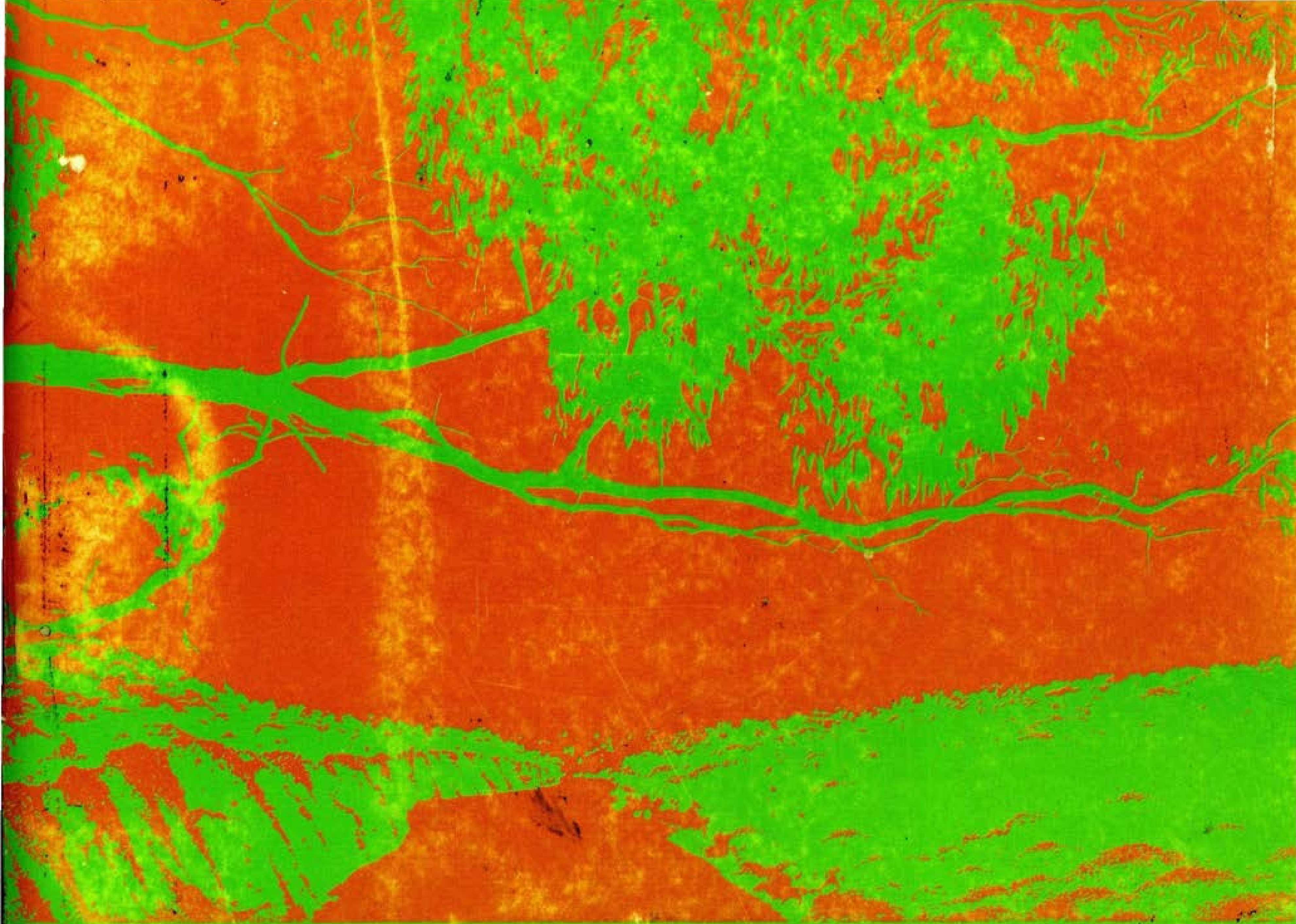

Land Conservation Council Victoria **Ballarat Area** **Price $6.00**

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267 1311, 267 1098

GOVERNMENT OF VICTORIA
LAND CONSERVATION COUNCIL
464 ST. KILDA ROAD, MELBOURNE, VICTORIA, 3004

REPORT

BALLARAT AREA

This Report is published to allow all who are interested the opportunity to comment by making written submissions to the Land Conservation Council.

All such submissions must reach the Secretary no later than Monday 6 October, 1980.

These submissions will be considered by the Council before Proposed Recommendations are made on the use of public land in the area.

I. KUNARATNAM
Secretary
Land Conservation Council

REPORT

ON THE

BALLARAT AREA

Land Conservation Council, Victoria
Melbourne : June 1980

ISBN 0 7241 9120 8

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FOREWORD

The *Land Conservation Act* 1970 established the Land Conservation Council, whose function is to 'carry out investigations and make recommendations to the Minister with respect to the use of public land in order to provide for the balanced use of land in Victoria'.

This report sets out to describe and assess the natural resources of the public land in the Ballarat study area and provides a factual basis on which members of the community may base their submissions to the Council. It ensures that all those persons and bodies who have an interest in the future use of public land in this area can obtain and study the basic information, which the Council itself will study. They will thus be able to make informed and constructive suggestions to the Council for its consideration.

In making this report available, the government hopes that all interested parties will be able to participate in an informed fashion in the process of considering how public lands should be used. It is hoped that, in making submissions, members of the community will use as a basis the information provided by this study.

The Council will make its recommendations only after due consideration of those submissions.

Demands for land for various purposes are many and varied; some of them are compatible and some conflicting or competitive. It is therefore important that decisions made are based on factual evidence, not on subjective criteria.

Submissions are now invited and should reach the Secretary of the Land Conservation Council within 60 days of the publication of this report, as notified in the Victorian Government Gazette.

Land Conservation Council
464 St. Kilda Road
MELBOURNE 3004

S.G.McL. DIMMICK
Chairman

LAND CONSERVATION ACT 1970

EXTRACT

Public Land

Section 2.

(1) "Public land" means -

(a) land which is not within a city, town or borough and is -

(i) unalienated land of the Crown including land permanently or temporarily reserved under section 14 of the *Land Act* 1958 and State forest;

(ii) vested in any public authority (other than a municipality or a sewerage authority within the meaning of the *Sewerage Districts Act* 1958); or

(iii) vested in the Melbourne and Metropolitan Board of Works; and

(b) any other land which the Governor in Council declares under sub-section (2) to be public land for the purposes of this *Act*

"Reserved forest" and "State forest" have the same meanings as in section 3 of the *Forests Act* 1958.

(2) The Governor in Council may on the recommendation of the Minister made after consultation with -

(a) any Minister of the Crown in whom any land is vested; or

(b) the Minister responsible for a public authority in which any land is vested -

by proclamation published in the *Government Gazette* declare any such land to be public land for the purposes of this *Act*.

Functions of the Council

Section 5.

(1) The Council shall -

(a) carry out investigations and make recommendations to the Minister with respect to the use of public land in order to provide for the balanced use of land in Victoria;

(b) make recommendations to the Governor in Council as to the constitution and definition of water supply catchment areas under the *Soil Conservation and Land Utilization Act* 1958; and

(c) advise the Soil Conservation Authority concerning policy on the use of land (whether public land or any other land however vested) in any water supply catchment area.

(2) In making any recommendation the Council shall have regard to the present and future needs of the people of Victoria in relation to -

(a) the preservation of areas which are ecologically significant;

(b) the conservation of areas of natural interest beauty or of historical interest;

(c) the creation and preservation of areas of reserved forest;

(d) the creation and preservation of areas for national parks;

(e) the creation and preservation of areas for leisure and recreation, and in particular of areas close to cities and towns for bushland recreation reserves;

(f) the creation and preservation of reserves for the conservation of fish and wildlife;

(g) the preservation of species of native plants; and

(h) land required by government departments and public authorities in order to carry out their functions.

(3) Where the Council recommends the alienation of any land the recommendation shall include the Council's opinion as to the best method of alienating the land to ensure the most satisfactory use and management of the land in the public interest.

(4) Any person or body may make submissions to the Council as to how any public land can be better used to meet the needs of the people of Victoria and the Council shall consider any such submissions before making any recommendation under paragraph (a) of sub-section (1)

Investigations, Notices and Reports

Section 9.

(1) The Council shall not make any recommendation under this *Act* in relation to any district or area without a prior investigation of the district or area.

(2) Before commencing any investigation under paragraph (a) of sub-section (1) of section 5 the Council shall publish a notice in the *Government Gazette*, in a newspaper circulating throughout the State and in a newspaper circulating particularly in or in the vicinity of the area or district to be investigated stating that an investigation of the district or area described in the notice is to be carried out for the purposes of this *Act*.

(3) On completing an investigation of a district or area under paragraph (a) of sub-section (1) of section 5 the Council shall -

(a) publish a report of the investigation;

(b) give notice in the *Government Gazette* of the publication of the report, the address where copies of the report may be obtained or inspected and stating that any submissions to the Council in relation to such report will be considered by the Council if they are made within 60 days of such notice; and

(c) publish notice in a newspaper circulating throughout the State and in a newspaper circulating particularly in or in the vicinity of the area or district investigated of the publication of the report, the address where copies of the report may be obtained or inspected and stating that submissions may be made to the Council and the date before which they should be made.

(4) The Council shall consider any submissions in relation to such report made by any person or body within 60 days of notice being given under paragraph (b) of sub-section (3).

Notice to be given to public departments and authorities in certain cases.

Section 10.

(1) Not earlier than 60 days after notice being given under paragraph (b) of sub-section (3) of section 9, the Council shall send a copy of its proposed recommendations to -

(a) the Council of any municipality in the municipal district of which the recommendation relates is situated;

(b) any other public authority or government department that in the opinion of the Council has an interest in the area of the proposed recommendation; and

(c) any person or body who made a submission under section 9 -

and shall consider any submissions received within 60 days of the sending of such copy to the council authority, department, person or body or in the case of a public authority or government department within such longer period as may be agreed upon between the Minister and the Minister administering that department or responsible for that authority.

(2) Where any recommendation is made to the Minister under this *Act* it shall be accompanied by a copy of any submissions received from any person body department authority or council pursuant to the provisions of sub-section (4) of section 9 or sub-section (1) of this section.

(3) Where the Council has made a recommendation to the Minister under paragraph (a) of sub-section (1) of section 5 the Minister may, after he has given not less than fourteen days notice of his intention so to do to the Minister administering a government department or responsible for a public authority recommend to the Governor in Council that notice of the recommendation or that part of the recommendation that affects the government department or public authority concerned and where notice of that recommendation or part is so given by the Governor in Council it shall be the duty of the government department or public authority to use all diligence and dispatch to give effect to such recommendation so far as it affects any land vested in or controlled by it.

Copy of every recommendation and of proposals to be tabled in Parliament.

Section 11.

