn Broken include heavy metals and salts. These wastes cannot be incorporated into the soil organic matter or converted to harmless substances. They can either be retained in the soil or leached through the soil. In this case it is important that elements retained within the soil do not build up to levels that become toxic to the soil flora thereby adversely affecting the capacity of the soil to function.

All industries have some possibility for changes in management and activities that will preserve this essential ecosystem service.

WHY IS THE WASTE ABSORPTION/ BREAKDOWN IMPORTANT?

Waste absorption and breakdown is an essential service to many industries of significance in the Goulburn Broken Catchment. In general, the wastes from these industries can be divided into point and diffuse sources, and some industries produce both. The separation is an important distinction because with point-source wastes there is a possibility of capturing or retaining the waste for treatment before it is released to the environment. Any treatment will reduce the reliance on the ecosystem service and for some wastes provides an opportunity to use the waste as a resource rather than regard it as something to be disposed of. In contrast, diffuse-source wastes are more difficult to manage and/or treat, therefore in general the industry is totally reliant on the ability of the receiving environment to absorb and break down the waste if contamination of ground and surface waters is to be avoided.

Industries in the Goulburn Broken producing point-source wastes include the dairy industry (both dairy shed wastes and factory wastes), the fruit processing industry, and the pig and poultry industries. The diffuse-source wastes are primarily leaching and surface runoff from dairy farming, grazing, hay and seed production, and ley farming (cereal cropping/legume pasture). The table below lists these industries as well as their approximate extent and value to the Catchment.

TABLE 19

Land-use	*Farmgate GVP ($M)*	*Point source*	*Diffuse source*
Fruit & grapes	174	•	•
Dairying	453	•	•
Grazing	236		•
Hay and seed	73		•
Pigs / poultry / aquaculture	43	•	
Ley farming	53		•

Other land-uses produce less significant amounts of waste. These wastes include effluents from other processing industries (e.g. abattoirs, vegetable processing), manufacturing wastes, domestic septic wastewater, and wastes from extractive industries.

Point Sources

Many of the point-source wastes in the Goulburn Broken Catchment primarily contain nitrogen, phosphorus and carbon although not necessarily in ratios that are optimal for treatment or reuse. These include, dairy shed effluent, dairy factory effluent, wastes from the processing of fruit and grapes, piggery wastes, and waste from poultry operations. Of these, effluent from dairy factories, fruit processing, and piggeries have high and unbalanced salt loads and may have considerable alkalinity or acidity further complicating treatment and reuse. Dairy shed and piggery, and poultry wastes are also high in faecal coliforms. Piggery solids can contain appreciable concentrations of copper.

The services of the soil in treating the wastes from these industries include the incorporation of carbon, phosphorus, and nitrogen into the soil organic matter or export in plant dry matter, and the temporary storage of salts in the soil. Undesirable microbes in some of these effluents are inactivated by a combination of retention time in the treatment process and the soil and by predation of the soil microbes. The ecosystem services are highly significant to industries, and the industries may be able to reduce their reliance on the ecosystem service through improved treatment of the wastes before application to the land. Alternatively, it may be better to regard some of these wastes as sources of nutrients to be reused to improve agricultural productivity.

Diffuse Sources

The diffuse sources of wastes are primarily runoff and leaching from dairy farming, grazing, hay and seed production, ley farming, and fruit and grape production. The contaminants in the wastes include carbon, phosphorus, nitrogen, and biocides, as well as microbes from the animal-based industries.

The waste absorption and breakdown ecosystem service is critical to the sustainability of industries producing diffuse-source wastes. If the wastes are not satisfactorily treated as they pass over or through the soil, surface and groundwater resources may become contaminated.

THREATS TO WASTE ABSORPTION/BREAKDOWN

The primary threat to the waste absorption/breakdown arises from the possibility of the soil becoming overloaded with the waste. With all wastes there is a certain amount that the soil can absorb and break down and ultimately recycle through the soil/plant system. That amount varies from soil to soil, with the time of year, and depends on the nature of the waste. Excessive loading of wastes on the soil can lead to a build up of the waste, or another species produced during decomposition, in the soil. Any amount that exceeds what can be recycled though the soil/plant system will result in mobile species being leached beyond the root-zone to contaminate receiving water, and can adversely affect the health and functioning of the soil.

Addition of excessive amounts of high-sodium wastes can cause a soil to become sodic, which in turn may lead to soil structure breakdown, poor aeration, and impaired ability to absorb other wastes and to provide a good root environment. An accumulation of biocides or heavy metals can adversely affect the soil micro-organisms also leading to soil structure breakdown and the contamination of the soil with heavy metals.

If wastes with a large amount of labile organic matter are applied to a soil, the resulting oxygen demand can exceed the soil's ability to transport oxygen. Under these circumstances the soil will become anaerobic, leading to decreased microbial activity and leaching of organic matter. Particulate organic matter (for example in dairy shed effluent) can filter out on the soil surface and block soil macropores leading to reduced infiltration rates and an anaerobic soil. Wastes with high or low pH can break down the soil organic matter, leading to a breakdown of soil structure, decreased infiltration, and anaerobic soil. Furthermore, continued application of such material will change the soil pH, which may have adverse impacts on the soil/plant productivity.

OPPORTUNITIES AND ACTIONS FOR WASTE ABSORPTION/BREAKDOWN

The actions required to preserve this ecosystem service revolve around ensuring that the waste additions to the soil do not exceed the capacity of the soil to absorb and break down that waste. Furthermore, they should not change the soil pH beyond optimal values. There are several management options available to reduce the amount or toxicity of the wastes. The options include i) reducing or modifying the inputs to the industry, ii) spreading the wastes over a larger area of soil (the dilution solution), iii) improved pre-treatment of point-source wastes, and iv) reusing point-source wastes as a resource.

Fruit & grape industry

The primary production side of this industry can preserve the ability of the soil to absorb wastes by only applying

sufficient material to satisfy the tree fertiliser requirements, reducing the use of biocides and where possible by preferentially using biocides that are readily broken down in the soil or are less toxic to the soil micro-organisms, by adding or recycling organic matter to the soil, and minimising soil cultivation and heavy traffic that adversely affects soil structure. The processing industry can improve the treatment of the wastewater and, where possible, by tailoring water treatment to intended reuse. If the pH or salt balance of the wastewater is a problem this might be remedied either through improved treatment or alternative practices in the factory.

Dairying

The dairy industry can reduce fertiliser inputs to match outputs, and avoid damage to the soil structure caused by grazing or traffic on wet soils. If irrigation water with a high sodium-absorption ratio is used, the accumulation of sodium in the soil can be counteracted with applications of gypsum or other Ca salts. In the dairy shed the use of chemicals in the washdown might be reduced. The dairy shed wastewater should be applied over large areas of pasture, perhaps after treatment in an anaerobic-aerobic pond system. Furthermore, the nutrients in the applied wastewater should be taken into account when applying other fertilisers. If necessary, factories should control the alkalinity or acidity of wastewater by improved treatment or processing methods and should irrigate the wastewater over a large area of soil so as not to overload the system.

Grazing

The grazing industry should ensure that fertiliser applications are only limited to those necessary to match exports, waterways should be fenced off, and damage from grazing wet soils should be controlled.

Hay and seed production, cereals and legumes

These industries should ensure that wet soils are not trafficked, match fertiliser use to farm exports, include semi-permanent pasture in the rotation to maintain soil organic matter levels, and limit drainage beyond the root-zone.

Pigs and poultry

The pig and poultry industries have many opportunities for preserving the ecosystem service. These opportunities arise from both reducing the amount of waste and using the waste as a source of nutrients. In the pig industry the feed can be manipulated to decrease the amount of nutrients in the waste. Both industries can utilise the solid part of the wastes by composting, so providing a useful fertiliser and soil amendment for use by other land-based enterprises. Another possibility is the generation of biogass from the wastes, which has the dual benefit of decreasing the amount needed to be applied to soils and providing an alternative energy source for the operation. There are opportunities in the pig industry for improved treatment of the wastes in anaerobic and aerobic ponds. Slurries and effluents should be applied to soil only at a rate that satisfies the nutrient requirements of the crop. This may require the use of supplemental irrigation with fresh water and the use of large areas of land. Continual application of waste to land will lead to salt imbalances that require correction. The area of land-used for the application of piggery solids should be sufficiently large to avoid excessively high concentrations of copper. Monitoring of the accumulation of nutrients, heavy metals and salts, and the adjustment of management, is needed for the sustainable operation of these systems.

LINKAGES TO OTHER ECOSYSTEM SERVICES

The ability of the ecosystem to absorb and breakdown wastes is dependent on the maintenance of the “soil health” ecosystem service. Without a properly functioning soil organic matter cycle, macronutrients in wastes cannot be incorporated into the soil nutrient cycles. Soil physical structure cannot be maintained in a state suitable for the acceptance and treatment of many of the wastes of concern here. In addition the ecosystem service “maintenance of water quality” is influenced by the degree to which wastes are broken down before entering surface waters.

Although there remain significant gaps in our fundamental knowledge of ecosystem functioning, particularly with respect to our ability to quantitatively predict outcomes of land-use change in the face of both spatial and temporal variability, we have sufficient knowledge to advise land managers and regulatory bodies on the likely outcomes of various land management systems of relevance to waste absorption and breakdown. In general, this needs to be evaluated on a paddock-by-paddock basis. In most cases, although there is sufficient knowledge to allow land managers to consider the tradeoffs between management systems that will improve the environmental consequences of their activities and the change in profitability of the enterprise, the knowledge may not have been encapsulated in a format useful to managers. Development and dissemination of this knowledge in a suitable format would lead to informed decisions being made by both land managers and Catchment management authorities.

Appendix 1

Ranking and identifying priority ecosystem services

This appendix provides the full set of rankings for all industries and land-uses effected by each of the ecosystem services discussed in this report.

Because of the diverse range and complex nature of the ecosystem services and industries in the Catchment it is important to use a robust and consistent method to sort through the complexity and to identify those issues of highest importance to the sustainable management of the Catchment's natural resources.

Drawing on the conceptual framework the relationship between each service and each land-use/industry has been ranked against the following two key high level functions of ecosystem services:

- **Input to production.** Assessment of ecosystem services in this role was based on a combined weighting of the value of goods associated with each land-use/industry and the importance of the ecosystem service in producing those goods.
- **Maintaining natural assets.** Assessment of ecosystem services in this role was based on the impact of each land-use/industry on the capacity of natural assets to continue to provide ecosystem services.

  Within these two functions three assessment criteria have been used:

  - **Overall importance/impact.** First in relation to inputs, the overall importance of the service in relation to the production of a good; and second in relation to maintaining natural assets the impact of the land-use/industry on ecosystem service's capacity to maintain natural assets;
  - **Importance at the margin.** The impact of a small change in a service on the production of a good or the maintenance of natural assets; and
  - **Manageability.** The capacity to manage the land-use/industry to ensure the ongoing delivery of the service (noting that a low ranking may imply a high priority for further effort).

Rankings were initially undertaken within the Catchment based on local knowledge and then crosschecked by scientific experts. Draft rankings were then used to consult more widely within the Catchment and with specialists in the period between November 2000 and April 2001 (see consultation section below for detailed breakdown of community involvement).

The process of ranking has involved a significant number of judgements within each of the decision criteria. Rationale for each ranking has been documented to ensure transparency.

Given the purpose of the ranking (i.e. prioritising key services and issues) it was determined that only three rankings could be sensibly derived:

Low	Not of importance to the Catchment
Medium	Of significance
High	Critical to the future of the Catchment

A difficult issue is to determine when a high ranking over-all is justified. A high ranking against each of the sub-criteria was generally required to lead to a high ranking for the service over-all.

However, there are quite a number of important exceptions, where a high ranking in one or two criteria was considered sufficient. This underscores the importance of documenting the reasoning behind each ranking and ensuring adequate review of the outcomes by local and technical experts. The process of consultation for this report has lead to a number of rankings being amended.

Because the high level criteria focus on the different functions of ecosystem services, the sub-individual criteria outlined above have been applied in different ways. The application of the assessment sub-criteria is explained below and is then followed by tables containing the rankings for each ecosystem service. Each table also provides a definition of the ecosystem service and how the criteria are applied to that service.

Note that land-uses and industries only appear in the tables if they significantly impact on the service or they significantly impact on the capacity of natural assets to provide the service.