A copy of every recommendation of the Council made under sub-section (1) of section 5 and of the proposals of the Council submitted to the Minister pursuant to section 7 shall be laid before both Houses of Parliament within fourteen days of the making thereof if Parliament is then sitting and if Parliament is not then sitting within fourteen days after the meeting of Parliament.

A copy of the *Land Conservation Act* 1970 can be obtained from the Government Printing Office, 7a Parliament Place, Melbourne, 3002.

ACKNOWLEDGEMENTS

This report covers so wide a field that its compliation would not have been possible without the generous assistance and co-operation of a great many individuals and organizations.

The Council acknowledges the assistance of these organizations, which prepared basic information for maps and chapters of this report: the Departments of Agriculture, Crown Lands and Survey, and Minerals and Energy; the Fisheries and Wildlife Division; the Forests Commission; the National Parks Service; the Soil Conservation Authority; the State Electricity Commission; and the State Rivers and Water Supply Commission.

This report is the product of an interdepartmental working group involving the following officers of participating departments: D. Alexander, C. Ashe, B. Clements, J. Davey, R. King, J. Lane, P. Lawson, J. Lumb, A. Middleton, B. Muir and J. Rowan.

Many other people and organizations supplied information or photographs, checked drafts or contributed discussion or advice. They include other Victorian government bodies, local government agencies, local apiarists, members of Field Naturalists Clubs, outdoor recreation and sporting organizations, individuals with expert knowledge in fields such as geomorphology, botany and zoology and those with special knowledge of particular localities including Messrs. R. Allen, W. Emison, J. Harris, B. Leach, M. Lorrimer, A. Millar, J. Wheeler, D. White.

Acknowledgement is also made to the La Trobe Library for photographs.

PART I

INTRODUCTION

AIMS AND METHODS

This report brings together information that is relevant to making decisions on the future use of public land in the study area.

It describes the physical nature of the land, examines the existing and likely forms of land use, and assesses the hazards associated with these uses. The report does not contain recommendations, but aims at providing a factual basis on which land use recommendations can be formulated.

Existing information collected from published reports, government departments, public authorities, private organizations, and individuals has been supplemented by short-term surveys of plants and animals.

Although public land has been emphasized, the report considers relevant aspects of all land in the study area to place the public land in perspective.

The text is divided into four main sections. Part I, an introductory section, sets out the aims of the study, and defines and briefly describes the study area, its history and prehistory.

Part II describes the main features of the environment for the whole study area. Climate, geology, geomorphology, soils, vegetation, fauna, water resources, and land systems are described. Maps showing the geology, geomorphology, topography, vegetation on public land, water resources, and land systems are included.

Part III deals with the main forms of land use that are likely to make demands on public land, and examines the present levels of activity. Hazards associated with these land uses, such as soil deterioration and fire, are also discussed. Primary production, minerals and stone, and recreation are depicted in maps for this section.

Part IV provides more detailed information and, for convenience, the study area has been divided into four blocks. The information is set out in a consistent format of headings, so that specific information can be readily found and compared with its counterparts in other blocks or areas.

A number of appendices, including lists of flora and fauna, complete the report.

CONSERVATION PRINCIPLES

Conservation is concerned with Man's relation to his environment. It is often said to be the wise or balanced use of resources. Because "wisdom" and "balance" are not absolute terms, the principles set out here attempt to explain this concept.

Conservation can be considered as an endeavour to anticipate and resolve conflicts between the individual and society about the present and future use of resources, and between competing uses of the same resource. The conservationist must be aware of long-term needs and recognise that a community requires land for recreation, scientific, and aesthetic purposes as well as for the production of food, timber, and minerals or for urban and industrial use.

Natural Resources

Two broad classes of natural resource may be distinguished, according to whether they are renewable.

Non-renewable resources

The quantity of these resources does not increase significantly with time, and use consumes them. In the last century the expansion of Victoria's economy was based on the exploitation of gold - a non-renewable resource. The oil and gas fields of Bass Strait provide another example.

Conservation of a non-renewable resource requires the best techniques for exploration, recovery, and processing, and the efficient use of the end product.

Renewable resources

The quantity of a renewable resource such as timber may increase or decrease with time. Animal and plant communities and landscape fall within this category. Abuse of these resources may reduce them to such a poor condition that the practical opportunity to restore them to a desired state is lost for many generations.

Conservation of renewable resources requires a thorough understanding of ecological principles and development of sound management techniques based on those principles. An ecosystem typically contains many interrelated components. A change in any one of these will have effects elsewhere in the system. In general, an ecosystem with a diverse range of species will be better able to adapt and absorb the impact of sudden change - such as that caused by fire, disease, or Man's activities - than a simple ecosystem with few species.

Man is part of the ecosystem and, like every other organism, influences and is influenced by the other parts. The development of new techniques has increased his ability to modify the environment. Many new techniques have both advantages and disadvantages. Often the disadvantages are not obviously linked to the new techniques and only emerge in the long term - for example, the use of insecticides can increase production of food or fibre dramatically, but may also reduce the population of predatory birds and insects and so encourage the build-up of populations of other insect pests.

Relations Between Resource Uses

Many uses of a resource are compatible. They may be supplementary and add to each other, or complementary in that one use benefits from the other, but they may also be competitive when an increase in one leads to a decrease in the other.

For example, the relation between timber production and picnicking within a forest may be complementary in the sense that picnickers gain access along tracks and use open spaces created during timber operations. It may become competitive if logging makes the forest an unsuitable picnic area, and at other times picnickers may present a considerable fire risk.

In general, decisions on land use will involve selecting major land uses for a particular area, determining other uses compatible with these, and specifying the intensity of use above which they become incompatible.

The Principles of Land Use

In the past our society has grown (and the economic welfare of the people improved) through mining, farming, timber production, and industrial development. These industries have usually been given prime importance when deciding the use of natural resources. The present pattern of land use is, of course, a result of these past decisions.

Recently there has been greater public demand for a shift in emphasis towards nature conservation and recreation as the economic welfare of the bulk of society has improved, the need and opportunities for outdoor recreation have grown, and an appreciation of nature has become more apparent.

The concept of balance is fundamental to land use and is directly related to the values that society puts on the goods and services that the land can provide. It also involves consideration of the needs of all sections of society, on both regional and State bases, as well as those of this and future generations.

These needs should be clearly stated as aims.

The intangible values of recreation, aesthetics, and preservation should be recognised by providing land for these purposes, and by considering the impact of other land uses upon them. The preservation of outstanding natural features should be considered.

Where several land uses are compatible, land should be available for the most beneficial combination of such uses. To achieve this, it may be necessary to define major aims and to assess levels above which secondary uses are unacceptable.

Where land has been committed to a particular use, it should be managed so that its capability for that use is not impaired. Uncommitted land should be maintained in a condition that will allow the widest possible choice of future uses.

Review and reassessment of land will become necessary as society and technology change.

THE STUDY AREA

The Ballarat area lies to the west of Melbourne, encompassing approximately 8,200 sq. km of mountains and plains in a broad sweep from Ballarat to Ararat, and from Lake Bolac to Shelford. Map 1 shows its location, together with those of surrounding areas investigated by the Land Conservation Council.

Local government areas

The study area wholly contains the cities of Ararat and Ballaarat, the Borough of Sebastopol, the Shires of Lexton, Ballarat, Bungaree, Ripon, Creswick, Buninyong, Leigh, and Grenville, and about half of the Ararat Shire. Except in the case of the Ararat Shire, the boundaries of the study area coincide with municipal boundaries (see Map 2). Crown land within the cities of Ballaarat and Ararat and in the borough of Sebastopol is not public land (as defined in the *Land Conservation Act* 1970) and is therefore not subject to recommendation by this Council.

Environments

Considerable variation is represented in the landscape of the Ballarat area as a result of geological processes. This is evident in a range of land forms, noticeably the flat volcanic plains and emergent hills and volcanoes, which contrast with granitic peaks and rolling midlands of the Great Dividing Range.

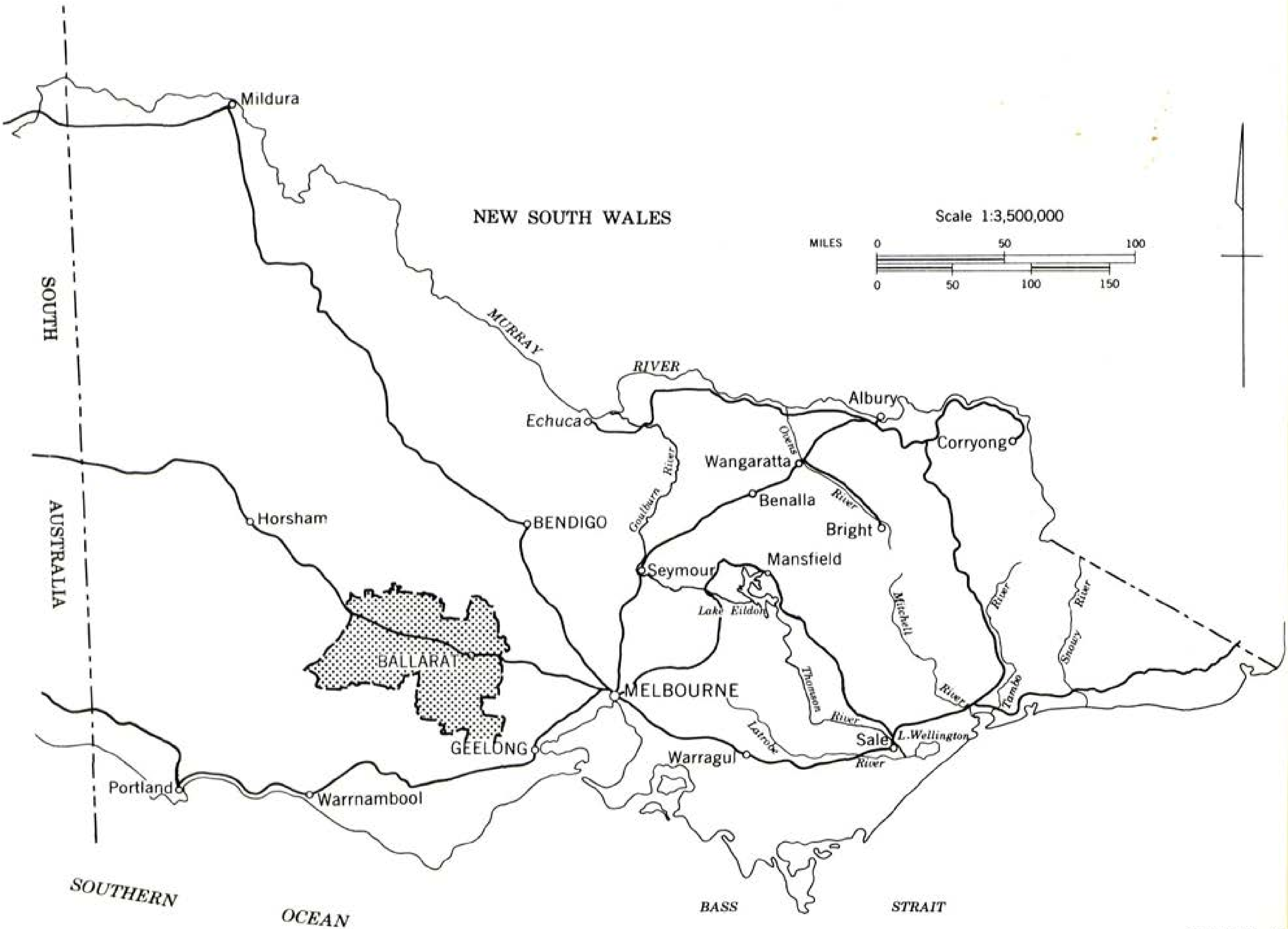
Tall wet forests, waterfalls, and associated flora occur on the Mount Cole Range, while in the drier regions to the south, the forests are of stringybark and ironbark, often assuming a woodland structure.

Several slow-moving river systems flow southwards across the volcanic plains (Hopkins River, Mount Emu Creek, Woady Yaloak River), which also contains large lakes varying in salinity (Burrumbeet, Wongan, Goldsmith, Bolac) and smaller saline lakes. Three river systems flow north of the Divide - the Avoca and Wimmera terminate in inland lake and water supply systems, and the Loddon enters the River Murray at Swan Hill.

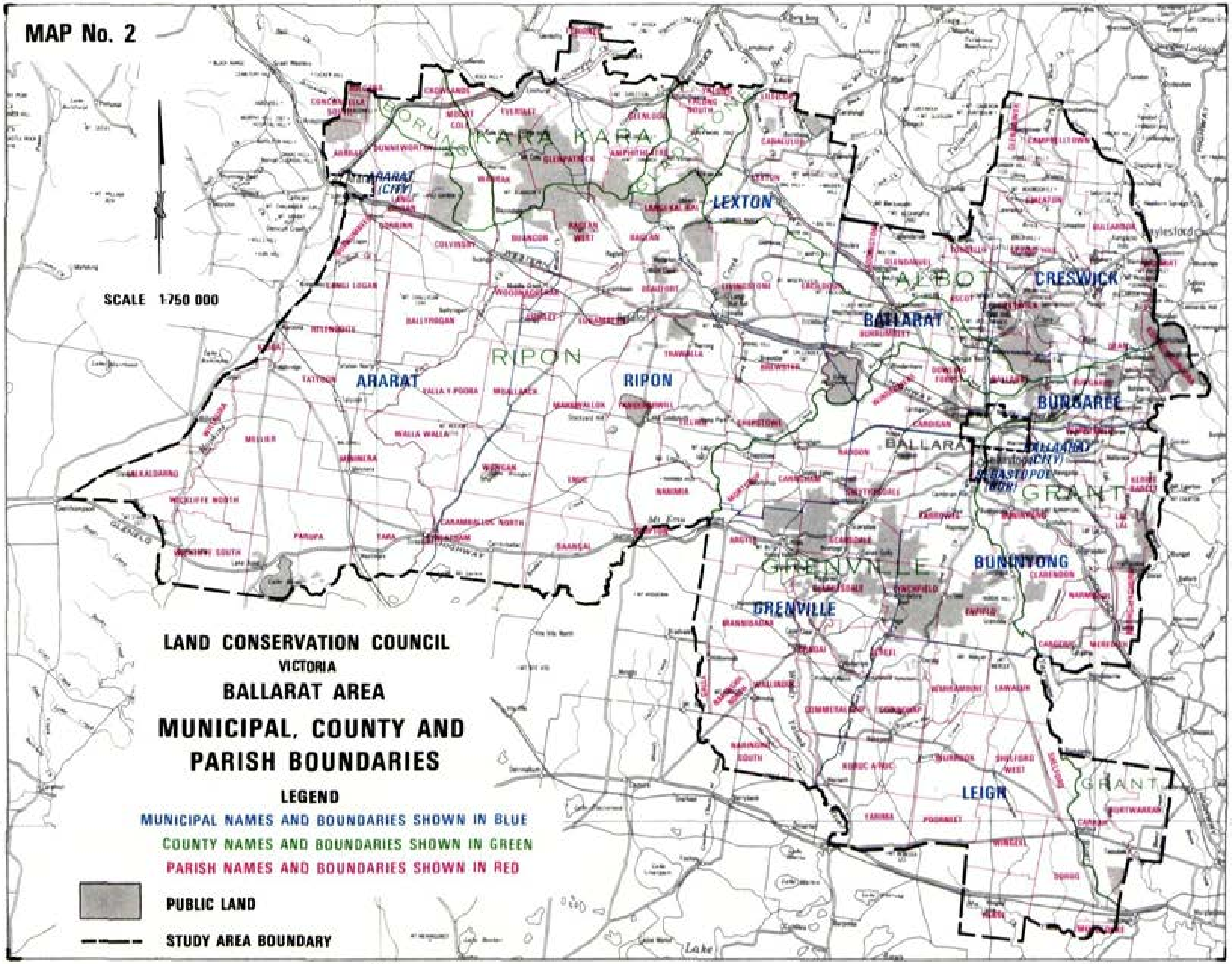
Land tenure and use

Approximately 15% of the Ballarat area is public land, which consists of Crown land (reserved and unreserved), reserved

LOCALITY PLAN



MAP No.1


MAP No. 2
SCALE 1:750 000
LAND CONSERVATION COUNCIL
VICTORIA
BALLARAT AREA
MUNICIPAL, COUNTY AND PARISH BOUNDARIES
LEGEND
MUNICIPAL NAMES AND BOUNDARIES SHOWN IN BLUE
COUNTY NAMES AND BOUNDARIES SHOWN IN GREEN
PARISH NAMES AND BOUNDARIES SHOWN IN RED
PUBLIC LAND
STUDY AREA BOUNDARY
143°00'
144°00'
38°00'
KARA KARA
RIPON
TALBOT
GRENVILLE
GRANT
BALLARAT
LEXTON
CRESWICK
ARARAT
RIPON
BALLARAT
BUNGAREE
BUNINYONG
GRENVILLE
LEIGH
ARARAT (CITY)

forest, and land owned or controlled by certain public authorities. Large, consolidated areas of public land occur at Mount Langi Ghiran, in the Mount Cole -- Ben Nevis -- Ben Major area, at Waterloo and Beaufort, at Creswick, and in the southern region roughly bounded by the townships of Smythesdale, Snake Valley, Linton, Staffordshire Reef, Berringa, Little Hard Hills, and Durham Lead.

As a result of early pastoral settlement, most lands suitable for agriculture were alienated from the Crown - these freehold areas occupy most of the

Table 1

POPULATION OF LOCAL GOVERNMENT AREAS

Local government area	Area (km^2)	Census figures as adjusted for under-enumeration		Population change 1971--76 (%)
		30 June 1971	30 June 1976	
Ararat City	19.06	8,360	8,540	+ 2.2
Ararat Shire *	3,657.00	4,200	4,260	+ 1.4
Ballaarat City	34.60	40,010	38,990	- 2.5
Ballarat Shire	476.60	14,490	17,550	+19.9
Bungaree Shire	227.90	2,530	3,220	+27.3
Buninyong Shire	777.00	5,150	6,460	+25.4
Creswick Shire	551.70	3,430	4,040	+17.8
Grenville Shire	844.30	1,810	2,870	+58.6
Leigh Shire	981.60	1,180	1,220	+ 3.4
Lexton Shire	821.00	1,320	1,320	0
Ripon Shire	1,533.00	3,230	3,300	+ 2.2
Sebastopol Borough	7.07	5,300	6,120	+15.5
Totals	9,930.83	91,010	97,890	+ 7.6

*Approximately half of shire located in study area.

Source: Victorian Year Book 1978.

Table 2

POPULATION OF URBAN CENTRES AND TOWNSHIPS

Urban centre/township	Population 1976
Ballarat	60,727
Beaufort	1,219
Creswick	2,033

Source: Australian Bureau of Statistics, Census, June 1976

flat plains, where little public land remains.

The flat plains support various agricultural enterprises including potato cropping and grazing of sheep and cattle. The larger areas of public land remaining today were considered unsuited to agriculture because of poor soils or as a result of mining activities.

Land use of forested areas includes various forms of recreation, timber production, water production, forest grazing, and honey production. Conservation of ecosystems and landscapes is an important function of public land, and numerous reserves have been made in the past for such purposes.

Population

Statistics show that the Ballarat urban region (Ballaarat City and the overflow into adjacent shires) has a large population relative to surrounding urban-centres. For example, it has more than seven times the population of the next largest one in the study area - Ararat. Ballarat urban region ranks as the third -largest population concentration in Victoria, after the Melbourne metropolitan area and Geelong.

Population has grown more slowly here, however, than in these and other major population centres. Table 1 shows population statistics and growth rates for local government areas, and Table 2 has figures for urban centres (population cluster of 1,000 or more persons) and townships in the region.

Transport

Transportation - focused on the major regional centre, Ballarat - is dominated by the movement of goods and people on the road network and to a lesser extent on the rail network. The Western High-

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way, designated as a national highway, is the major link between Melbourne and Adelaide and forms a central spine for the road system of State highways (Glenelg, North-western, and Midland, main roads, and an extensive system of minor roads.

The rail network radiates from Ballarat, with links to Melbourne, Geelong, Ararat, Maryborough, Creswick, and Skipton. Other lines radiate from Ararat to Geelong, Portland, Maryborough, and Stawell. Services between Ballarat and Buninyong, Waubra and Waubra Junction, Newlyn and Daylesford, and Newtown and Colac have been discontinued.

The area is serviced by two licenced aerodromes situated at Ballarat and Ararat and owned by the respective municipalities. Lake Bolac has as authorized landing area and there are numerous private landing strips in the region.

HISTORY

Aboriginal History

To date, insufficient is known about the prehistory of Victoria to permit a definitive comment on the cultural sequence for any specific part of the State. Archaeological excavation and carbon-dating techniques have indicated that Aboriginal Man was established in Victoria during the late Pleistocene. Varying dates from 18,000 to 30,000 years ago have been determined.

Our knowledge of the way in which Aborigines used their environment is obtained from contemporary sources coupled with modern interpretation of archaeological and ethnographic information. Recent surveys in the Western District of Victoria have discovered thousands of mound sites, stone arrangements, and other signs of Aboriginal occupation.

Based on these researches and information pieced together on the distribution and seasonality of food resources, a picture of the life strategy of the Aborigines may be constructed. The Victoria Archaeological Survey proposes that a relatively specialized form of subsistence strategy and economic technology operated over the last 2--3,000 years. This involved group movements to exploit food resources available seasonally in different environmental zones - for example, waterways, grassland, forest, woodland, and coastal.

Stone eel traps at Lake Condah and the Hopkins River and reportedly at Lake Bolac testify to the people's technological ingenuity. The construction involved an appreciation of the hydrology of the waterway and the optimum use of topography and natural rock materials. It appears that these were exploited by organized social groups, using fish spears and nets made from bark strips and plaited rushes.