APPLYING THE CRITERIA TO ECOSYSTEM SERVICES AS INPUTS TO PRODUCTION

Overall Importance

This criterion was applied by assessing: *The overall importance of each ecosystem service in the production of goods associated with with each land-use/industry.*

Two factors were considered: first the overall value of the goods associated with the land-use/industry; and second the extent (in land area) of the land-use or industry.

The financial value of goods were derived from data collected with thresholds for rankings as follows:

Low = less than $20M

Medium = $20M – $80M

High = $80M+

Local knowledge was used to rank these goods where financial value was difficult to derive, for example landscape aesthetics.

The significance of goods was also derived from the area of land devoted to their production. This addressed goods that may have strong significance to the management of the Catchment but lower economic returns, such as dryland grazing.

A high ranking is given through either high value of the goods or the extensive nature of the good's production in the Catchment.

Importance at the margin

This criterion was applied by assessing: *The sensitivity of goods associated with each land-use to a marginal (small) change in the delivery of the ecosystem service.*

In relation to inputs to production, for example, in the case of pollination of fruit trees, the question asked is: Will a small change in pollination significantly affect the production of the fruit yields?

Because the criterion is applied at the margin, some ecosystem services, whilst vital to the production of goods, may receive a low ranking because their status is relatively secure. For example, pollination services are essential but adequate for most land-uses other than fruit production in the Catchment.

Conversely a high ranking would generally be given for services such as soil health that have a consistent and/or incremental impact on productivity and yields.

Manageability

This criterion addresses the capacity to manage the service at reasonable cost and have a significant improvement on its delivery.

APPLYING THE CRITERIA TO ECOSYSTEM SERVICES ASSOCIATED WITH MAINTAINING NATURAL ASSETS

In the case of ecosystem services associated with maintaining natural assets it is the impact of different land-uses/industries on the capacity of natural assets to continue to deliver the ecosystem service that must be assessed.

Impact of Land-use/Industry

This criterion was applied by assessing: *The overall impact of each land-use on the capacity of natural assets to provide the ecosystem service.*

For example, the aggregate level of N and P contributed to waterways by different industries has been considered in relation to both the services of maintaining healthy waterways and waste absorption and breakdown. For some smaller scale land-uses/industries the average impact per unit of production has also been considered.

Importance at the margin

This criterion was applied by assessing: *Significance of a marginal change in the provision of the ecosystem service on the maintenance of natural assets.*

For example, would a small increase in the capacity of waterways, soils and plants to assimilate nitrogen and phosphorous improve the health of the Catchment's waterways.

This criterion is aimed at determining if natural assets in the Catchment are at risk of degradation. This can be measured in two ways.

First, if an ecological threshold is at risk of being passed. For example, the filtration and absorption of nutrients (nitrogen and phosphorous) in waterways is a natural process necessary to stimulate plant growth and hence maintain healthy waterways. However, a threshold may be passed if excessive loads of nutrients are deposited in waterways leading to toxic algal blooms.

Second, if the pace of depletion of natural assets is exceeding the rate of regeneration of the asset. For example, if soils are being lost at a faster rate than they are being created. It is noted that the scale at which this question is answered will vary. For example, in the case of waste absorption (N and P) the question is one of overall loads in water-ways and should be answered at a Catchment scale (hence a ranking for each land-use would not be done but for the overall Catchment). In contrast soil health may be assessed by land-/use at the paddock scale.

Finally it is noted that each ecosystem service maintains natural assets through a wide range of complex processes interactions. For this reason only those processes that are having (or have the potential in the near future) a significant impact on natural assets are considered in the ranking tables. For example, in water table levels (salinity), water flows and flooding are considered in relation to water quantity flows and regulation.

Manageability

This criterion assesses whether the impact of the land-use/industry can be managed at a reasonable cost. Further, this will lead to a significant improvement in the state of the Catchment's natural assets.

CONSULTATION PROCESS

The Ecosystem Services Project consulted widely in all stages of the inventory presented in this document, and remains committed to this approach for the entire project. To facilitate this, CSIRO, has entered into a full partnership with the Goulburn Broken Catchment Management Authority (GBCMA) for the life of the project. The Ecosystem Services Project in the Goulburn Broken is guided by a steering committee consisting of land managers, interested community members, CMA staff, state agency representatives (NRE), external bodies (Productivity Commission) and CSIRO. In the spirit of the consultation process, a full time communicator has also been employed to facilitate internal and external communication of the project.

The Ecosystem Services Project held an initial workshop in November 1999 where a preliminary investigation into the importance of ecosystem services in the Catchment was conducted. That initial workshop served to guide the following twelve months, which was spent designing the theoretical framework for the project, as well as aiding in the development of at least four other case studies.

The team of people who worked on the inventory consisted of Goulburn Broken locals and Catchment experts, scientific experts and members of the project team. The Catchment experts were responsible for gathering, collating, analysing and verifying much of the information presented on the Catchment. The scientific experts wrote the specialist papers on each service and were also involved in ensuring the process remained transparent and rigorous.

The entire inventory process was highly iterative with regular revision and feedback, culminating in a major workshop in November 2000, followed by five smaller briefings and further revision.

The consultation process in summarised in the following nine steps:

- Catchment experts and project team members gather and collate data on Catchment goods.
- In consultation with scientific experts and Catchment experts, services involved with the production of a Catchment good, or maintaining a natural asset, were identified.

- an overall ranking of services and their importance in the production of goods, or maintaining natural assets, was undertaken and revised by both Catchment and scientific experts.
- A draft copy of the report was circulated to approximately 80 Catchment representatives in November 2000, and feedback invited.
- The draft was also circulated to a range of other stakeholders for comment.
- Also in November 2000, the draft report was presented and discussed at a workshop of approximately 50 people in Shepparton.
- In November 2000 through to March 2001, feedback from all stakeholders on the draft report was incorporated into the report.
- Revised material was recirculated to scientists involved in the report for final comment.
- In April 2000, five briefings on the revised report were held across the Catchment (Yea, Benalla, two in Shepparton, and Tatura) where further feedback on the goods, management actions and rankings was sought and incorporated.

TABLE 20

The importance of the ecosystem service of pollination

Pollination is the service of fertilising flowers allowing for seed and fruit production. Pollination is critical to the regeneration of plants and to the production of fruit for consumption by animals and people.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/ industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Pollination is an essential input to the production of all plants and fruits. Plants dependent on wind pollination are secure (provided they have viable populations). However plants requiring insect pollination are dependent on an adequate number of pollinators. The dependence and sensitivity of each land-use of pollination is assessed.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). Pollination is required to facilitate habitat regeneration. This issue is addressed under habitat regeneration, and not here.

A: Land-Use	*B: Ha*	*C: Farmgate GVP $,000*	*Input to Production*			*G: Ranking*	*Explanatory Notes*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in pollination control services	**F:** Manageability		
Dairying – on farm	112,000	453,348*	H	L	M	M	D, E, F Nitrogen fixing plants (clover and lucerne) are animal pollinated, and important to dairy pastures. Pollination can be managed on site, or in seed production areas.
Fruit & Grapes	11,000	173,553	H	H	H	H	D, E, F Imported hives cost about $15 each and currently meet the gap in pollination requirements caused by declining numbers of native pollinators. However, importing hives may be threatened in the future by disease to bees such as the Varroa mite.
Vegetables – below ground	310	5,185	L	L	M	L	D, E, F Seed is imported.
Vegetables – above ground	1,445	22,999*	M	M	L	L-M	D, E, F Tomatoes will self pollinate when grown outdoors, but need pollinators when grown in a greenhouse in the absence of wind. Outdoor tomato growers do not perceive pollination as a problem, but native insects might make a significant unmeasured contribution to fruit production in some circumstances.
Grazing	1,223,000	236,315	H	L-M	L	L	D, E, F Grass is wind pollinated and secure, clover and lucerne are dependent on insect pollination
Crops – Cereals	104,700	51,857	H	L	L	L	D, E, F Cereals are generally wind pollinated
Crops – Legumes	9,400	953	L	H	M	M	D, E, F Pollination is an important service. The ranking is low because of the low scale of the industry in the Catchment
Crops – other including oil seeds	7,800	4,500	L	H	L	L	D, E, F Pollination an important service. The ranking is low because of the low scale of the industry in the Catchment
Crops – Summer	900	290	L	L	L	L	
Hay and seed production	112,600 (all)	72,691*	M-H	M	M	M	D, E, F Animal pollination service is irrelevant to grass, but crucial to clover and lucerne.
Forests – Hardwood	439,445	7,500	M	M	L	L	D, E, F Pollination levels seem adequate for recruitment. Difficult to manage pollination of such a broad, largely natural area. (Perhaps understorey, which attracts pollinators, could be encouraged in some areas.)
Forests – Softwood	17,352	78,000	M	L	L	L	D, E, F Pine trees are wind pollinated.
Other public land – mostly trees	233,806		M	H	L	L-M	D, E, F Native vegetation requires pollination for regeneration. There are many small blocks of public land (reserves) that have insecure pollination services — these blocks often suffer from "edge effects" which means that the blocks are not good habitat for pollinators. Levels of pollination have been demonstrated to have fallen (see pollination paper). Difficult to manage — increasing effective size of small blocks is an option. Debate over continued access of managed bees to native forests.

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 21

The importance of the ecosystem service of life-fulfillment

Life-fulfilling services are defined as provision of aesthetic beauty, cultural, intellectual, and spiritual inspiration, sense of place, existence value, scientific discovery, and serenity.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/ industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Life-fulfillment arises from the sense of place or enjoyment derived from our landscape. It is a key input to housing and recreation industries.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). The impacts of land-uses/ industries in the case of life-fulfillment services are assessed in relation to their effects on the state of the landscape and the extent of landscape change.

A: Land-Use	*B: Ha*	*C: Farmgate GVP $,000*	*Inputs to Production*			*Maintaining Natural Assets*			*J: Ranking*	*Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
						Landscape Change				
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in life-fulfilling services	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide life fulfillment services	**H:** Significance of a marginal change in life fulfillment services on maintenance of natural assets	**I:** Manageability		
Dairying – on farm	112,000	453,348*	-	-	-	H	M	M-H	H	G. Value of land for pasture is very high. "Life fulfilling" remnants of vegetation and wetlands and new plantings are therefore in a very competitive market place. "Life fulfilling" native fauna dependent on this habitat are under considerable pressure. This can be a perception issue – some might regard fence to fence green pastures across the entire property as the ideal vista. Anecdotal information from real estate agents indicate the treed properties are worth 10% more. H. Many would say that the dramatic increase in tree plantings over the last 10 years has greatly improved the landscape. Others would point to the "living dead" – small remnants that are declining, mainly due to water table rise and grazing. I. Tree planting, remnant protection and enhancement and watertable control of high value areas are all achievable ways of "managing."
Vegetables – above ground	1,445	22,999*	-	-	-	M	L-M	M	M	G. Scale of damage (tree removal) small but severe. H. As for "Dairying – on farm". I. Tree removal does not need to be as severe.
Grazing	1,223,000	236,315	-	-	-	H	H	H	H	G. While grazing properties provide an image that is a significant part of the Australian psyche, this image is under great threat: The trees are getting old, have little understorey, and no young trees are regenerating to replace them. There is a whole layer within the structure of remnants that is not present – from the start of grazing in the mid to late 1800s until the advent of environmental awareness of the late 1900s. This layer cannot be replaced. H. Large-scale death of mature trees over the next 10-100 years would have a great impact on the aesthetic values. I. Large-scale protection of remnants and tree planting is possible

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 21 CONTINUED

The importance of the ecosystem service of life-fulfillment

Life-fulfilling services are defined as provision of aesthetic beauty, cultural, intellectual, and spiritual inspiration, sense of place, existence value, scientific discovery, and serenity.