Other food resources - staple foods and those available seasonally - are the yam *(Microseris scapigera)*, roots of sedges (such as *Eleocharis sphacelata)*, fruits of the native cherry *(Exocarpos cupressiformis)* and kangaroo apple *(Solanum aviculare)*, as well as mammals, birds, and emu eggs.

European contact

Beginning around 1834, the European settlers had a rapid and decisive impact on the Aboriginal population as they converted tribal lands to sheep runs. For instance, George Robinson, Chief Protector of Aborigines, recorded in 1841 that a number of residential groups of them had already been completely wiped out. It is estimated that squatters had killed 158 Aborigines in western Victoria before 1860 - this is probably a conservative figure. A far greater devastation stemmed from the introduction of afflictions such as venereal diseases and smallpox, against which the Aborigines had little resistance.

Aboriginal cave art at Mount Langi Ghiran

As a result of these dramatic events, Aboriginal tribal organization and traditional way of life broke down. The number of Aborigines in western Victoria (estimated at the time of contact at about 1,800) fell rapidly, and by 1877 the full-blood population was only 170 individuals.

Aboriginal Relics

Despite the great many changes since European settlement, many signs of Aboriginal activity remain. Large numbers of relics have been discovered and more are being found as archaeological surveys progress. Modern detailed surveys have only been completed in the west of the study area, around Ararat, Willaura, and Lake Bolac. The following brief description covers the types of relics found to date.

Mounds

Mound sites (also called myrnyongs, 'earthen heaps', or 'ovens') vary greatly in dimensions, but at least 60% of the examples measured in a recent survey have a circular shape and were between 2 and 20 m in diameter and up to 1 m high. They are often characterized by the presence of darker soil due to the accumulation of charcoal, burnt earth, and organic matter. Our knowledge of their function is limited. Early settlers' journals indicate that the Aborigines probably camped on them, and this has been verified by archaeological research for certain sites in the central Western District. Excavation has shown a wide variety of archaeological remains, indicating that the mounds had been used for cooking, as general camp sites, and also for burials.

Mounds appear to be located along major drainage systems.

Lithic scatters

Probably the most common evidence of Aboriginal occupation is the presence of Lithic scatters - accumulations of chipped stone waste from stone found in that locality and elsewhere. Usually found in the region of camp sites, they resulted from activities such as the manufacture, maintenance, and reshaping of tools. Concentrations that indicate a specific form of manufacturing activity are termed 'workshops'. Quarries, in the archaeological sense, are sites that have been used for the extraction of stone for tools. Mount Staveley, just outside the south-western corner of the study area, is an example.

Rock art

Only one site occurs in the study area - 'the cave of the serpent' near Mount Langi Ghiran; but the nearby Grampians contain at least 40 examples of rock art.

Scarred trees

The bark stripped from trees had a number of uses, including slabs for the construction of huts, canoes, dishes, and water containers.

Stone arrangements

Stone arrangements and fish-trap complexes have been found at the Hopkins River and Lake Bolac. An arrangement of basalt boulders at Lake Wongan is believed to have ceremonial significance. Aborigines of the stony rises used basalt boulders to construct semicircular houses, probably roofed with brushwood. There are also reports of windbreaks being constructed from basalt rocks. It is believed that most of these were destroyed by settlers stone-picking their land in preparation for agriculture.

Significance

While the more unusual types of Aboriginal relics have the highest priority for preservation, in one sense every individual site is unique, whatever its similarities to sites elsewhere.
All Aboriginal sites result from human activity that, although somewhat patterned, depended on the particular combination of resources in that locality. It is these small differences that are important to the archaeologist in his task of explaining how the Aborigines adapted to and exploited their environment.

There are other reasons for preserving sites. Aboriginal relics form part of our national heritage. Although Australian history is commonly conceived as beginning in 1770, Aboriginal occupation is now known to have been of at least 40,000 years' duration. Hence, the sites that provide evidence of this immense period of settlement are as much a part of our historical heritage as anything built here by Europeans in the past 200 years.

Preservation

The *Archaeological and Aboriginal Relics Preservation Act* 1972 was enacted to protect these relics. Under this legislation it is an offence to negligently deface, damage, or interfere with a relic, or to excavate without the appropriate permit in order to uncover a relic. Further, if a person discovers a relic it must be reported to the Protector of Relics appointed under the *Act*. Where sites of great significance are threatened, the *Act* provides for the declaration of 'Temporary Archaeological Areas' or 'Archaeological Areas' and, under special circumstances, for compulsory acquisition of land that contains the threatened relic. The legislation is being reviewed currently and could be amended at some future time.

European History

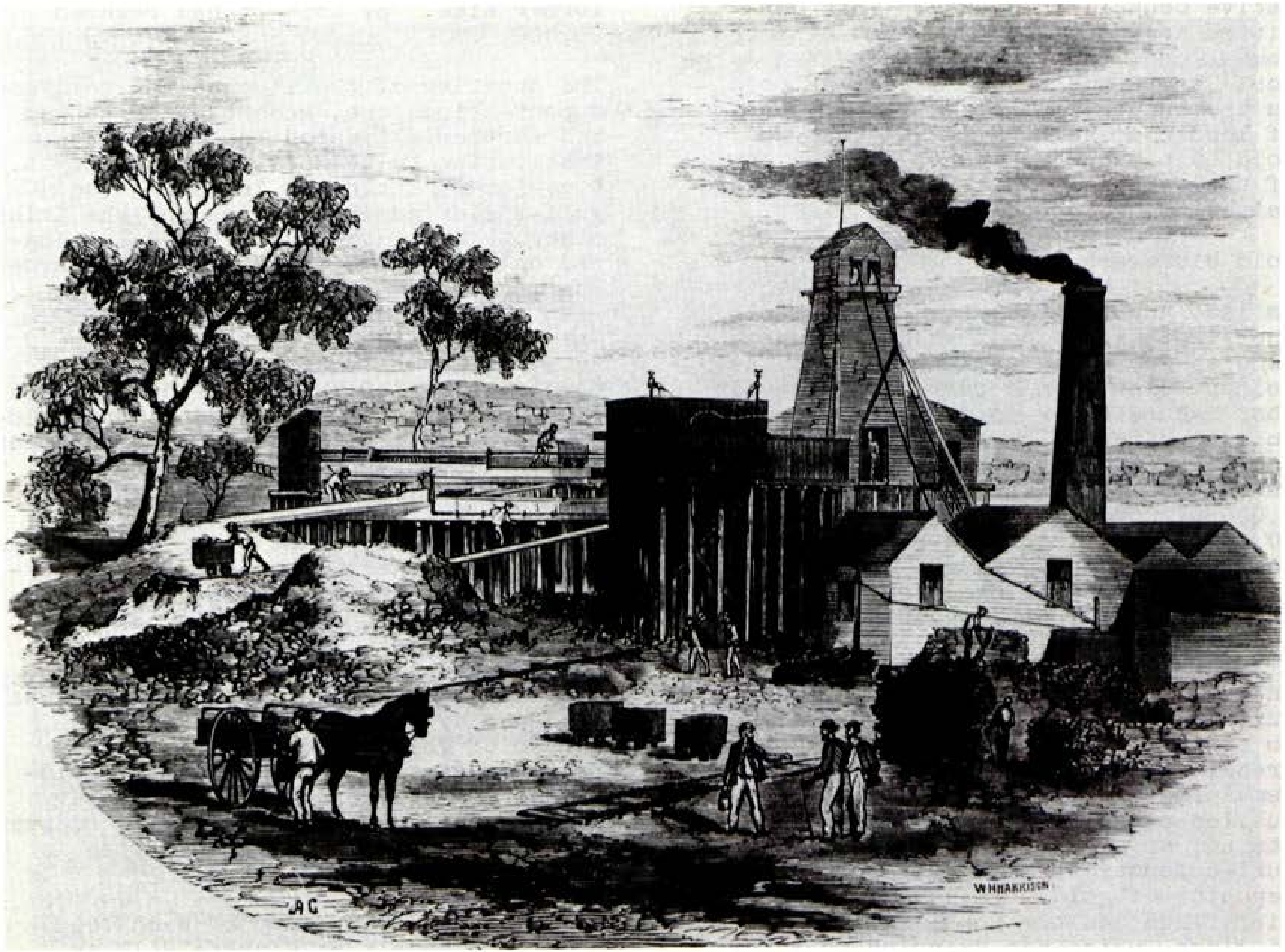
Three major phases in land use describe the history of European settlement. The first, associated with exploration and settlement, was primarily a pastoral one. Second was the discovery and exploitation of gold, which dramatically stimulated settlement and the primary and secondary industries. The final phase was one of consolidation, and the pattern of land use developed from the 1880s has remained substantially the same until the present day.

Exploration and settlement

Settlement of the area was a three-pronged affair - spreading from the Hentys' settlement at Portland, from the Geelong and Port Phillip region, and overland from New South Wales. It was Major Thomas Mitchell's authoritative account of his exploration of Victoria's western half in 1836, however, which greatly accelerated settlement. The following sheep runs were rapidly established on the grasslands and savannah woodlands of the basalt plains:

- 1837: The Learmonth brothers from Geelong, at Bunninyong and Burrumbeet
- 1838: Yuille, Clarke, and Hepburn, around Ballarat
- 1839: Baillie at Carngham; Kirkland at Trawalla
- 1840: Campbell at Fiery Creek--Mount Cole; Thompson at Challicum and later at Yalla y Poora

In 1836 the first act to legalize squatting had been passed by the Legis-



Deep lead gold-mine, Ballarat

lative Council in Sydney. This permitted a squatter, on payment of a ten pound bond, to occupy as much land as he could stock and hold. A tax was paid on the number of stock. The alienation of land commenced in 1838. Land was sold by public auction at an upset price of twelve shillings per acre, which was raised to one pound in 1840.

Gold discovery

In late August--early September 1851, the first significant gold finds were made at Buninyong and at Ballarat, near Golden Point - in a terrace of gravels that had been the inside bend of an ancient river. The numbers reaching the diggings grew with alarming speed. There were 800 miners on September 21, 3,000 by October 6, and 6,000 by October 20, although Victoria's population at the time was only 77,000. By late September, a gold-fields licence tax of 30 shillings per month, payable in advance, had been levied.

In the absence of good returns from surface alluvials, many diggers moved on to other fields opening at Castlemaine, Creswick, and Smythesdale--Berringa. Remaining diggers searched into the gullies pursuing shallow alluvial deposits and so discovered the 'leads' or buried former streams containing rich deposits of gold. This was an era of rich finds and the population on the diggings, which had dwindled to a few hundred miners, rapidly returned to its former size. By 1854 it had reached 25,000.

The question of the licence tax remained a contentious one, and Governor Hotham had further alienated the miners by instituting twice-weekly licence hunts. A series of incidents involving the gold-fields administration and the Irish miners working the Eureka lead culminated on December 3, 1854, in bloody armed conflict.

The wrath of the Irish had been roused by a series of factors, including the murder of one of their comrades coupled with corrupt court proceedings and gold-fields officials, and a minor depression brought about by the absence of any holes bottoming on the Eureka lead.

The coup by government troopers over the rebellious miners at the 'Eureka Stockade', in which 30 men were killed, was the beginning of major social change on the gold-fields. To the chagrin of Hotham, the arrested stockaders were acquitted, the crushing licence tax was replaced by the Miners Right, and a number of gold-fields officials were relieved of their duties. Eight gold-fields members were added to the Legislative Council, thus giving representation to a major portion of the population.

Following the discovery of deep leads under the basalt at Clarkes Hill in 1854, deep lead mining began in earnest.

Miner's Right

Fossickers at Nerrena, 1904

Sinking through basalt was a new form of mining. Initially small enterprises were involved, however this situation changed with the advent of large companies with sophisticated equipment.

Often the leads were up to 300 m wide and considerable ingenuity was required to deal with weak ground and the enormous quantities of water flowing through the lead gravels. The leads under the basalt were delineated with great difficulty, and legal wrangles as to ownership of frontage were commonplace.

Many nuggets were found on the Ballarat gold-fields. The 'Welcome', found by miners working the Bakery Hill lead in 1858, weighed 2,217 oz. (68 kg) and is the second-largest nugget found in Victoria.

Reefs of quartz had been mined previously, but with only limited success - and even then the miners often viewed them as an alternative, to work when the deep lead mines were flooded. In the 1870s, however, it was realised that wherever a quartz vein crossed a thin, vertical pyritic or black slate stratum - the indicator - the gold was richest. This discovery permitted a much more systematic working of the reefs and a new boom in mining.

As the returns from the deep leads became more difficult to obtain, capital was poured into the quartz reef mines.

Table 3 shows the increase in yields from quartz mining and the concomitant downturn in alluvial yields over the period from 1870 to 1899.

Mining conditions, however, deteriorated as the mines deepened. Ventilation was generally bad and, following the introduction of machine drills, the dust in the mines became a serious threat to health. Inhaled particles damaged the lung tissue and produced silicosis, a condition known as miners' phthisis or miners' lung. This disease became a major killer, as it reduced the resistance to tuberculosis. In 1904, following considerable public concern, Parliament enacted legislation requiring adequate ventilation of shafts and use of water sprays with the drills to minimize dust.

At the turn of the century, the quantities of gold extracted were declining. Some of the mines closed and, with their water pumps no longer operating, water problems in the mines that remained open increased; in some cases, these were forced to close, although the reef contained payable gold. By 1918, the last mine on the Ballarat gold-field had closed.

The decline can be attributed to the reefs being worked to their economic limit. Closures were also due to poor management and profit-taking, however, which did not allow for sufficient return of working capital to the mines. The war came as a final blow, robbing the mines of much of the manpower needed to work them.

The gold-fields

The gold-fields, of which some are briefly described below, are shown on Map 4. Portions of many of these his-

Table 3

GOLD YIELDS (OZ.), BALLARAT CENTRAL DIVISION: 1870--1899

	alluvial	quartz	totals
1870--79	620,375	278,720	899,095
1880--89	67,594	706,171	773,765
1890--99	23,026	803,201	826,227

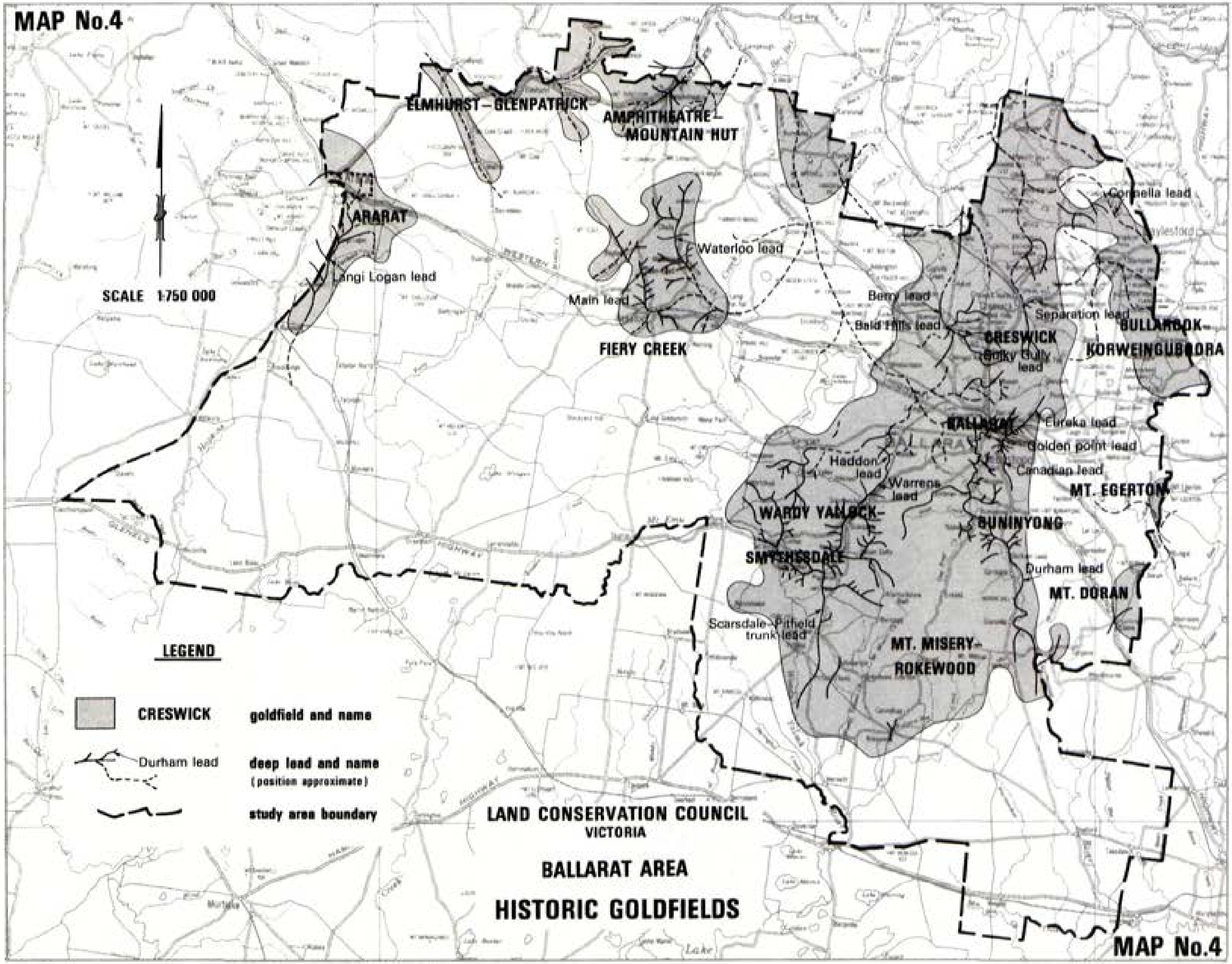
Source: Quarterly Reports of Mining Surveyors and Registrars, from Bate (1978).

Ground sluicing

toric gold-fields encompass public land to the north and south of Ballarat and north of Beaufort.

Ballarat: The Ballarat gold-field was divided into three parallel belts - Ballarat West (Sebastopol), Ballarat East, and little Bendigo (Nerrena). This gold-field has been dealt with above.

Creswick: Creswick was opened up by diggers prospecting from Ballarat during September 1851. Together with Castlemaine, it attracted many diggers when the shallow alluvials failed at Ballarat during October 1851. Until 1860, numerous shallow and deep leads were worked and the major rush in 1854 drew 20,000, but during the 1860s, mining activity declined.



MAP No.4
ELMHURST–GLENPATRICK
AMPHITHEATRE–MOUNTAIN HUT
ARARAT
Langi Logan lead
SCALE 1:750 000
Waterloo lead
Main lead
FIERY CREEK
Berry lead
Bald Hills lead
Coghill's lead
Separation lead
CRESWICK
Bulky Gully lead
BULLAROOK–KORWEINGUBOORA
BALLARAT
Eureka lead
Golden point lead
Canadian lead
Haddon lead
Warrens lead
MT. EGERTON
WARDY YALLOCK–SMYTHESDALE
BUNINYONG
Durham lead
MT. DORAN
Scarsdale–Pitfield trunk lead
MT. MISERY–ROKEWOOD
LEGEND
CRESWICK goldfield and name
Durham lead deep lead and name (position approximate)
study area boundary
LAND CONSERVATION COUNCIL
VICTORIA
BALLARAT AREA
HISTORIC GOLDFIELDS
MAP No.4

A series of immensely rich leads, known as the Berry lead system, extended in a northerly direction under the basalt from Learmonth, Ballarat, Creswick, Spring Hill, and Bullarook. This system ranks as the best gold-producing lead in Victoria. Among the many successful mines was the Madame Berry, which produced 12,045 kg of gold.

Mining ceased at Creswick during World War II.

Buninyong: At Buninyong, the shallow alluvial gold was poor, but the discovery of deep leads on the Ballarat gold-field stimulated the search for deeper gold. By 1856, deep lead mining at Buninyong had attracted 10,000 miners. The Durham lead and its tributaries - extending from Enfield, Napoleons, Buninyong, and Durham lead townships - comprised the Buninyong gold-field. Quartz mining developed in 1960 and continued for many years.

Woady Yaloak--Smythesdale: As early as 1848, gold was discovered along Smythes Creek, but the main rushes did not occur until 1855. Areas rushed included Piggoreet, Salt Creek, and Happy Valley.

Shallow workings along Smythes Creek (Woady Yaloak River) were traced into the main Smythesdale lead. Important areas along this lead were Smythesdale, Scarsdale, Cape Clear, and Pitfield Plains; the Italian Gully, Happy Valley and Linton leads formed major tributar-

Miner crushing quartz in dolly pot

ies. Large-scale deep lead mining commenced in the Pitfield area in the 1890s and continued to 1909.

Mount Misery--Berringa--Rokewood: The Mount Misery gold-field was located on the drainage system running south from Staffordshire Reef and Little Hard Hills, much of which remains as public land. The Illabarook lead system was discovered following a rush to the area in 1861.

Berringa was a small alluvial field until 1864, when operations began on several quartz reefs. The field was rushed in 1875 and subsequently enjoyed periods of success and decline as new reefs were discovered and then worked out. In 1897 the rich Birthday quartz

Hand puddling

lode was discovered. This consistently payable line of reef, together with other nearby reefs, resulted in numerous mines being established in a narrow north--south belt between Berringa and Staffordshire Reef.

Important mines in the area included Williams Fancy Mine at Berringa and the Jubilee Mine near Staffordshire Reef. Much of these once-important gold-fields remain as public land.