A: Land-Use	B: Ha	C: Farmgate GVP $,000	Inputs to Production			Maintaining Natural Assets			J: Ranking	Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)
						Landscape Change				
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	Sensitivity of goods associated with land-use to a marginal change in life-fulfilling services	F: Manageability	G: Overall impact of land-use on capacity of natural assets to provide life fulfillment services	H: Significance of a marginal change in life fulfillment services on maintenance of natural assets	I: Manageability		
Forests – Hardwood	439,445	7,500	-	-	-	H	L-M	M-H	M	G. The extensive area of forested public land makes an enormous contribution to this service; timber production covers a small area. Paradoxically, the land-use of recreation (which is often derived from the life-fulfillment service) can have significant negative by-products – such as scarring of the landscape from human pressure and declining water quality from sediments off tracks. H. Like much of Australia, the Catchment is blessed with large areas that are relatively natural – aesthetically, the landscape is only declining slowly. I. Timber harvesting is managed via plans and codes. Managing recreationists takes considerably more resources because of sheer numbers of people to deal with.
Forests – Softwood	17,352	78,000	-	-	-	M	L	L-M	L-M	G. Pine plantations are generally on leased public land and private land – generally they are perceived to have lower life-fulfillment values, especially aesthetically and especially until trees have grown. H. Pressure for conversion of existing natural native remnants into softwood plantations is not expected to be high. I. Screening of harvesting operations and new plantings can assist aesthetically – e.g. leaving mature trees at edge.
Extractive Industries – Land & Water Based	n.a.	1,000	-	-	-	L	L-M	M-H	L-M	G. Generally low. Some visual impact from mining operations. H. Site specific scarring of landscape can detract from local vistas. I. Can be carefully managed to avoid negative impact – reasonable for high value extractions to provide aesthetic compensation.
Housing	73,266	276,000	-	-	-	M	M	H	H	G. Rural housing developments can impact on landscape values. Even the proliferation of weeds on some hobby farms detracts from the aesthetic values for many. An opposing argument points out that subdivisions may not be detracting from landscapes – just changing it. For example, in some subdivisions there are more trees now than there were while it remained primarily farming land. H. The sheer pressure for developments in some areas – especially the foothill country in the south – potentially detracts from the values that drew people there in the first place – people went there to get away from high density living and into a semi natural environment and can now find themselves surrounded by people and dwellings. At certain times of the year, stubble burning causes asthmatics problems. I. It is very possible to promote lifestyle developments that enhance aesthetics – including placing conditions on developments that add value (e.g. does the requirement for building colourbond sheds increase or decrease appeal).

TABLE 21 CONTINUED

The importance of the ecosystem service of life-fulfillment

Life-fulfilling services are defined as provision of aesthetic beauty, cultural, intellectual, and spiritual inspiration, sense of place, existence value, scientific discovery, and serenity.

A: Land-Use	B: Ha	C: Farmgate GVP $,000	Inputs to Production			Maintaining Natural Assets			J: Ranking	Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)
						Landscape Change				
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	E: Sensitivity of goods associated with land-use to a marginal change in life-fulfilling services	F: Manageability	G: Overall impact of land-use on capacity of natural assets to provide life fulfillment services	H: Significance of a marginal change in life fulfillment services on maintenance of natural assets	I: Manageability		
Water production	2,431,654	80,000	-	-	-	M-H	M-H	M	M	G. Water levels and quality are managed for many purposes. Some of these can be conflicting with life-fulfillment (e.g. low stream levels can impact heavily on aesthetic values – positively or negatively, depending on perception). H. Droughts in recent years demonstrate the effect on all industries dependent on water – considerable community angst resulted and the sense of fulfillment diminishes as lifestyles suffer from lower household incomes and recreational areas dependent on water became unavailable. In a dry continent and with all water-usage allocated, marginal changes have a big impact. I. Competing uses of water in a relatively dry land makes it difficult to fundamentally change current water regimes – our more pressing "needs" (e.g. water for domestic consumption) will take precedence over the "wants" implied by life-fulfillment. Longer-term perception of "need" is changing as people receive greater fulfillment out of better natural environments than artificial ones like lawns, and this might result in more water becoming available.
Recreation – land based		100,000+	H	L-M	L-M	-	-	-	L-M	D, E, F. Mostly forested public land
Recreation – water based			H	L-M	L-M	-	-	-	L-M	D, E, F. Different perceptions means some conflict (e.g. maintaining lakes and rivers in a full state or allowing natural fluctuations in flow and level)
Other public land – mostly treed	233,806			-	-	-	H	L-M	M	MG-I. As for "Forests – Hardwood" but excludes timber harvesting.
Areas of culture/ future options			H	M	M	-	-	-	H	D, E, F. Cultural values are generally localised and often managed because it happens to be there rather than as a product for which the ecosystem is managed.

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 22

The importance of the ecosystem service of regulation of climate

This service relates to the maintenance of climate stability by the services provided by plants, animals and other organisms. These services include regulating atmospheric composition and weather patterns, which in turn create the environment in which different plants and animals, including humans, live.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Variation in climate will lead to large fluctuations in agricultural yields from year to year. Variations are a normal part of the climatic cycle and are not addressed here. However, the capacity of land-uses and industries to adapt to changes in climate patterns are. Of particular interest is the sensitivity of different land-uses to small changes in climate. It will be difficult to manage impact of climate change on those land-uses that rely on regeneration of endemic native vegetation. Agricultural plants have shorter life cycles and plants can be genetically selected to adapt to climate change—transition times and costs of research could be large. Adaptation of softwood plantations would be difficult. Heat stress on dairy cattle could also be an issue.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). Climate change is occurring at a global scale because of the increases of greenhouse gases in the atmosphere (for example carbon dioxide and methane). The impact of the land-uses is assessed in this case using net emissions and emissions per unit of production as indicators of whether the natural assets are maintaining the sub-service of maintaining a stable atmospheric composition.

A: Land-Use	*B: Ha*	*C: Farmgate GVP $,000*	*Inputs to Production*			*Maintaining Natural Assets (Atmosphere)*			*J: Ranking*	*Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in climate	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide regulation of climate	**H:** Significance of a marginal change in regulation of climate on maintenance of natural assets	**I:** Manageability		
Dairying – on farm	112,000	453,348*	H	L-M	M	H	High: Greenhouse gas emissions will affect climate change at a global scale. Catchment will need to contribute to Australia's contribution to meeting global targets.	H	H	G. Very high emissions by both industry and per unit – wastes from 510,000 cows (methane, carbon), waterlogged pasture (nitrous oxide) in hotter months (irrigation season). H. Small change across the industry has major effects on the capacity of natural assets to assimilate greenhouse gases. I. Waterlogging can be readily reduced via increasing efficiency of water, and diet of cows can be altered to reduce methane emissions.
Fruit and Grapes		173,553*	H	H	L-M	-		-	H	D, E, F Change in number of chilly nights affects ability of trees to set fruit.
Vegetables – above ground	1,445	22999*	M	M	M	-		-	M	
Vegetables – below ground	310	5,185	L	M	M	-		-	L	
Intensive animals – pigs and poultry	n.a.	31,914	-	-	-	M-H		H	H	G. Piggeries are large emitters per unit of production, the size of the industry (240,000) is moderate. H. As for Forests – Softwood. I. Piggeries can be managed to minimise emissions – excess methane could be used for energy.
Intensive animals – fish	200	10,700	-	-	-	L		H	L	G. Low C emissions via algal growth that results from nutrients from fish farms. H. As for Forests – Softwood. I. Improvements on emissions can be made via sensitive handling of nutrients.
Intensive animals – horses			-	-	-	L-M		L	L	G. Low scale emission of those wastes which generate gases. H. As for Forests – Softwood. I. Horses generally need to have reasonable space – difficult to control inputs and outputs from the animal.

TABLE 22 CONTINUED

The importance of the ecosystem service of regulation of climate

This service relates to the maintenance of climate stability by the services provided by plants, animals and other organisms. These services include regulating atmospheric composition and weather patterns, which in turn create the environment in which different plants and animals, including humans, live.

A: Land-Use	*B: Ha*	*C: Farmgate GVP $,000*	*Inputs to Production*			*Maintaining Natural Assets (Atmosphere)*			*J: Ranking*	*Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in climate	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide regulation of climate	**H:** Significance of a marginal change in regulation of climate on maintenance of natural assets	**I:** Manageability		
Forests – Hardwood	439,445	7,500	H	M-H	L	L	High: Greenhouse gas emissions will affect climate change at a global scale. Catchment will need to contribute to Australia's contribution to meeting global targets.	L	M	G. Old growth forests are low emitters of greenhouse gases – but regenerating forests is a significant sequestration process. H. Minor change in land-use in forest not likely to result in forests becoming a significantly larger emitter. I. Forest emissions are difficult to control – extensive area. Relatively benign land-use (in terms of emissions).
Forests – Softwood	17,352	78,000	M-H	L-M	M	M		M	L-M	G. Softwood plantations are net sequesters of greenhouse gases. There is an issue of emission following harvesting. H. Marginal change in softwood forests – extent or management regime – could result in significant changes in emission. I. Management regimes and extent can be managed – carbon markets are emerging.
Food processors – dairy, fruit & tomatoes	n.a.	2,514,600	-	-	-	H		H	H	G. Waste from this land-use is high in organic matter and the land-use is a big energy user – high greenhouse gas emissions. H. Minor change significant. I. Improved waste management and energy usage costly – but achievable given ease of controlling point sources and high value of produce.
Water Production		80,000	H	M-H	L	-		-	M	D, E, F. Altered stream flows expected under climate change, which affect water availability. Manageability low as climate change must be managed at a global scale and has long lead times. Some degree of climate change is likely to occur within the Catchment.
Other public land – mostly treed	233,806		H	M-H	L	L		L	M	G-I. As for forests.

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 23

The importance of the ecosystem service of pest control

Pest control is the service of controlling organisms that are unwanted or cause damage to things that are valuable to people. Interactions among individuals and species in ecosystems control populations of the vast majority of potential pest species.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). Pest control may be required to facilitate habitat regeneration, maintain soil biota or the health of water systems. In turn pest control is dependent on having intact ecosystems that maintain biological balance. These issues are addressed under other services and therefore are not considered under pest control.

A: land-use	*B: Ha*	*C: Farmgate GVP – Input to other Catchment Good*	*D: Farmgate GVP $,000*	*Input to Production*			*H: Ranking*	*Explanatory Notes*
				E: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	F: Sensitivity of goods associated with land-use to a marginal change in pest control services	G: Manageability		
Dairying – on farm	112,000	453,348		H	M	M	M	E, F, G. Pest management is important in pasture management but is a modest issue because of the relatively small costs associated with its management per dollar return.
Fruit & Grapes	11,000		173,553	H	H	H	H	E, F, G. High use of pesticides: Fungus mainly, and insects and native birds (Musk Lorikeets)
Vegetables – below ground	310		5,185	L	H	H	L-M	E, F, G. Insects: only rates lowly because of the small scale of the industry.
Vegetables – above ground	1,445	22,999		M	H	H	H	E, F, G. Relatively high use of pesticides. Fungicides, black spot; grasses removed prior to planting
Grazing	1,223,000		236,315	H	H	M	H	E, F, G. Relatively important in pasture management, higher cost for management per unit compared to dairy. There are also impacts from loss of lambs associated with dogs and foxes and competition from kangaroos and rabbits.
Crops	122,800		57,600	H	H	H	H	E, F, G. Pests have a significant impact on crop yields
Hay and seed production	112,600 (all)	72,619		M	M-H	H	H	E, F, G. Lucerne and seed pasture represent a large investment that is susceptible to pest attacks.
Honey/Beeswax	n.a.		1,060	L	L-M	L-M	L-M	E, F, G. There is a threat of mite invasion (see pollination service paper)
Forests – Hardwood	439,445		7,500	M	M	M	M	E, F, G. Forests are multipurpose. pest control is necessary for many reasons but forests generally are not at high risk from pest invasion
Forests – Softwood	17,352		78,000	M	M	M	M	E, F, G. Pest control is low cost
Other public land	233,806			M	H	M	M	E, F, G. Other public land is multipurpose, especially for nature conservation values. Pests may have a significant impact on the survival of native species (especially fauna)

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 24

The importance of the ecosystem service of maintenance and provision of genetic resources

This service involves many ecosystem processes that maintain a diversity of ecosystems and species, within which are contained genes that are potentially of importance to people in a wide range of ways.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Maintenance of genetic resources can contribute capacity to develop new crops and other products, although this contribution is hard to assess at the level of this report. In general, high levels of biodiversity, for example among native grasslands, are expected to provide resilience of agricultural systems to disturbance and to confer tolerance to acid soils.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). In general, high levels of biodiversity are expected to confer resilience of native biota to disturbance. Maintenance of genetic resources is a key service for maintaining the natural asset of biota.

A: Land-Use	*B: Ha*	*C: Farmgate GVP $,000*	*Inputs to Production*			*Maintaining Natural Assets (Biota)*			*J: Ranking*	*Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in genetic variation	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to maintain genetic diversity	**H:** Significance of a marginal change in maintenance of genetic resources on natural assets	**I:** Manageability		
Grazing		236,315	H	L-M	M	H	H	M-H	H	G. Native grassland conservation can provide resilience and tolerance to acid soils – grazing is impacting heavily on these grasslands. H. As for Other Public Land, but including acid soil tolerance. I. Short-medium term improvements in pasture production can be achieved – requires improvement in knowledge and knowledge transfer.
Crops	122,800	57,600	H	L	H				L	
Forests – Hardwood	439,445	7,500	L	M	H	-	-	-	M	
Forests – Softwood	17,352	78,000	M-H	L	H	-	-	-	M	
Recreation		100,000	H	L	M					
Other public land – mostly treed	233,806		M-H	M-H	M	H	M	M	M	G. Isolated blocks of public land contain remnants that are banks of different genes, including those of threatened species. Direct grazing and edge effects from surrounding agricultural land can have a significant impact on vegetation and soils – and therefore regenerative capacity of these remnants. H. Potentially there is a large impact from a reduced bank of genes on ecological communities (e.g. diverse genetic stock is needed in response to the greenhouse effect and other threatening processes). I. Improving management of small blocks is a high priority – this can be achieved directly through funding public land managers or by developing cooperative management agreements with local people. Genetic migration can occur via corridors."
Areas of cultural/ future significance			H	M	M	-	-	-	M	

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 25

The importance of the ecosystem service of maintenance and regeneration of habitat

Habitat regeneration is the service of maintaining the living requirements for viable populations of plants, animals and other native organisms

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. The very existence of "habitat" itself is a primary reason for our use of the land in that way. From forests to houses and recreation, we value the environment in which we live and recreate. Habitat regeneration is an important input to maintaining areas of native vegetation that are used for recreation, protection of biodiversity and through the growth of wood as an input to production of native forest.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). Biota (vegetation and fauna) will degenerate in the absence of regeneration. A range of processes can reduce the capacity of habitat to regenerate including, for example, grazing, clearing and weed invasions.

A: land-use	*B: Ha*	*C: Farmgate GVP $,000*	*Inputs to Production*			*Maintaining Natural Assets*		*I: Manageability*	*J: Ranking*	*Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in habitat regeneration	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide habitat regeneration services	**H:** Significance of a marginal change in habitat regeneration services on maintenance of natural assets			
Dairying – on farm	112,000	453,348*				M	M-H	M	M	G. Clearing has largely finished, although remaining remnants on and adjacent to dairy farms are declining. Flooding regimes of wetland and terrestrial habitat from irrigation directly and indirectly from water table rise has a major impact. There are generally better examples of endangered vegetation communities on other land-uses – hence the impact is not rated as high. Irrigated pasture does seem to act as a food source for a number of bird species (e.g. Ibis). H. Marginal change in the way remnants are managed can have a significant impact – although the threat of a high water table does not auger well for long-term health. I. Health of remnants can be dramatically improved with sensitive management (especially grazing and irrigation).
Fruit & Grapes	11,000	173,553				H	H	H	H	G. There is significant pressure for further clearing severely depleted vegetation types on newer ground. H. Vegetation types associated with this land-use are generally not well represented. Clearing or insensitive management can have locally significant impact, and contributes to the broader cumulative incremental loss. I. Difficult to manage due to extremely high competition for primary land-use – fruit and grapes are high value.
Vegetables – above ground	1,445	22999*				M	H	H	H	G. There is significant pressure for further clearing severely depleted vegetation types on newer ground. H. As for Fruit & Grapes. I. Opportunity to increase sensitivity of clearing – perhaps including a whole of industry perspective.
Grazing	1,223,000	236,315				H	H	H	H	G. Native vegetation and soil structure breakdown continues to occur due to grazing, weed invasion, inappropriate fire regimes and other threatening processes. H. Vegetation types associated with this land-use are generally not well represented. Marginal change in the remnants across the industry would have a large effect. I. Some fencing and conservation management has been initiated. Competition for land-use (value of land for grazing compared with habitat) is not as high as for most other primary industries. There is limited capacity to implement more sustainable practices.

TABLE 25 CONTINUED

The importance of the ecosystem service of maintenance and regeneration of habitat

Habitat regeneration is the service of maintaining the living requirements for viable populations of plants, animals and other native organisms

A: land-use	*B: Ha*	*C: Farmgate GVP $,000*	*Inputs to Production*			*Maintaining Natural Assets*		*I: Manageability*	*J: Ranking*	*Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in habitat regeneration	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide habitat regeneration services	**H:** Significance of a marginal change in habitat regeneration services on maintenance of natural assets			
Crops	122,800	57,600				L-M	H	M	M	G. Cultivation impacts on newly regenerating native grasses and other vegetation -although the primary land-use has been established for a long time (little pressure for new sites to crop). H. A small change in cultivation practice, especially near remnants, could have a dramatic impact on quality and viability of remnants. Protection of native pastures and establishment of buffers around remnants may be priority actions. I. Although natural regeneration might be easy to encourage (by doing nothing), the value of crops means that there is strong competition for the land.
Intensive animals – horses						M	H	M	M	G. Few remnants remaining, very low value (relatively small scale). H. Impacts locally high. Because vegetation types are usually not well represented, contributes to cumulative incremental loss. I. Remnants can be fenced, alternative shelter can be provided, although at considerable cost.
Honey/Beeswax	n.a.	1,060				L	H	M	L-M	G. Probably very local impacts only. (Introduced bees invade hollows affecting native fauna.) Some native plants flowers are destroyed by feral bee visitation. H. Expect a marginal change in bee numbers to significantly impact on hollow dependent fauna. I. Management of commercial bee sites is possible – although once they have invaded hollows on a large scale, difficult to control.
Forests – Hardwood	439,445	7,500	H	H	H	M	L	H	H	G. Forests regenerate well following logging. It is argued that other uses of this land – e.g. 4 wheel driving – can be just as significant as logging. Firewood gathering removes habitat near human populations and has a high impact. H. Vegetation types within forests are well represented relative to lowland woodland and grassland communities (mainly on private land) and are generally regenerating well – a marginal loss within forests is therefore not as significant as a marginal loss on private land. I. Codes of Forest practice and firewood permits are easy ways to manage wood extraction – although this requires more diligence in auditing and follow-up than at present. Education and enforcement are used to improve sensitivity of other uses (e.g. recreation).
Forests – Softwood	17,352	78,000				L	H	H	L	G. Clearing for softwood plantations is largely finished although impacts on habitat were previously high. H. There is some evidence that remnant vegetation in softwood plantations is significant to biodiversity values, and it is expected that marginal changes in its management are therefore important. I. Relatively few landowners to communicate the issue of managing remnants to.

TABLE 25 CONTINUED

The importance of the ecosystem service of maintenance and regeneration of habitat

Habitat regeneration is the service of maintaining the living requirements for viable populations of plants, animals and other native organisms

A: Land-use	*B: Ha*	*C: Farmgate GVP $,000*	*Inputs to Production*			*Maintaining Natural Assets*		*I: Manageability*	*J: Ranking*	*Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in habitat regeneration	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide habitat regeneration services	**H:** Significance of a marginal change in habitat regeneration services on maintenance of natural assets			
Extractive Industries – Land & Water Based	n.a.	1,000				L	H	H	L	G. Very local scale impacts only. H. Large, local impacts occurring – marginal change would exacerbate this. I. Practices can be managed readily through license conditions and enforcement.
Housing – Urban	73,266	276,000				L	L-M	L	L	G. Damage is largely finished – urban areas are not encroaching on significant habitat. Some altered habitat (i.e. native species using houses and orchards as habitat). H. Habitat types impacted on generally not confined to poorly represented types. Marginal increase in demand for housing would not have as much impact other land-uses. I. Land values for housing in urban areas generally much greater than values for natural habitat – competition high.
Housing – Rural			H	M	M	M	H	H	H	G. An important issue, especially for rural subdivided blocks and hobby farms. These increase fragmentation of habitat and can introduce new threats from people, pets and weeds. H. Because remnants associated with this style of housing are relatively small, marginal changes in the remnants themselves impact dramatically on their ability to regenerate. I. On the positive side there is an opportunity for lifestyle/conservation estate developments that promotes habitat.
Water production	2,431,654	80,000				M	H	M	M	G. Water storages impact on habitat in water systems (dams alter on-site habitat dramatically and changed downstream flooding regimes of lakes, rivers and streams also dramatically alter habitat of water dependent flora and fauna). Cold storage water from Lake Eildon impacts on the ability of fish and other fauna species to procreate (thermal pollution). Original construction of dams would have had a significant impact at the time. H. Slight changes (volume and timing) can have major impacts on habitat and its ability to regenerate. I. Slight changes (volume and timing) are not difficult to achieve – although it is complex administratively and scientifically to optimise the changes. (Bulk Water Entitlement and Stream Flow Management Plans are being progressed.)
Recreation – water based						M	M	M	M	G. Fishing, boating and camping are controlled but have a minor impact on regeneration (generally the impact is localised). H. Habitat impacted on is reasonably well represented in protected areas. Although marginal change will impact on the ability of habitat to regenerate, this impact is not as great as elsewhere. I. Pressure for recreation is very large (e.g. Lake Eildon is the largest inland tourist destination in Victoria), which can be balanced by investment in management of users.

TABLE 25 CONTINUED

The importance of the ecosystem service of maintenance and regeneration of habitat

Habitat regeneration is the service of maintaining the living requirements for viable populations of plants, animals and other native organisms

A: Land-use	*B: Ha*	*C: Farmgate GVP $,000*	*Inputs to Production*			*Maintaining Natural Assets*		*I: Manageability*	*J: Ranking*	*Explanatory Notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in habitat regeneration	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide habitat regeneration services	**H:** Significance of a marginal change in habitat regeneration services on maintenance of natural assets			
Recreation – land based		100,000+	H	H	H	M-H	H	M	H	G. Vegetation and soil degradation from people disturbing native vegetation – walking trails, 4WD, trail-riding, etc. H. High numbers of people and impact of activities means high pressure – some areas of bush are extremely sensitive and therefore do not cope well with marginal change. I. A growing issue in the Catchment that will require careful management.
Other public land – mostly treed	233,806		H	H	M	H	M-H	M	H	G. Land in this category is distributed across the Catchment. Small and narrow blocks, particularly in lowland areas, are at risk from grazing, fragmentation and/or a number of other threatening processes. H. Many of the smaller blocks contain ecological communities that are poorly represented and are of high priority for protection and enhancement. Regeneration of quality habitat within these areas is often marginal. I. Improving management of small blocks is a high priority – this can be achieved directly through funding public land managers or by developing cooperative management agreements with local people.
Areas of culture/ future options			H	H	M				H	D, E, F. Regeneration of habitat is critical to maintain heritage and future use options.

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit is an input to fruit processing

TABLE 26

The importance of the ecosystem service of provision of shade and shelter

Shade and shelter is provided by vegetation. It ameliorates extremes in weather and climate at a paddock scale. Shade and shelter are required for both plants (in the case of wind damage to crops) and animals.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Availability of shade and shelter are generally not considered significant issues in the Catchment. However, there may be significant issues in relation to animal health and fruit production.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). Shade and shelter are required for the regeneration of habitat and the maintenance of water systems. Theses issues are addressed under the services of habitat regeneration and maintenance of healthy waterways.

A: Land-Use	B: Ha	C: Farmgate GVP $,000	Input to Production			G: Ranking	Explanatory Notes
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	E: Sensitivity of goods associated with land-use to a marginal change in shade and shelter services	F: Manageability		
Dairying – on farm	112,000	453,348*	H	M	M	H	D, E, F. Heat stress has many adverse effects on livestock, including reduced reproductive efficiency, decreased live weight gain, and reduced milk production.
Fruit and Grapes	11,000	173,553	H	M	M-H	H	D, E, F. Orchards are generally protected by shelter – mostly non-indigenous plantings (e.g. poplars for kiwi fruit, casuarinas for pome fruit). This shelter protects from wind, temperature extremes and also spray drift (from biocide application). Extensive built structures are sometimes provided for high value fresh produce (e.g. nashi fruit, cherries) to protect from birds.
Vegetable – above ground	1,445	22,999	L-M	M	M	L-M	D, E, F. Some evidence of wind damage to broad leafed crops
Vegetables – below ground	310	5,185	L	M	M	L-M	D, E, F. Some evidence of wind damage to broad leafed crops
Grazing	1,223,000	236,315	H	M	M-H	H	D, E, F. No huge sheep losses, but higher growth in beef and sheep, less sunburn, higher water-use efficiency (don't have to drink as much)
Crops – Cereals	104,700	51,495	M	M-H	M	H	D, E, F. Evaporation and transpiration losses from crops can be significant, especially when they are exposed to hot, drying winds.
Hay and seed production	112,600 (all)	78,604*	M	M	M	M	D, E, F. Protection from wind can enhance hay and seed yield, as crops are less likely to be damaged by strong winds and more likely to retain their seed.
Intensive animals – horses			H	M	L-M	M	D, E, F. Built shade readily substitutes for natural, although natural shade is generally much cooler than that provided by built structures, as plants do not store heat and contribute to further cooling through the evaporation and transpiration from their leaves.
Housing	73,266	276,000	H	M-H	H	H	D. Construction is a significant industry. E. Impact of wind is significant in regulating building temperature. F. Highly manageable through appropriate sub-division design and investment in shelter belts.