Ararat: The Ararat gold-field was opened in May, 1854, when a party of Avoca diggers, prospecting out to the west, found gold in shallow alluvials at Pinky Point, just west of where Ararat now stands. The discovery in 1857 of the Canton lead on Flint Hill, almost at Ararat itself, caused 20,000 people to move into the area within the first weeks.

Most of Ararat's gold came from the deep leads and reef mining was generally insignificant. Several leads pass beneath the basalt south-east of Ararat forming the main Langi Logan lead, which has been traced 20 km to the south. The Langi Logan South Company and others worked this lead and its tributaries until 1925. Minor revivals of activity occurred in the 1930s and 1950s. Exploration in the late 1960s and 1970s has failed to show anything of interest.

Glenpatrick--Amphitheatre: Gold was first worked at Amphitheatre in 1853 and

Cradling

Elmhurst was rushed in 1888. In more recent times, from 1954 to 1956, a large-scale dredging of the gravels along the Avoca River at Amphitheatre yielded 451 kg of gold.

Fiery Creek (Beaufort): A small party of the earliest visitors to the Ararat diggings, on hearing of likely areas to the east and directed by the natives, made their way to Yam Holes, the site of Beaufort today. After a few weeks of digging, they struck enough gold in the gullies to attract more diggers. It was the following year, 1855, however, that the rich alluvials of Fiery Creek to the west were found, bringing 4,000--5,000 people to the district. There was little quartz mining on this field, and most of the activity ceased with the demise of the alluvial mines in the 1890s.

The former Beaufort gold-field and the adjacent Raglan and Waterloo gold-fields cover large areas of public land.

Development of Primary and Secondary Industries

Agriculture

The first settlers in the Ballarat district used their land mainly for sheep grazing. Cultivation prior to the discovery of gold was mainly confined to growing feed for horses and cattle and produce for household use.

The discovery of gold in 1851 brought a change in land use, however. Initially, the diggers' food requirements were met by transporting food from Melbourne at high prices. So the opportunity for gaining rich returns from the land by dairy farming and cropping was soon realized. Landholders near the gold-fields grew wheat, oats, and vegetables and established dairy herds. In addition to feeding the miners themselves, many graziers turned to growing oats for hay or grain, to meet the demand for horse-feed.

Barley was another crop with a ready market in the mining towns, where malt-houses created the demand for it.

Fruit was grown in several areas in the region, including Kingston, Clarendon, Learmonth, Rokewood Junction, Yandoit, and Clunes.

Land subdivision started in 1854 and by the 1880s various *Land Acts* had provided many small-holdings around the mining towns. Intensive agriculture on these small-holdings eventually produced more than could be consumed locally, and surplus dairy produce, fruit, vegetables, hay, and oats were sold in Melbourne.

Despite this, grazing remained the predominant land use, and the region was renowned for its production of high-class wool.

Up until the 1900s, stock were grazed on natural pastures. Between 1913 and 1925, however, the Victorian Department of Agriculture demonstrated the greatly improved productivity of pastures sown with subterranean clover and topdressed with superphosphate. This was a major advance. With improved techniques in harvesting and sowing subterranean clover seed, the area of improved pasture soon increased. Between 1925 and 1944 the area of improved pasture in the Western District increased eight-fold, and a similar expansion occurred in the Central Highlands region. The livestock population also increased considerably, although this was restricted by an enormous rise in rabbit numbers.

Pasture development was checked during the 1939--45 period due to shortage of superphosphate. Another era of rapid development started in the late 1940s, however. An easing of the shortage of superphosphate, a boom in wool prices in 1951, discovery and widespread distribution of myxomatosis to control rabbits, and the discovery of a soil deficiency of molybdenum at this time all contributed to a trebling of improved pasture in the area between the late 1940s and the late 1960s. Over that same period, numbers of sheep and cattle in the regions doubled. This development was curtailed in the late 1960s by a combination of drought, lower financial returns from livestock, and a change in the Commonwealth income tax provisions making pasture improvement less attractive.

The general pattern of land use that had developed by the 1880s has remained substantially the same to the present day. The vegetable - and fruit-growing of the mining days declined as other parts of the State were found to be more suited to these crops. And dairying declined after World War II, with the expansion of dairying in more favourable areas of the State. Oaten hay gave way to oaten grain with the demise of the farm horse and the increasing cost of labour, but by the 1970s the increase in the numbers of horses kept for recreation caused a resurgence of demand for oaten hay.

The area sown to potatoes reached a peak during World War II, but has declined since then as improved technology has considerably increased productivity. In particular, the advent of spray irrigation of potatoes in the 1950s greatly increased productivity and contracted the industry largely to well-drained red soils in areas where sufficient water was available. In the 1950s and 1960s, potato-growing changed from being mostly unirrigated to mostly irrigated from private supplies.

The number of rural holdings reached a peak in the early 1920s and has since declined as farmers sought larger holdings - initially to improve their income and standard of living. Since the 1950s this trend to larger holdings has become a necessity to survive in the face of stagnant prices and rising costs.

Forestry

The earliest records indicate that sawmilling commenced in the 1840s to provide timber for early pastoral runs. The discovery of gold and the parallel population explosion created a huge demand for domestic and industrial fuelwood and for building and mining timbers.

Workers with steam-powered sawmill in the Wombat forest

Until this time, the forests had consisted of even-aged stands of large-sized trees, but these stands were felled at a rapid rate. In the 1850s and 1860s, tall timbers on the volcanic soils surrounding Buninyong, Warrenheip, Springhill, and Kingston were milled and the land turned over to agriculture.

The old-growth forests in the Creswick area were almost entirely cut by 1875 and the forests south of Ballarat were cut over by 1890. In the Wombat forest (a small portion of which is included in the study area), sawn timber production in 1897 had fallen to only 7% of the volume cut in 1876. The Mount Cole forests were closed to utilization in 1904, as practically all the milling timber had been harvested, and were not re-opened to sawmilling until 1947.

The clear-felling of these forests was often accompanied by fire, commonly the result of deliberate lighting to assist in clearing for agriculture. This combination resulted in the establishment of regrowth forests, mainly from seedling regeneration, which were well suited to provide mining timbers and firewood. In the late 1880s, the regeneration that followed cutting in these stands was mainly by coppice stems growing from the tree stumps.

From the early 1900s, mining activity declined, but the demand for industrial and domestic fuel remained high. In 1907 the first *Forests Act* was ratified and in 1918 a new *Act* provided for the establishment of the Forests Commission. The legislation strengthened the control of forest-harvesting activities. This control, supplemented by silvicultural operations, has been instrumental in improving the condition and productivity of the remaining forests.

Softwood plantings took place in 1888 on public land adjacent to the present State nursery at Creswick.

Its aims were to provide employment for ex-miners as gold-mining declined, and to revegetate and stabilize sluiced areas. Until 1900, a range of species was tried at Creswick, but radiata pine (*Pinus radiata*) soon established its superiority as a commercial timber species.

Following the success of the Creswick plantings, establishment began at Scarsdale in 1916, and at Yarrowee in 1918. Plantings continued at Creswick, Scarsdale, and Yarrowee at varying rates, with peaks in the annual areas planted occurring in the late 1920s and early 1930s as a result of the availability of unemployment-relief labour.

In the 1880s softwood plantations were also established by the Ballarat Water Commissioners to provide protective cover to catchments cleared many years earlier. Initially, a variety of tree species were established, but radiata pine proved to be the most successful.

Water supply

A gold-mining community required vast quantities of water - to sluice the wash dirt as well as provide water for domestic and industrial consumption.

Until 1860 Ballarat drew its water from Yuille's swamp (Lake Wendouree). In 1861, the government commenced the construction of reservoirs on an *ad hoc* basis as well as purchasing the privately owned Kirks Dam. Beales Reservoir was constructed in 1863, Pincotts in 1867, and Gong Gong in 1877. A storage constructed on Sawpit Creek, at Mount

Langi Ghiran, supplied water to Ararat in 1876. It was augmented by water from a dam at Mount Cole constructed in 1906.

Transport

The advent of the railway to Ballarat (via Geelong) in 1862, Creswick and Beaufort in 1874, and Ararat in 1875 saw the end of the traditional horse-drawn coach and bullock wagon as major forms of transport. Prior to this, in 1859, J.D. Morgan coachbuilders at Ballarat had built a passenger coach named the 'Leviathan', which according to an early engraving was drawn by 8 horses and carried 89 passengers.

Remnants of History

No gold-mines are operating at present, although exploration licences cover the auriferous country. Remnants of the early days of pastoral and mining activity are common, however. Homesteads and buildings of many of the early sheep stations still exist, although most are in private hands.

Remnants of the gold-mining era are evident in the agricultural environment in terms of tailings heaps of the former deep lead mines, including the Australasian and Berry Consul at Creswick.

In the forested country around Smythesdale, former open-cut mines can be found. Machinery foundations and battery sand occur around the Birthday mine at Berringa. Mining dams, water races, puddling machines, shafts, and sluiced areas are relatively common throughout the public land. The blast furnace still stands at Lal Lal, as does the distillery at Dunnstown.

Representative examples of historic sites should be preserved to enable the study and understanding of historical archaeology and also to provide an educational resource that can be visited and appreciated by the people of the State. Unfortunately, little appreciation has been given to the significance of historic sites, and over the years many have been destroyed or changed.

For example, tailings dumps tend to be a ready source of gravel and open-cut mines a ready-made tip, historic buildings have been demolished or altered, and various artifacts souvenired.

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Early photograph of Skipton

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PART II

NATURE OF THE LAND

GEOMORPHOLOGY

This chapter describes the present landscape of the Ballarat area in terms of its geomorphic subdivisions and drainage systems. The two major geomorphic subdivisions, the midlands and the volcanic plains, are correlated with major rock types and are the result of evolutionary processes of land formation and erosion that have occurred throughout geological time. (Table 4, on page 42, shows the geological time scale.)

Geomorphic Evolution

During the Mesozoic era (150 million years ago), an extensive low and featureless peneplain developed across much of Victoria on rocks of Palaeozoic age. Part of this plain, covering the Ballarat area, was essentially destroyed as a result of uplift and erosion during the late Mesozoic. Resistant granite and metamorphic rocks that comprise the Mount Langi Ghiran and Mount Ben Major summits may represent either remnants of the former peneplain or monadnocks rising above it.