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 27

The importance of the ecosystem service of maintenance of soil health

Soil health services include: providing a physical medium for plants to grow in; providing moisture and nutrients to plants; maintaining soil biota that regenerate soils; supporting the growth of plants; and supporting the transport of water and nutrients in the landscape.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Soil is integral to the growth of all plants. Soil fertility is considered as the key input to the production of plants and crops. As with most of Australia, Goulburn Broken soils are generally old and fragile and hence are sensitive to marginal changes in land-use. In economic terms, soils producing high value crops justify the large cost of soil management (fertiliser and tillage).

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). The impact of land-uses on soil structure, acidity, compaction and soil biota are considered in ranking the service.

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*			*J: Ranking*	*Explanatory notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in soil health	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide soil health services	**H:** Significance of a marginal change in soil health services on maintenance of natural assets	**I:** Manageability		
Dairying – on farm	112,000	453,348*	H	H	H	M	H	H	H	G. Water logging, soil compaction and breakdown of soil structure (from machinery, stock, cultivation) and excess nutrient supply possibly leading to acidification are all important issues but are not considered to have a high impact on natural assets under current management. Nutrient run off to water ways can be a problem. H. Given the highly productive nature of dairy pasture, a small change in soil health results in large change in ability of soils to grow grass and other plants. I. Fertile soils are essential for this land use. Heavy use of fertilisers is required, with high costs and high benefits. Manageability is high. There is a lack of understanding of the relationship between fertiliser and soil biota in promoting pasture growth.
Fruit & Grapes	11,000	173,416	H	H	H	M-H	H	M-H	H	G. Soil acidification is an important issue with in excess of 45% of orchards in the Catchment dropping below a pH of 5. Compaction is also an issue. H. Similar to Dairy Farming; changes in soil fertility will result in large changes in the ability of soils to grow plants. I. As for Dairying.
Vegetables – above ground	1,445	22,999*	M	H	L-M	M-H	H	M	H	G. High use of inputs (including pesticides) leads to loss of soil health via reduced soil microbial activity. Yield declines evident within 2-3 years requiring long spelling between use. Excessive use of ammonia-based fertilisers has, in some instances, caused severe topsoil and subsoil acidification and the leaching of potassium. H. As for the other plant growing land uses – any change in soil health services has significant impacts on natural assets.
Vegetables – below ground	310	5,185	L	H	H	L-M	H	H	L-M	G. This land-use impacts on soil structure in the long term, however the small spatial scale of the land-use leads to a lower ranking. H. Fertility a key issue for yields. I. As for Dairying.

TABLE 27 CONTINUED

The importance of the ecosystem service of maintenance of soil health

Soil health services include: providing a physical medium for plants to grow in; providing moisture and nutrients to plants; maintaining soil biota that regenerate soils; supporting the growth of plants; and supporting the transport of water and nutrients in the landscape.

A: Land-Use	B: ha	C: Farmgate GVP $,000	Inputs to production			Maintaining natural assets			J: Ranking	Explanatory notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	E: Sensitivity of goods associated with land-use to a marginal change in soil health	F: Manageability	G: Overall impact of land-use on capacity of natural assets to provide soil health services	H: Significance of a marginal change in soil health services on maintenance of natural assets	I: Manageability		
Grazing	1,223,000	236,315	H	H	L-M	H	M	M	H	G. Nitrification of soils – from clover production – has lead to increases in the acidity of soils and an increase of 1 pH unit in acidity of major rivers; loss of calcium is also an issue. H. As for Dairying; soil health is important for pasture productivity – a recognisable decline in productivity of neglected soils indicates that soil health service is declining. I. Lime helps, so do perennial grasses which take up nitrates in the long-term. However, capacity to use fertilisers is limited by poor returns to the industry.
Crops	122,800	57,600	H	H	H	H	H	H	H	G. Soil fertility, structure, moisture availability, organic matter, nutrient cycling and acidity are all heavily impacted on by crop production. H. As for Dairying. I. Very high ranking due to poor tillage practices in the past. Improved tillage and cropping technologies may reduce impacts on soil health.
Hay and seed production	112,600 (all)	72,691*	H	H	H	M-H	H	H	H	G. Breakdown of soil structure from tillage, acidification from fertiliser application. Similar to Crops. H. As for Crops. I. As for Crops – Establishment of perennial grasses may improve soil structure.
Intensive animals – horses						M-H	H	M	M	G. Compaction and erosion of soils by trampling is an issue. Horses are largely fed imported feed rather than pasture, so fertility is less of an issue than for other land-uses. H. Small increases in soil compaction may result in large changes in ability of grass cover to establish and/or remain. I. Vegetation cover could be maintained by more sensitive management of soil.
Forests – Hardwood	439,445	7,500	H	M	M	L-M	L	M-H	M	G. Some breakdown of soil structure from timber harvesting operations (roads/ machinery). H. Marginal change in soil health services not expected to have high impact on natural assets in forests. I. Soils will generally be maintained with the native ecosystem in place. Fertiliser can be added to accelerate growth.
Forests – Softwood	17,352	78,000	M-H	M-H	M	M	H	M	M	G. Evidence shows that softwood plantations can lead to acidification of soils on-site. H. For soils that are prone to acidification – any marginal change in soil health services could have a large impact on natural assets on-site. I. Fertiliser is applied in private land plantations to lift productivity (historically this did not occur in public land plantings – all public land plantings have been converted to private land).

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 28

The importance of the ecosystem services of maintaining healthy waterways

The state of water bodies can be described by a near–natural balance of fish, invertebrates, plants and algae, with the appropriate in–stream, riparian and flood plain habitats for these organisms to live in. Water quality relates to the chemical composition of water and the state of water bodies. Chemically it is desirable that water is free of artificial chemicals and contains a level of chemicals found in nature, for example phosphate, nitrate and trace metals.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/ industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. The dependence of each land-use/industry on water quality is assessed. Marginal changes in water quality are more important for some industries than others. Most are real, some are perceptions that translate into real market issues (e.g. the impact of blue–green algal blooms on the 'clean green' image of agricultural products).

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). The contribution/impacts of each land-use/ industry on the state of waterways is assessed. Linked issues including erosion, filtration, waste absorption and water flow are addressed under separate ecosystem services.

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*			*J: Ranking*	*Explanatory notes (mostly relating to maintaining natural assets, as inputs to production are usually self–evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in healthy waterways	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide healthy waterways	**H:** Significance of a marginal change in waterway health services on maintenance of natural assets	**I:** Manageability		
Dairying – on farm	112,000	453,348*				H	High: Waterways in the Catchment are already under stress. A major challenge is to stabilise and rehabilitate waterway health	H	H	G. Historically this land-use has had a large impact. Superphosphate, carbon and nitrogen run–off into waterways are the main issues. Site–specific impacts of bacteria and viruses in drainage (leptospirosis) are also important. Bovine Johnnes Disease is an example. H. As for Other Public Land. I. There have been major improvements in nutrient management in the last few years – e.g. re–use dams, drains, wetland rehabilitation and construction. Perhaps up to 70% of nitrogen is taken up in drains on–farm. The costs are high, but so are the benefits. See also Waste Absorption.
Fruit & Grapes	11,000	173,553				M		M–H	H	G. Fungicides (mainly) and pesticides, nitrogen and phosphorus (from blood and bone and other fertilisers) potentially enter waterways. Some furrow irrigated orchards remain – nitrogen, carbon and phosphorous are filtered by soils and if less water is applied there is less run–off and less impact. H. As for Other Public Land, and including the impact of fungicides and pesticides. I. Increased water–use efficiencies are encouraged (e.g. micro–sprays). See also Waste Absorption.
Grazing	1,223,000	236,315				H		M	H	G: High impact from phosphate, nitrogen and acid run off from nonpoint sources. I: Relatively difficult to manage because of the broad acre nature of industry.
Intensive animals – pigs and poultry	n.a.	31,914	M	L	H				L–M	
Intensive animals – fish	200	10,700	L	M	H				L–M	

TABLE 28 CONTINUED

The importance of the ecosystem services of maintaining healthy waterways

The state of water bodies can be described by a near–natural balance of fish, invertebrates, plants and algae, with the appropriate in–stream, riparian and flood plain habitats for these organisms to live in. Water quality relates to the chemical composition of water and the state of water bodies. Chemically it is desirable that water is free of artificial chemicals and contains a level of chemicals found in nature, for example phosphate, nitrate and trace metals.

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*			*J: Ranking*	*Explanatory notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self–evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land–use to a marginal change in healthy waterways	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to provide healthy waterways	**H:** Significance of a marginal change in waterway health services on maintenance of natural assets	**I:** Manageability		
Forests – Hardwood	439,445	7,500	–	–	–	M	High: Waterways in the Catchment are already under stress. A major challenge is to stabilise and rehabilitate waterway health	H	H	G. Timber harvesting (including impact of vehicles) and recreational activities (also includes impact of vehicles) in hardwood forests have a moderate impact on increased water turbidity via increased sediments. H. Marginal change (e.g. harvesting close to streams) can result in more sediments (and nutrients) entering streams, contributing to water quality problems. I. Forests near large streams have a positive impact by providing buffers and riverine habitat.
Forests – Softwood	17,352	78,000				L		M	M	G. Softwood plantations are generally not located close to streams, and therefore softwood operations (including establishment, maintenance and harvesting) do not impact significantly on waterways. H. Streams are vulnerable – especially in dry times – to blue green algal blooms. I. Enforcement of Code of Forest Practices could help control adverse impacts.
Food processing – Dairy, fruit, tomatoes	n.a.	2,519,600	H	H	H				H	
Water production	2,431,654	80,000	H	H	H	–		–	H	
Other public land – mostly treed	233,806					L		L	L	G. As for Forests – Hardwood except no timber harvesting. H. Streams are vulnerable – especially in dry times – to blue green algal blooms. I. Control of uses (e.g. recreation) relatively easy to achieve.
Recreation – water based			M	H	M				H	D, E, F. It is felt that a decrease in water quality in the Catchment, particularly in the upper Catchment, would have significant impacts on the recreation industry (e.g. fishing)

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing.

TABLE 29

The importance of the ecosystem services of filtration and erosion control

Filtration and erosion control relate to the functions performed by soil components (including soil biodiversity) and vegetation in minimising soil loss and filtering sediments from water to improve water quality.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Filtration and erosion control make a direct contribution to the production of clean water, which is a key input to many industries in the Catchment.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). Filtration and erosion control contribute directly to the maintenance of soil and water resources, both in their role as stabilising processes in native ecosystems and in the assimilation and stabilisation of additional sediments mobilised by human activities, including agricultural production.

The impact of land-uses and industries is assessed in the table separately for filtration and erosion control. Impact on the ability of natural assets to maintain filtration services is assessed in terms of sediments and turbidity in water systems (rivers, lakes and wetlands). Impact on erosion control is assessed in terms of soil loss resulting in a reduced stock of fertile soils for future use. Soil loss through gully, sheet and wind erosion is an important longer term issue in some grazing and cropping regions."

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*					*L: Ranking*	*Explanatory notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)*
						Filtration		Erosion control				
			D: Overall importance of good associated with land-use based on ha and/or $ value	**E:** Sensitivity of good associated with land-use to marginal change in filtration and erosion control services	**F:** Manageability	**G:** Overall impact of land-use on the capacity of natural assets to provide filtration services	**H:** Significance of a marginal change in filtration services on maintenance of natural assets	**I:** Overall impact of land-use on the capacity of natural assets to provide erosion control services	**J:** Significance of a marginal change in erosion control services on maintenance of natural assets	**K:** Manageability		
Dairying – on farm	"112,000	453,348*	-	-	-	L-M	High: Sedimentation is a critical issue for maintenance of water quality	L	High: Soil loss reduces stock of soils incrementally. A key issue because all soil loss is significant in the long term	L	L	G, I. Soil loss is a minor issue under current management – usually dairy paddocks are well vegetated. The losses that do occur are often nutrient rich which impacts on vegetation providing filtration services and on water systems (eutrophication). K. Management for soil retention can be achieved by reducing grazing pressure – but the cost-effectiveness of this strategy is questionable.
Fruit & Grapes	11,000	173,553	-	-	-	L		L		L	L	G. Soil loss is a minor issue under current management. Spray residues have some minor impacts on water systems when inappropriately managed. K. Manage cover crops between rows to maintain soil structure and minimise runoff.
Vegetables – above ground	1,445	22,999*	-	-	-	L-M		M-H		M	M-H	G, I. Minor soil mobilisation at a local scale. Excess clearing of remnant vegetation has occurred. Sprays and spray residues impact on soil fertility. K. Soil conservation practices can improve soil retention. Minimisation of chemical use could reduce chemical effects but has costs.
Vegetables – below ground	310	5,185	-	-	-	L		M		M	L	G, I. Soil loss is at a local scale only, thus impact Catchment-wide is low. K. Soil conservation practices can improve soil retention.
Grazing	1,223,000	236,315	-	-	-	M		M-H		H	H	G, I. Soil loss and turbidity are particularly significant issues at times of drought – especially in areas with soils more susceptible to breakdown and erosion. Relative overall impact is slightly greater on soil retention than on filtration services. K. Improved stock management is very achievable – e.g. stocking rates can be reduced, gullies and streams can be fenced.

TABLE 29 CONTINUED

The importance of the ecosystem services of filtration and erosion control

Soil health services include: providing a physical medium for plants to grow in; providing moisture and nutrients to plants; maintaining soil biota that regenerate soils; supporting the growth of plants; and supporting the transport of water and nutrients in the landscape.

A: Land-Use	B: ha	C: Farmgate GVP $,000	Inputs to production			Maintaining natural assets					L: Ranking	Explanatory notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self-evident)
						Filtration		Erosion control				
			D: Overall importance of good associated with land-use based on ha and/or $ value	E: Sensitivity of good associated with land-use to marginal change in filtration and erosion control services	F: Manageability	G: Overall impact of land-use on the capacity of natural assets to provide filtration services	H: Significance of a marginal change in filtration services on maintenance of natural assets	I: Overall impact of land-use on the capacity of natural assets to provide erosion control services	J: Significance of a marginal change in erosion control services on maintenance of natural assets	K: Manageability		
Crops – Cereals	104,700	51,857	-	-	-	M	High: Sedimentation is a critical issue for maintenance of water quality	M-H	High: Soil loss reduces stock of soils incrementally. A key issue because all soil loss is significant in the long term	H	H	G, I. Some cropping practices (e.g. tillage) result in breakdown of soil structure and consequent erosion. K. It is feasible to improve cropping practices that promote soil retention.
Intensive animals – horses			-	-	-	L		H		L	L	G. This land-use has a minor impact on water systems (via turbidity and sedimentation) due to the relatively small areas involved. I. Soil loss within those small areas can be high. K. It is possible to maintain vegetation cover on soil with more sensitive management (e.g. reduced stocking rates).
Forests - Hardwood	439,445	7,500	-	-	-	M		M		M-H	M	G, I. Timber harvesting (including the impact of vehicles & roads) and recreational activities (also includes impact of vehicles) in hardwood forests have a moderate impact on water quality through mobilisation of sediments and reduced capacity to recapture sediments and mobilised nutrients. K. Forests near large streams have a positive impact by providing good buffers and riverine habitat.
Extractive Industries – Water Based	n.a.		L	H	H	-		-		-	L	D, E, F. Mining of sand from stream beds would be impacted on by a small change in erosion control.
Extractive Industries – Land Based	n.a.	1,000	-	-	-	L		M		H	L	G. This land-use has a limited off-site impact on water systems, although on-site impacts can be high. The significance and extent of the industry in the Catchment is declining. I. Loss of soils also limited to on-site. K. Conditions on licences effectively manage the issue.
Water production	2,431,654	80,000	H	H	H	-		-		-	H	D, E, F. Sedimentation affects water quality.
Other public land – mostly treed	233,806	-	-	-	-	L		L		L-M	L	G, I. As for Forests – Hardwood (above) except that this land-use does not include timber harvesting. K. Control of access and uses (e.g. recreation) is relatively easy to achieve – although there will always be a need for some vehicle tracks.

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 30

The importance of the ecosystem service of regulation of river flows and ground water levels

This service relates to the collection and distribution of water through rivers, lakes, wetlands and ground water systems

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question "Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?". The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Many dairy producers have developed some dependence on "sales" (extra) water as well as their "water right" for maximising production – they have often developed infrastructure with the expectation of sales water being available. Other industries use relatively less water and have relatively more security over what they need for maximum production. Manageability depends largely on the market for water, and the cost of water versus the value of goods produced from it. Water reforms in recent years have resulted in competition that ultimately favours production of higher value goods. The quantities of water needed to maintain production of recreation, housing and hydroelectricity values are relatively large.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). In this case, we have considered impacts of land-uses/industries in relation to three sub–services: maintaining hydrological balance; maintaining water flows; and flood mitigation.

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*							*L: Ranking*	*Explanatory notes (mostly relating to maintaining natural assets, as inputs to production are usually self–evident)*
						Hydrological balance		*Water Flow*		*Flood Mitigation*		*M: Manageability*		
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land–use to a marginal change in water availability	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to maintain hydrological balances	**H:** Significance of a marginal change in maintenance of hydrological balance on natural assets	**I:** Overall impact of land-use on the capacity of natural assets to maintain water flows	**J:** Significance of a marginal change in maintenance of water flows on natural assets	**K:** Overall impact of land-use on the capacity of natural assets to provide flood mitigation services	**L:** Significance of a marginal change in flood mitigation services on maintenance of natural assets			
Dairying – on farm	112,000	453,348*	H	H	H	H	H	L–M	High: Water flow in dry times has been reduced below desirable levels resulting in impacts such as algal blooms	Unknown: Flooding is a key issue in the Goulburn Broken. However, we are unclear of the extent to which different land-uses contribute to the problem. The question is one of speed and volume of run–off in high rainfall events	High in general. However do all land-uses contribute to flooding in the same extent or can this be measured at a Catchment scale?	H	H	G. Irrigation practices, especially flood irrigation, on dairy farms can impact dramatically on watertables. If breakdown of soil structure occurs, it leads to changes in infiltration rates. H. Minor change in water table control service dramatically affects pasture production. It is also worth noting that the impact on natural assets (trees, wetlands etc) is high because the water table is managed to keep it below 2m only – there is a large cost to manage it deeper. The 2m level is satisfactory for agriculture but native vegetation is deeper rooted. I. High water usage impacts greatly on water storage levels. J–L. See notes for Hardwoods. K. Barmah Forest and the wetlands of the forest along the Lower Goulburn River play a major role in flood mitigation. L. Levee banks and clearing have decreased the extent of this service in some areas. M. All three services are very manageable. Water tables are managed through mitigation measures (e.g. drainage, water use efficiency programs). However, it is questionable whether ecosystem services have a major role to play in managing water table in irrigation areas (groundwater pumps may be the only cost effective solution at the intensive scale). Irrigation is not expected to have a high impact on water flows – allocations are made within a capped system (although irrigation is a heavy user).
Fruit & Grapes	11,000	173,553	H	M–H	H	L–M	H	M–H				H	H	G. Irrigation practices have a much less dramatic impact (mainly drip or spray) than dairying (mainly flood). Viticulture is least impacting although clearing to put new areas under grapes reduces the flood controlling services from large trees. H. Minor change in the water table control service dramatically affects pasture production. I. Relatively high water usage impacts on water storage levels.

TABLE 30 CONTINUED

The importance of the ecosystem service of regulation of river flows and ground water levels

This service relates to the collection and distribution of water through rivers, lakes, wetlands and ground water systems

A: Land-Use	B: ha	C: Farmgate GVP $,000	Inputs to production			Maintaining natural assets							N: Ranking	Explanatory notes (mostly relating to maintaining natural assets, as inputs to production are usually self–evident)
						Hydrological balance		Water Flow		Flood Mitigation		M: Manageability		
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	E: Sensitivity of goods associated with land–use to a marginal change in water availability	F: Manageability	G: Overall impact of land-use on capacity of natural assets to maintain hydrological balances	H: Significance of a marginal change in maintenance of hydrological balance on natural assets	I: Overall impact of land-use on the capacity of natural assets to maintain water flows	J: Significance of a marginal change in maintenance of water flows on natural assets	K: Overall impact of land-use on the capacity of natural assets to provide flood mitigation services	L: Significance of a marginal change in flood mitigation services on maintenance of natural assets			
									High: Water flow in dry times has been reduced below desirable levels resulting in impacts such as algal blooms	Unknown: Flooding is a key issue in the Goulburn Broken. However, we are unclear of the extent to which different land-uses contribute to the problem. The question is one of speed and volume of run–off in high rainfall events	High in general. However do all land-uses contribute to flooding in the same extent or can this be measured at a Catchment scale?			J–L. See notes for Dairying. M. Water tables are very manageable in the irrigation zone – high value products mean it is cost–effective to invest in groundwater pumps and water use efficiency programs.
Vegetables – above ground	1,445	22,999*	M	L	H	L	H	L				H	M	G–M. As for Dairying but smaller scale. Intense sites can have significant impacts on waterways.
Vegetables – below ground	310	5,185	L	L	H	L	H	L				H	L–M	G–M. As for Dairying but smaller scale.
Grazing	1,223,000	236,315				M	H	M				M	M	G–M. As for Hay and Seed. In addition, over–grazing in hill country contributes to downstream salinity and water quality problems. Tree planting is a management option, although it is expensive. Proliferation of farm dams on subdivided properties is an emerging issue for water availability.
Crops	122,800	57,600				H	H	M				M	H	H. Short–rooted annual crops allow rainfall to infiltrate to the water table over large areas – high impact. I. Minor changes (e.g. increases in cropping area where perennials grew) would cause increases in local dryland salinity problems. J. Increased water flow is expected from annual crops – especially outside the growing season – which leads to a moderate impact. Most of the run–off will be below water storages, however. L–M. Unknown impact on flood mitigation, although we suspect that high vegetation cover decreases run–off rates and thus has a high impact on flooding. N. Water infiltration to the water table and extent of run–off can be managed relatively easily through crop rotation and summer cropping. Cost effectiveness in some places is questionable.
Hay and seed production	112,600 (all)	72,691*				L–M	H	M				M–H	H	G. Short–rooted annuals lead to high recharge of the water table, although this is offset by lucerne and other perennial pastures decreasing recharge. The overall impact depends on grazing pressure and pasture used. H. Minor changes can contribute to large local problems. M. As for Crops
Intensive animals – pigs and poultry	n.a.	31,914	M	L–M	H	–	–	L				H	M	I–M. As for Food Processing.
Intensive animals – fish	200	10,700	L	L	H	–	–	L				H	L	I–M. As for Food Processing.

TABLE 30 CONTINUED

The importance of the ecosystem service of regulation of river flows and ground water levels

This service relates to the collection and distribution of water through rivers, lakes, wetlands and ground water systems

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*							*N: Ranking*	*Explanatory notes (mostly relating to maintaining natural assets, as inputs to production are usually self–evident)*
						Hydrological balance		*Water Flow*		*Flood Mitigation*		*M: Manageability*		
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land–use to a marginal change in water availability	**F:** Manageability	**G:** Overall impact of land-use on capacity of natural assets to maintain hydrological balances	**H:** Significance of a marginal change in maintenance of hydrological balance on natural assets	**I:** Overall impact of land-use on the capacity of natural assets to maintain water flows	**J:** Significance of a marginal change in maintenance of water flows on natural assets	**K:** Overall impact of land-use on the capacity of natural assets to provide flood mitigation services	**L:** Significance of a marginal change in flood mitigation services on maintenance of natural assets			
Intensive animals – horses			H	L–M	H	L	H	L	High: Water flow in dry times has been reduced below desirable levels resulting in impacts such as algal blooms	Unknown: Flooding is a key issue in the Goulburn Broken. However, we are unclear of the extent to which different land-uses contribute to the problem. The question is one of speed and volume of run–off in high rainfall events	High in general. However do all land-uses contribute to flooding in the same extent or can this be measured at a Catchment scale?	H	L–M	G. We expect water demands to be insignificant and water table/ salinity impacts to be moderate – small scale. H. See notes for Dairying. I–M. As for Food Processing.
Forests – hardwood	439,445	7,500				M	L	H				M	M	G. Trees and other deep–rooted Hardwood perennials in forests take up water, which helps control the regional water table (these forests are located across the Catchment, although most of it is in the high country). The hydrological system in the Catchment is complicated, thus the trees located in the upper Catchment may not play as important a role in hydrological control as the traditional model may suggest. H. Any slight change in the forests' role in maintaining the water table will not have a great impact on natural assets, although at a local scale this can be very important. I. Water use by forests means there is relatively less water flowing into storages. J. Forests cover a huge area, often above water storages. Any marginal decrease in water flowing into storages would reduce the volume available for dilution and contribute further to water quality (e.g. blue–green algae) problems. However, the role of forests in filtering water increases water quality. K. Barmah Forest and the wetlands of the forest along the Lower Goulburn River play a major role in flood mitigation. L. Levee banks and clearing have decreased the extent of this service in some areas. M. These forests are on public land, and therefore are able to be managed reasonably easily – although the multiple purposes of their use can be conflicting.
Forests – Softwood	17,352	78,000				M	?	L–M				M–H	L–M	G–J. It is not known by the authors what impact softwood plantations have on tables and water flows. The large plantation water east of Euroa could be significant – at least locally K–L. Not expected to have significant impact on flooding. M. Management possibilities via code of practice changes as knowledge improves.
Food processing – dairy, fruit and tomatoes	n.a.	2,519,600	H	L	H	–	–	L–M				M	M	I. Water demand not expected to be great. J–L. See notes for Hardwoods. M. We expect that improving on current management is possible (especially water use efficiency), but at relatively large costs. Intensive management means a high level of control of relatively small water volumes.