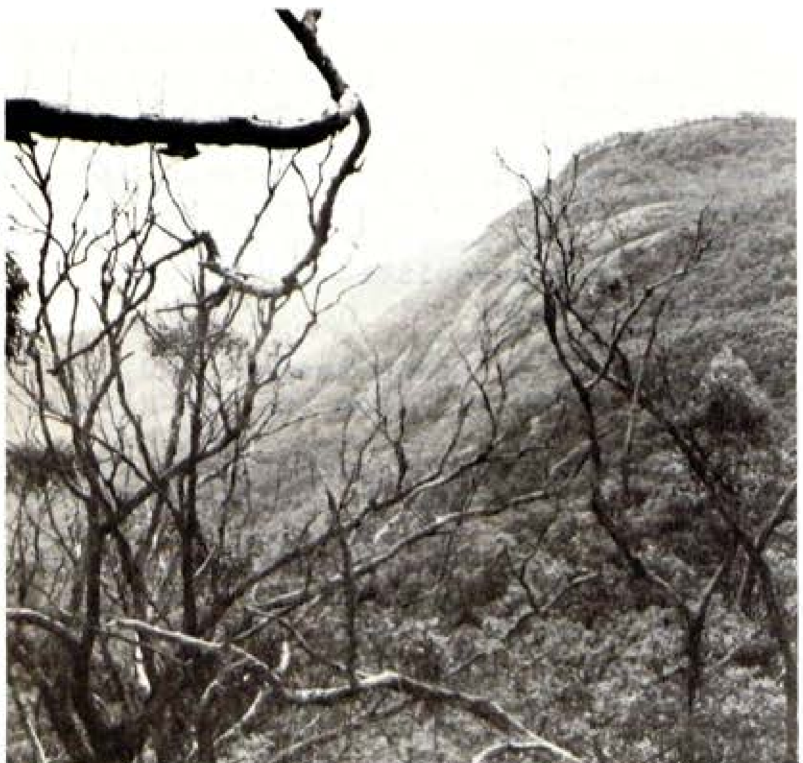
By the early Tertiary (60 million years ago), continued erosion had produced a gently undulating terrain over much of the study area. Erosion and limited continental deposition probably continued during much of the early and middle Tertiary, further flattening the general topography.

During the middle Tertiary the sea from the Otway Basin inundated the south-eastern corner of the study area, laying down sediments. Continental deposition became more widespread as stream-base levels adjusted to the rising sea level, depositing coarse alluvial (deep leads in part) and associated fresh-water sediments.

By the early Pliocene the sea had retreated completely from the study area.

A general State-wide uplift, commonly known as the Kosciusko Uplift, commenced during the late Tertiary (about 7 million years ago). These earth movements initiated the rejuvenation of streams, and the resultant stream down-cutting. In many places the valley erosion was interrupted by the extrusion of the Newer Volcanics, which resulted in lava flowing onto the plain previously developed on Lower Palaeozoic rocks and continental deposits, including the deep leads. This volcanicity was associated with the earth movements and is believed to have been initiated by them.

Tectonic activity was most marked during the late Tertiary and early Quaternary (Pliocene and Pleistocene eras - about 7.2 million years ago), but valley erosion has continued up to the present, aided by diminished but continued uplift. Earth movements recorded in the mines of Ballarat, apparently unrelated to mining procedure, demonstrate that tectonic activity is still continuing.



Granite face of Ben Nevis

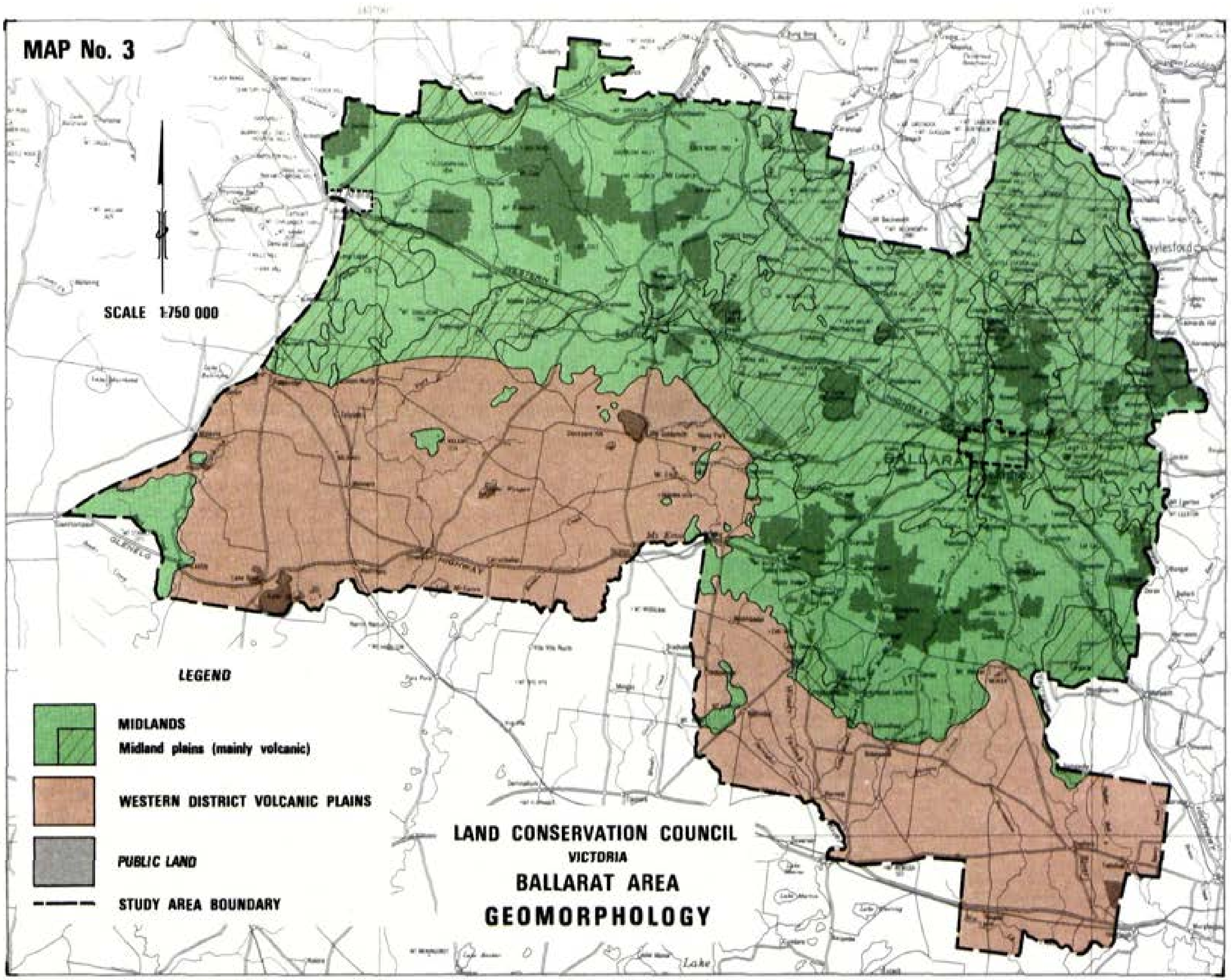
Geomorphic Subdivisions

A combination of geological structure (types of rocks present) and geomorphic expression (or topography) has resulted in the delineation of two distinct geomorphic subdivisions in the study area - the midlands and the Western District volcanic plains (see the map facing this page).

Midlands

The Great Dividing Range - of Lower Palaeozoic rocks - extends in an east--west direction across the northern part of the area. Mount Buangor (989 m), the highest point, is part of a resistant granite mass that also includes Mounts Langi Ghiran (922 m), and Cole (899 m), and Ben Nevis (879 m). The southern tip of the Pyrenees Ranges, consisting of tightly folded sediments, extends to the south of Beaufort where the relief is relatively more gentle. In the headwaters of the Wimmera and Avoca Rivers, erosion of granite masses has produced a basin-like feature surrounded by ridges and peaks of resistent metamorphosed sediments. These include the peaks of Mount Ben Major (610 m) and Mount Lonarch (966 m).

This rugged area of the midlands represents a much eroded remnant of the Mesozoic peneplain described earlier.


MAP No. 3
SCALE 1:750 000
LEGEND
MIDLANDS
Midland plains (mainly volcanic)
WESTERN DISTRICT VOLCANIC PLAINS
PUBLIC LAND
STUDY AREA BOUNDARY
LAND CONSERVATION COUNCIL
VICTORIA
BALLARAT AREA
GEOMORPHOLOGY

Midlands plains

Broad areas of plains extend across the midlands from north to south. These were developed by the drainage system and, in some cases, extended by lava inundation of part of that system. The largest midlands plains in the study area are of volcanic origin.

Midlands plains, made up of alluvial sediments and volcanic flows, are associated with the upper reaches of the Hopkins River and the Fiery Creek--Middle Creek system. The watershed (which is in this case the Great Dividing Range between the latter system and the north-flowing Wimmera system is a low undulating plain developed on late Palaeozoic rocks between Mount Langi Ghiran and Mount Buangor. The plains near the upper reaches of the Wimmera system, around Mount Cole Creek and Elmhurst, have been formed by the more rapid erosion of granitic rocks in the area, accompanied by the deposition of alluvial sediments.

Around Ballarat, the gently undulating section of the midlands extends from Creswick as far south as Rokewood, south-east to Lal Lal, and west to Linton and Pittong.

The original stream pattern determined the course of some basalt flows in this area - for example, along the Leigh and Woady Yaloak Rivers - and has resulted in tongues of basalt bisecting this part

Granite tors on top of Mount Misery

of the midlands. Remnants of earlier late Tertiary--early Quaternary continental deposits are found, particularly around Rokewood Junction and Woodbourne.

Monadnocks of granite protrude through the lava plain at Mount Bolton, Mount Misery, Mount Emu, and Mount Kinross. Mount Weejort is a monadnock of lower Palaeozoic sediments.

Western District volcanic plains

The Western District plains, made up of Palaeozoic bedrock and Tertiary sediment, existed before volcanic activity commenced during the Pliocene around 4 million years ago. Liquid lava from a succession of volcanic eruptions covered vast areas of this pre-existing plain

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and parts of the midland plains, building up flat basalt sheets. The basalt capping is generally less than 60 m thick and individual flows are often less than 30 m thick.

Volcanic flows also extended into the midlands and, particularly north and north-west of Ballarat, lava flows filled 'deep-lead valleys' to a depth of 150 m, overtopping the intervening ridges or interfluves to form broad plains. Many of the larger valleys were blocked by lava flows, which resulted in modification to drainage systems.

The volcanic plains are notable for the large number of extinct volcanoes of relatively small size. In the study area more than 60 have been named and the greatest concentration occurs on the midland volcanic plains to the north-west, north, and north-east of Ballarat. The volcanoes range in height from Smeaton Hill (250 m) down to unnamed hillocks of less than 15 m, with the majority lying between 15 and 60 m. These small hills mark points of eruption at which large quantities of lava poured out, covering the plains and portions of the midlands.

These lavas, known as the Newer Volcanics, began erupting during the Pliocene (4.5 million years ago) and extended to the Recent (15,000 years ago). The relative youth of many volcanoes is indicated by their well-preserved shape and minimal erosion. Similarly, the most recent flows, such as those south of Cambelltown and surrounding Stockyard Hill, retain many of the original surface features. Known as 'stony rises' - a combination of rough flow tops, steep flow edges, and collapsed lava tunnels and tumuli - these features are the result of differential draining of liquid lava from beneath the skin of a partly congealed flow. Older flows develop deep soils and include boulders showing spheriodal or onion weathering.