TABLE 30 CONTINUED

The importance of the ecosystem service of regulation of river flows and ground water levels

This service relates to the collection and distribution of water through rivers, lakes, wetlands and ground water systems

A: land-use	B: ha	C: Farmgate GVP $,000	Inputs to production			Maintaining natural assets							N: Ranking	Explanatory notes (mostly relating to maintaining natural assets, as inputs to production are usually self–evident)
						Hydrological balance		Water Flow		Flood Mitigation		M: Manageability		
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	E: Sensitivity of goods associated with land–use to a marginal change in water availability	F: Manageability	G: Overall impact of land-use on capacity of natural assets to maintain hydrological balances	H: Significance of a marginal change in maintenance of hydrological balance on natural assets	I: Overall impact of land-use on the capacity of natural assets to maintain water flows	J: Significance of a marginal change in maintenance of water flows on natural assets	K: Overall impact of land-use on the capacity of natural assets to provide flood mitigation services	L: Significance of a marginal change in flood mitigation services on maintenance of natural assets			
Housing	73,266	276,000	M	L	M	–	–	L	High: Water flow in dry times has been reduced below desirable levels resulting in impacts such as algal blooms	Unknown: Flooding is a key issue in the Goulburn Broken. However, we are unclear of the extent to which different land-uses contribute to the problem. The question is one of speed and volume of run–off in high rainfall events	High in general. However do all land-uses contribute to flooding in the same extent or can this be measured at a Catchment scale?	H	M	I. Housing demands relatively low water supply. J–L. See notes for Hardwoods. M. Historically, location of houses in flood prone areas resulted in construction of protective levees in less than ideal places – these levees affect water flows and translocate flooding. New developments are very manageable – flood mitigation is taken into account in sophisticated planning for new houses.
Water production	2,431,654	80,000	High: circular reference water – water									H		
Hydroelectric water			?	L–M	L–M	–	–	L–M				H	H	I. Water flows can be affected in times of low storage volumes by the priority to ensure security of water for hydroelectricity. This reduces flexibility for release of water for environmental flows. J–L. See notes for Hardwoods. M. Likely to be manageable through bulk water entitlement processes and full costing approach that could identify alternative electricity generation sources.
Recreation – water based		M–H	M–H	L–M								L	H	K–L. See notes for Hardwoods. M. The strong role of this service as an input to production is the main reason for the "moderate" ranking.
Other public land – mostly treed	233,806					L–M	L	H				M	M	H–M. As for Forests – hardwood (above). Most of this land is in the upper areas of the Catchment.

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

TABLE 31

The importance of the ecosystem service of regulation of waste absorption and breakdown

These services include the roles played by various organisms (above and below ground, and aquatic) in absorbing and breaking down wastes from people, their production systems, and nature.

INPUTS TO PRODUCTION The columns under this heading contribute to an overall assessment of the importance of the ecosystem service in relation to production. The first column assesses the overall importance of the land-use/industry and the goods produced by it, in area and dollar terms. The second column addresses the question Will a marginal change in the delivery of the ecosystem service significantly affect production of goods?. The third column assesses the capacity to manage the service at reasonable cost and for significant benefit. Waste absorption and breakdown make an important contribution to water production where waste absorption works to improve water quality.

MAINTAINING NATURAL ASSETS Columns under this heading contribute to an overall assessment of the impact of the land-use on the capacity of natural assets in the Catchment to provide the service, and the impact that a marginal change in the service will have on the maintenance of natural assets (soil, water, biota, atmosphere). Waste absorption is a natural function performed by ecosystems that have the capacity to assimilate wastes. However, ecosystems can only absorb a certain quantity before the wastes can no longer be assimilated resulting in undesirable outcomes. Nitrogen and phosphorus loads in water ways are considered at a Catchment scale with a number of on–site wastes including sodium, bacteria, biocides and heavy metals considered at a site scale.

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*			*J: Ranking*	*Explanatory notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self–evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in waste absorption	**F:** Manageability	**G:** Overall impact of land–use on the capacity of natural assets to provide waste absorption services	**H:** Significance of a marginal change in the capacity of natural assets to provide waste absorption services	**I:** Manageability		
Dairying – on farm	112,000	453,348*				H	HIGH: particularly for P, N, Carbon, Salt and Acidity in waterways, any change in waste absorption services will have significant impact on natural assets.	H	H	G. This land-use can be a relatively large contributor of wastes and nutrients (e.g. superphosphate run–off) in waterways although a large amount (perhaps 70%) is taken up in drains on–farm (rushes etc). H. Any change in waste absorption services will have a significant impact on natural assets as waterways are often at threshold levels for problems such as algal blooms. I. Nutrient management is the major issue although on farm measures can significantly reduce nutrient runoff.
Fruit & Grapes	11,000	173,553				H		H	H	G. Use of fungicides, pesticides and fertilisers (e.g. blood and bone). H. Any change in waste absorption services will have a significant impact on natural assets as waterways are often at threshold levels for problems such as algal blooms. I. N & P are filtered in soils – if less water is applied there is less run–off thus reducing impact on waterways. Increased water–use efficiencies are encouraged (e.g. micro sprays) although some furrow irrigated orchards remain.
Vegetables – above ground	1,445	22,999*				M		L–M	M-H	Note: Impact of wastes on soils captured in the table on the ecosystem service of "Maintenance of Soil Health". G. This land-use makes a relatively large contribution to total loads of biocides in waterways locally, although the Catchment–wide extent is not large. H. We suspect that biocides are not at threshold levels (i.e. small changes will not lead to large changes in natural assets). I. This is currently a high input system driven by consumer demand for unblemished appearance of products. It may be possible to reduce chemical inputs and increase application efficiencies.
Vegetables – below ground	310	5,185				L		M–H	L	G. Although the impact of fertilisers and biocides can be significant on site, the small extent of the industry results in the lower ranking (Depending on management though, there is a reasonable potential for leaching from potato cropping due to high fertiliser inputs and frequent cultivation). H. We suspect that biocides are not at threshold levels (i.e. small changes will not lead to large changes in natural assets). I. It may be possible to reduce chemical inputs and increase application efficiencies.
Grazing	1,223,000	236,315				H		M	H	G. A diffuse source of runoff. H. We suspect that biocides are not at threshold levels (i.e. small changes will not lead to large changes in natural assets).

TABLE 31 CONTINUED

The importance of the ecosystem service of regulation of waste absorption and breakdown

These services include the roles played by various organisms (above and below ground, and aquatic) in absorbing and breaking down wastes from people, their production systems, and nature.

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*			*J: Ranking*	*Explanatory notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self–evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in waste absorption	**F:** Manageability	**G:** Overall impact of land–use on the capacity of natural assets to provide waste absorption services	**H:** Significance of a marginal change in the capacity of natural assets to provide waste absorption services	**I:** Manageability		
							High particularly for P, N, Carbon, Salt and Acidity in waterways, any change in waste absorption services will have significant impact on natural assets.			I. Management options include reducing grazing pressure to allow for waste absorption by vegetation, and increasing waterway buffering. However, both options can be expensive, thus only a medium ranking is warranted.
Crops	122,800	57,600				M–H		M–H	H	G. Superphosphate run–off is a significant contributor to nutrient loads in waterways. H. We suspect that biocides are not at threshold levels (i.e. small changes will not lead to large changes in natural assets). I. Buffering waterways is similar to grazing, but the returns on investment are greater for this industry. Increasing fertiliser application efficiency and maintaining soil structure through minimum tillage aids waste absorption.
Hay and seed production	112,600 (all)	72,619*				M		M–H	M	G. Large superphosphate and nitrogen run–off – although as much as 70% may be taken up in drains on–farm. H. We suspect that biocides are not at threshold levels (i.e. small changes will not lead to large changes in natural assets). I. Nutrient levels on drains can be reduced by vegetation in drainage – but the vegetation would need to be harvested to remove the nutrient from the system.
Intensive animals – pigs and poultry	n.a.	31,914				H		M	H	G. Nutrient management is particularly important on–site (some feedlots are being constructed that will increase point source pressures) as well as nutrient loads in waterways. H. We suspect that biocides are not at threshold levels (i.e. small changes will not lead to large changes in natural assets). I. Much of the wastes are managed on site or via treatment works, and are considered to be relatively well managed.
Intensive animals – fish	200	10,700				H		M	M	G. As for Pigs and Poultry although nutrient loading into waterways is a more significant issue. H. We suspect that biocides are not at threshold levels (i.e. small changes will not lead to large changes in natural assets). I. As for pigs and poultry, licensing for fish farming is enforced.
Intensive animals – horses						M		L	L–M	Modest scale G. As for pigs and poultry H. We suspect that biocides are not at threshold levels (i.e. small changes will not lead to large changes in natural assets). I. High stocking rate on pasture in reasonably good condition. Animals are fed, thus limited reduction in vegetation cover through grazing so reduced opportunities to increase effectiveness of waste absorption (only option would be to reduce waste by reducing stocking rates).
Forests – Hardwood	439,445	7,500				L		L	L	G. Generally a benign land-use, forests act as good waste absorbers of small amounts of waste but have a low threshold that is easily exceeded and so have a limited impact on capacity to provide waste absorption services in the future. Tracks for recreation and harvesting impact negatively on waterways via sediment mobilisation. Shepparton sewage treatment plantation appears not to be working as effectively as anticipated in absorbing excess nutrients.

TABLE 31 CONTINUED

The importance of the ecosystem service of regulation of waste absorption and breakdown

These services include the roles played by various organisms (above and below ground, and aquatic) in absorbing and breaking down wastes from people, their production systems, and nature.

A: Land-Use	*B: ha*	*C: Farmgate GVP $,000*	*Inputs to production*			*Maintaining natural assets*			*J: Ranking*	*Explanatory notes (mostly relating to Maintaining Natural Assets, as inputs to production are usually self–evident)*
			D: Overall importance of land-use in the production of goods based on ha and/or $ value of goods	**E:** Sensitivity of goods associated with land-use to a marginal change in waste absorption	**F:** Manageability	**G:** Overall impact of land–use on the capacity of natural assets to provide waste absorption services	**H:** Significance of a marginal change in the capacity of natural assets to provide waste absorption services	**I:** Manageability		
							High: particularly for P, N, Carbon, Salt and Acidity in waterways, any change in waste absorption services will have significant impact on natural assets.			H. Positive impacts of land-use generally outweigh negatives: there is potential for positives to be elevated (i.e. provision of clean water). I. As for Recreation, except not managed by Parks Victoria.
Extractive Industries – Land Based	n.a.	1,000				L		H	L	G. Small industry and declining, thus not considered to have a major impact on natural assets. H. Extraction often mobilises sediment and can contribute to water quality problems. A rating of high is not warranted for this land-use given the limited scale. I. Licensing conditions are readily enforced.
Food – processing	n.a.	2,519,600				M		H	H	G. High organic wastes generated in plants – needs intensive treatment – most goes to sewage treatment plants. (Food processors in the area mean that water provided and treatment needed are equivalent to a city of 1 million people.) H. As for Dairy Processing I. Withholding periods for spraying prior to harvest (e.g. one month) are specified, but not always followed, especially after rain.
Vegetables – tomato processors	1,445	22,999				L		H	L–M	G, H, I. As for Dairy and Fruit & Grapes processing
Housing						M		M–H	H	G. Nutrient management is important to on–site impacts and nutrient loads in waterways. Landfill is not expected to be an issue. Septic tank management, especially in the south of the Catchment, is an issue. H. Any change in waste absorption services can have significant impact on natural assets. I. Caravan parks were issues historically, but are now all are EPA licensed.
Water production	2,431,654	80,000	M	H	H			H	H	D, E, F. Wastes in waterways is a key issue (N, P and salt) and may lead to algal blooms.
Recreation – land based /water based		100,000+				M		M	H	G. Tracks near waterways mobilise sediments to waterways and various recreational activities leave behind assorted wastes. H. Many environmental recreation activities are based on a "pristine" environments – It is unclear how big a role is played by waste absorption, although bacteria such as Giardia and E. coli are being recorded in upper streams near campsites. I. Managed largely by Parks Victoria and NRE Forests – recreationists' practices have improved dramatically over last 20 years (especially with respect to rubbish). Recreationists driving off–road are still a problem in some places.

* A proportion of these values are inputs to the production of other goods in the Catchment. For example fruit to fruit processing

Appendix 2

Summary of economic structure of the Goulburn Broken Catchment

TABLE 32

Land-use	Products or Goods	Ha[1]	Quantity[2]	Gross Value of Production $000 (1996)[3]	Value Added[#]	Comments	Data Source* (Column-source)
PRIMARY INDUSTRIES							
Dairying – on farm	Milk	112,000	840 ML	$453,348	$148,937	GVP includes dairy production from the Sheparton Irrigation Region that is outside the G-B (ie the area west of the Campaspe River). The value of dairy production from the Goulburn-Broken is estimated as $374,665 by M Young and Associates.	1-9 2-9 3-1
Fruit & Grapes	All fruit including grapes, berries, kiwi fruit, citrus	11,000	269813 tonnes	$173,553	$63,963	Almost all fruit and grapes within the Shepparton Irrigation District are located within the Goulburn Broken Catchment.	1-2 2-2 3-1
Vegetables – below ground	Potatoes (mainly)	310	7,768 tonnes	$5,185	$1,911		1-2 2-2 3-1
Vegetables – above ground	Tomato – (mainly), includes fresh and processed	1,445	63,192 tonnes	$22,999	$8,476	GVP is dominated by tomatoes but includes carrots (expect to be minimal); terminology of category questionable.	1-2 2-2 3-1
Grazing	Wool and meat and horses (spelling)	1,223,000	quantities can be found for wool and meat	$236,315	$123,157	GVP estimate derived by subtracting the value of pig meat from livestock and wool values.	1-3 3-1 3-2
Crops – Cereals	Barley, oats, wheat, triticale	104,700	237900 tonnes	$51,857	$33,138	GVP includes cereal crop production from the Sheparton Irrigation Region that is outside the G-B (ie the area west of the Campaspe River). The value of cereal from the Goulburn-Broken is estimated as $43990 by M Young and Associates.	1-2 2-2 3-1
Crops – Legumes	Beans, lupins, peas, faba beans, chick peas	9,400	15000 tonnes	$953	$609	Figure based on an estimate of tonnages from 1997. An estimate of value has then been derived from the tonnages in 1997. Note legume cropping is significantly increasing within the Catchment.	1-2 2-2 3-1
Crops – other including oil seeds	Canola, safflower	7,800	14900 tonnes	$4,500	$2,876	Figure based on an estimate of tonnages from 1997. An estimate of value has then been derived from the tonnages in 1997. Note oil seed (canola) cropping is significantly increasing within the Catchment.	1-2 2-2 3-est.
Crops – Summer	Irrigated maize, millet, sunflower	900	2900 tonnes	$290	$185		1-2 2-2 3-est.
Hay and seed production	Hay – grass and cereal, pasture seed	112,600 (all)	426100 tonnes	$72,691	$37,883	GVP is derived by adding hay and seed production. Note that values for hay may be understated as a significant proportion of hay produced is utilised on-farm.	1-2 2-2
Intensive animals – pigs and poultry	Pork, bacon, eggs, poultry	n.a.		$31,914	$16,632	Derived by adding 24 006 from Ag Stats (poultry and pig sales) and 7907 664 (eggs) from M Young's report	3-1 3-2
Intensive animals – fish	Trout (mainly), yabbies and eels	200		$10,700	$5,350	Emerging industry – growth 10-18% p.a. Fish only (trout 10,000); glass eels by 2000. Estimate of value added is derived from other intensive industries.	1-est. 3-1
Intensive animals – horses	Thoroughbreds, standardbreds			No estimate available but likely to be in excess of $10 million	No estimate available	A large industry for which estimates of GVP are difficult to obtain. There are over 100 horse breeding and training properties in the Shire of Strathbogie alone.	
Apiculture	Honey	n.a.		$1,060	$530	One third income from pollination (via Peter Jerie pers com). Note that the value added is derived from other industry estimates.	3-1
Forests – Hardwood	Woodchips, pulp, firewood, sawlogs	439,445	120,000 m3	$7,500	$5,139		1-3 2-1 3-1
Forests – Softwood	Pine chips, particle board, posts, poles, sawlogs	17,352	220,000 m^3	$78,000	$53,445		1-3 2-1 3-1

TABLE 32 CONTINUED

Land-use	Products or Goods	Ha[1]	Quantity[2]	Gross Value of Production $000 (1996)[3]	Value Added[#]	Comments	Data Source* (Column-source)
Mining – Land Based	Quarries, pits, stripping, mines	n.a.		$1,000	$593	$ – Gold only – data for 96/7, by 2000 had decreased to almost 0. (Municipal data via NRE for non-mineral industries coming.)	3-5
Extractive Industries – Water Based	Excavating for sand	n.a.		No estimate available but a low value expected.		Low value from sand mining in the Goulburn at Seymour and Seven Creeks (and possibly Castle Creek) at Euroa. Included here because of impacts (both positive and negative) on natural resources could be high see notes next column.	
Alternative industries	Flowers, emus, llamas, ostriches, deer, goats, turkeys			No estimate available but significance is growing with significant investments in mushroom production		Other small industries are included in this category.	
ESTIMATE OF FARMGATE GVP				**$1,151,865**	**$502,826**		
MANUFACTURING							
Dairy – processing	Powder, cheese, butter/oil, milk	n.a.	n.a. – varied products	$1,562,000	$346,695	GVP is a year 2000 estimate and includes all of the Shepparton Irrigation Region.	3-1
Fruit & Grapes – processing	Cans, soups, wine	n.a.		$798,000	$278,292	GVP is a year 2000 estimate and includes all of the Shepparton Irrigation Region. Includes Fruit processing ($734 million) and Wine ($64 million)	3-1
Vegetables – tomato processors	Tomato sauce, canned tomatoes, tomato paste	n.a.	55,452 tonnes	$159,600	$55,658	Data based on 1998 data that estimated 285 000 tomes of tomatoes were processed in the Catchment (pers.com, Bill Ashcroft, NRE Tatura). Estimate includes all of the Shepparton Irrigation Region.	2-2
Timber Products	Sawn timber, pressboard	n.a.		$171,000	$68,698	GVP is a year 2000 estimate and includes all of the Shepparton Irrigation Region.	3-1
Other Manufacturing	Metal and mineral products, machinery and other manufacturing products			$236,000	$84,256	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
TOTAL FOR MANUFACTURING AND PROCESSING SECTOR				**$2,926,600**	**$833,601**		
HOUSING AND CONSTRUCTION							
Building and Construction	Urban real estate Alternative is the value of all housing and commercial construction	73,266		$276,000	$151,189	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	1-3
TOTAL HOUSING AND CONSTRUCTION				**$276,000**	**$151,189**		
ELECTRICITY GAS AND WATER							
Electricity and gas	Electricity and gas production and distribution			$118,000	$48,972	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
Water	Includes surface and sub-surface	2,431,654	3,400 GL	$80,000	$60,103	3,400 GL is the mean annual flow (discharge) from the Catchment. It doesn't include tanks and dams on dryland farms (don't go down the river!) Figures vary markedly depending on year (especially for Goulburn-Murray Water – rural water) Goulburn Valley Water 1998/99 (urban): c. $40 m and Goulburn Murray Water 1997/98 (rural) income $78 million across whole system of which approximately 50% is attributable to the Catchment.	1-3 2-6 4-8
TOTAL ELECTRICITY, GAS AND WATER				**$198,000**	**$109,075**		

TABLE 32 CONTINUED

Land-use	*Products or Goods*	*Ha*[1]	*Quantity*[2]	*Gross Value of Production $000 (1996)*[3]	*Value Added*[#]	*Comments*	*Data Source** *(Column-source)*
SERVICES SECTOR							
Wholesale and retail trade	wholesalers, shops, mechanical repairs			$636,000	$387,422	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
Transport and Communication	Road, rail, water and air transport, services to transport and communication			$310,000	$188,689	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
Finance and Business Services	Banking, finance, insurance, real estate, technical support			$248,000	$158,474	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
Housing services	Dwelling ownership			$180,000	$139,433	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
Public Administration	Public administration and defence			$141,000	$58,720	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
Community Services	Health, education, welfare, religious and community organisations			$327,000	$249,453	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
Entertainment and Recreation	Recreational services and hospitality (hotels and restaurants)			$158,000	$84,676	Estimates derived from multiplying gross value of production 5.63 billion by % value of output of sectors from Farmstats Australia pty ltd report (pg 18).	3-11
TOTAL FOR SERVICES SECTOR				**$2,000,000**	**$1,266,867**		
ENVIRONMENTAL, CULTURAL, AND AESTHETIC GOODS						Note all goods in this category are significant inputs to other sectors.	
Biodiversity	Values associated with the existence of biodiversity			N/A		Significant non-financial value	
Aesthetic values	scenic ammentiy			N/A		Significant non-financial value	
Cultural values	Cultural and natural heritage values			N/A		Significant non-financial value	
Option Values	Values associated with maintaining natural assets for future uses (yet to be defined).			N/A		Significant non-financial value	
TOTALS – ALL SECTORS				**$6,552,465**	**$2,863,558**		

* Data sources: The first number relates to the column in this table and the second to the data source. For example 1-4 relates to the estimate for hectares of land-use and is sourced from data source 4: Goulburn Broken Catchment Water Quality Strategy

Value added is derived from estimate of the %value added by each industry in the Farm Stats Pty Ltd Input Output study of the Shepparton Irrigation District (see Data source 11).

DATA SOURCES FOR SUMMARY TABLE OF ECONOMIC STRUCTURE OF THE GOULBURN BROKEN CATCHMENT

1 Young and Associates (2000) (draft) *An Economic Profile of the Goulburn Broken Catchment (Including all of the Shepparton Irrigation Region) 2000* Report prepared for Goulburn Broken Catchment, 2000.
(Data derived from Australian Bureau of Statistics—reduced from "Goulburn Statistical Division" to "Goulburn Broken Catchment")

2 "Australian Bureau of Statistics ("Ag stats" – general) from Department of Natural Resources and Environment's Corporate Database

3 Department of Natural Resources and Environment Corporate database (reported in *Draft Goulburn Broken Native Vegetation Management Strategy 1999*)

4 Goulburn Broken Water Quality Working Group *Goulburn Broken Catchment Water Quality Strategy*, Component of the Regional Catchment Strategy prepared for the Goulburn Broken Catchment and Land Protection Board, Tatura 1997."

5 Department of Natural Resources and Environment – Minerals and Petroleum Victoria 1997/98 Database, gathered from Database administrator (Kemal Inan) November 2000.

6 Department of Water Resources Victoria *Water Victoria* – A Resource Handbook, 1989.

7 Goulburn Valley Water *Goulburn Valley Water Annual Report* 1998/99.

8 *Goulburn-Murray Water Annual Report* 1997/98.

9 Department of Natural Resources and Environment Industry (1993-2001, Northern Region Extrapolation, *assume* Goulburn Broken = 50% of Northern Region, Farm Productivity Survey by Victorian Dairy Institute of Victoria, 1996."

10 (pers.com.) Stuart Bowe Alpine Resorts Management Board October 2000.

11 EconSearch Pty Ltd FarmStats Australia Pty Ltd, *The Economic Impact of Irrigated Agriculture in the Shepparton Irrigation Region*, Prepared for Sustainable Regional Development Board, 1996."