Soil relations are complex, and red-brown earths, krasnozems, and black earths may be found on the same flow.

When liquid lava is extruded, its temperature is around 1,100°C. As it cools and solidifies it contracts or shrinks and so regular cracks or joints develop, leaving the lava as a series of 6-sided (some 5- or 7- sided) columns. Excellent examples of this columnar jointing can be seen on Crown land at Lal Lal Falls and Piggoreet West.

Other volcanic features of the plains are represented by lava volcanoes, scoria cones, and maars, which are described below.

Lava volcanoes

Three types of lava volcano are recognized:

* lava cones: repeated eruptions of liquid lavas with no apparent scoria

Lal Lal falls drop over the edge of the basalt escarpment south-east of Ballarat have formed low-angle lava cones of moderate relief. Few show any signs of a crater - for example, Stony Rises and Rocky Hill north of Smeaton and Langdon Hill east of Newlyn. Wallinduc is an asymmetric lava cone.

* lava discs: viscous lava extrusions have produced flat-topped hills rather than cones, in which the flow edge forms the steep sides - for example, Lawaluk south of Mount Mercer.

* lava domes: other viscous lava extrusions have tended to form steep-sided domes lacking a crater - examples are Badger Hill north of Wallace, Talents Hill north-east of Dean, Coghills Hill, Mount Blowhard, Mount Pisgah, Mount Hollowback, and McLean Hill north of Ballarat.

Mount Lawaluk - a flat-topped lava extrusion termed a lava disc

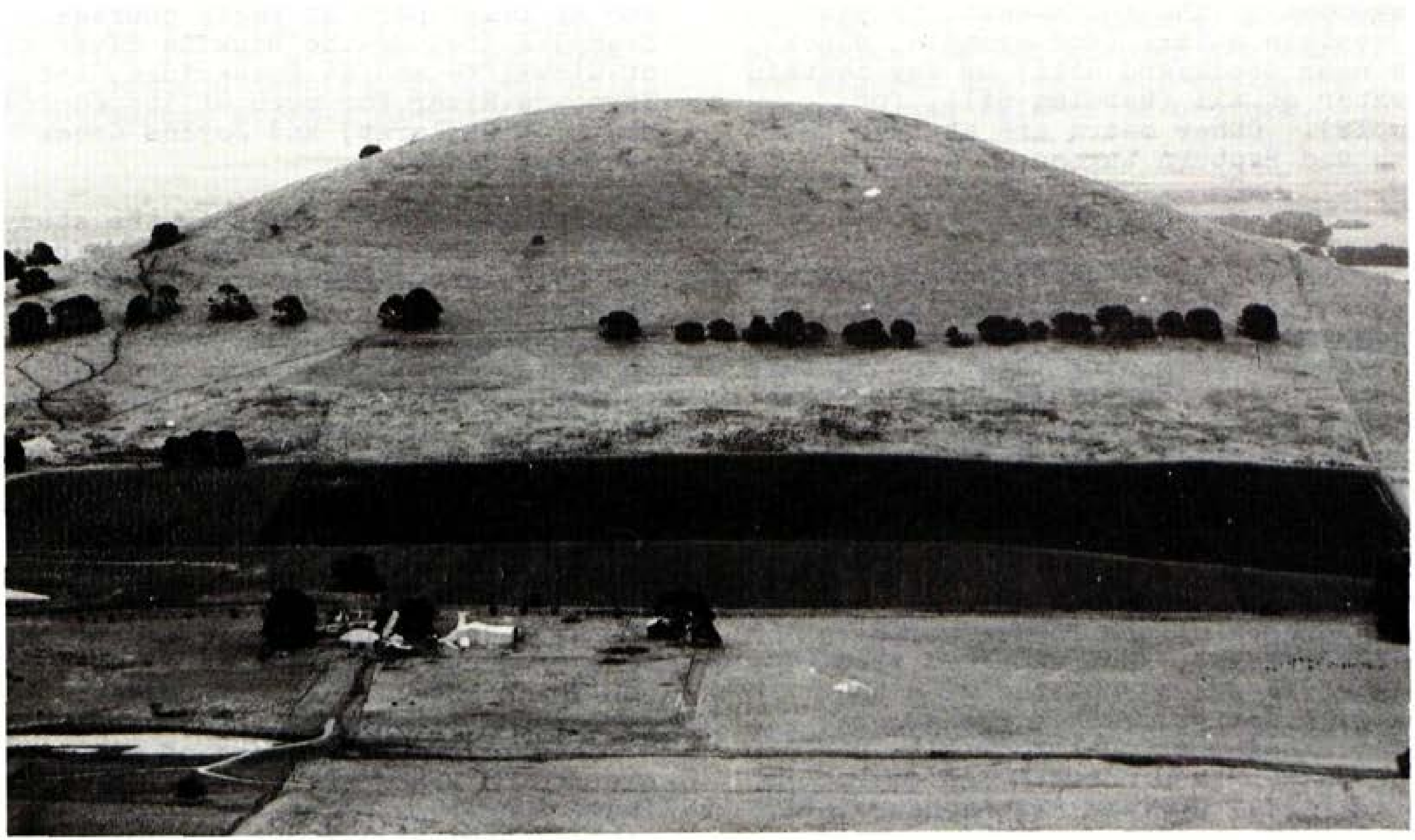
Scoria cones

Scoria cones are generally built by pyroclastic activity, but some may be composites having alternate layers of lava and scoria. They are also steeper than lava volcanoes, and many possess distinct craters. The ejected material ranges from fine ash to blocks of basalt and coarse bombs - consisting of basalt fragments that may have kernels of country rock or olivine.

Country rock of sandstone, quartzite, granite, and quartz pebbles may also be thrown out with the general scoria. For example, granite rocks from beneath Mount Callender can be found imbedded in tuff surrounding Lake Burrumbeet.

The shape and form of the volcano depends on the size of the ejectmenta and on the direction of the prevailing wind at the time of eruption, which may result in the unequal accretion of scoria. While many eruption points are domes that lack a visible opening - Springmount and Mount Moorookyle, for example - others such as Bald Hill have perfect craters.

Many of the scoria cones are breached (usually on the north-western or western flanks). Such breaches are formed by lava break-through, slumping of the wall into the crater, and by explosive shock. The breach in the north-western crater rim of Mount Warrenheip and Mount Buninyong was caused by explosive shock.



Mount Moorookyle - a scoria cone

Lava subsequently flowed through the breach at Mount Buninyong.

Maars or tuff rings

Maars have the form of a circular ring of volcanic materials and country rock surrounding an explosion crater that extends below ground level. The wall of the maar is steep on the inside and slopes gently on the outside to merge with the surrounding plain. Callender Bay, part of Lake Burrumbeet, is probably a maar with a tuff ring and agglomerate open to the south-west. A maar may contain a lake (for example, Black Lake near Stockyard Hill) or may contain no water at all (Hardies Hill, for example). Other maars are at Lake Learmonth and Hepburn Lagoon.

Drainage

The extrusion of lavas associated with the Newer Volcanics resulted in considerable modification to the drainage system. Deep-lead mining late last century and early this century established that the main divide in pre-Newer Volcanic times was clearly defined and situated to the south of Ballarat some 20 km or more south of its present position.

The outpouring of lava in the Burrumbeet and Learmonth areas obliterated the upper reaches of the former north-flowing streams, and, combined with earth movements associated with the Kosciusko Uplift, raised the general elevation of the country to give a slope south rather than north. The divide is now quite ill defined in the Learmonth area, being little more than a broad plain covered with basalt.

In the Ballarat, Creswick, and Beaufort regions many former river courses and associated gold-bearing gravels (termed deep leads) were also overlain by lava flows.

Lava flows diverted many streams, causing them to become lateral to the flow for at least part of their courses. Examples include the Hopkins River north of Wickliffe and at Rossbridge, the Yarrowee River for much of its course south of Ballarat, and Joyces Creek north of Blampied.

Natural lakes and swamps in the study area have developed where volcanic flows and pyroclastic material have closed off catchment outlets, or created small catchments with internal drainage, disconnected from the general drainage system. Examples are Lake Goldsmith, Lake Wongan, Cockajemmy Lakes, and many other lagoons and swamps across the basalt plains.

Broad areas of alluvium are often sites of former lakes that have subsequently developed outlets. For example, the deposits near Ercildoun represent the site of a former lake that eventually cut an outlet to Lake Burrumbeet. Lake Burrumbeet itself was formed as a result of basalt damming. Areas of alluvium are common along the contact of midland and volcanic plain, where catchment outlets were sealed off by basalt flows. This is evident around Mena Park, Langi Kal Kal, Buln Gherin Swamp, and Mannibadar.

Some lakes and swampy area are directly linked to explosive events that formed craters lower than the surrounding countryside - for example, the maars at Black Lake, Hepburn Lagoon, and Callender Bay.

Drainage of the plains is often indistinct, with little erosion of the lava flows. Strong dissection is found only along permanent streams exemplified by the Yarrowee River south of Mount Mercer, which has cut through the basalt and exposed the Tertiary sedimentary sequence and Palaeozoic bedrock.

GLOSSARY

Agglomerate - a chaotic assemblage of coarse, angular, pyroclastic material.

Ash, volcanic - uncemented pyroclastic material consisting of fragments mostly less than 4 mm diameter; consolidated ash cones are called tuff rings.

Basalt - fine-grained, dark-coloured igneous rock.

Country rock - general term applied to the rock surrounding and invaded by an igneous intrusion.

Lava - fluid rock from a volcano or fissure; or the same material solidified by cooling.

Monadnock - a residual rock, hill, or mountain standing above a peneplain or a residual of an old topography.

Olivine - magnesium iron silcate - an important rock-forming mineral of basic rocks such as basalt.

Peneplain - a land surface worn down by erosion to a nearly flat or broad undulating plain.

Pyroclastic - detrital volcanic materials that have been explosively ejected from a volcanic vent.

Scoria - vesicular, cindery lava. The vesicular nature is due to the escape of volcanic gasses before solidification.

Tuff - a rock formed of compacted volcanic ash and dust. Tuff may contain up to 50% sediment.

Volcanic bombs - pyroclastic ejectments, consisting of fragments of lava that were liquid at the time of ejection and have forms, surface markings or internal structures acquired during flight through the air or at the time of landing after flight; sizes range from a few millimetres to a metre or more.

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GEOLOGY

The earth's history of more than 4,000 million years is divided into major time units termed eras. From oldest to youngest, these are the Precambrian, Palaeozoic, Mesozoic, and Cainozoic. Rocks from the last three eras are represented in the Ballarat area.

Table 4, which depicts the geological time scale, and maps of geology and geomorphology will assist in an understanding of the geology of this area. In addition, a glossary of technical terms appears at the end of this chapter.

The Ballarat area can be broadly divided into two groups of rocks - those derived from processes occurring in the Palaeozoic and Cainozoic eras.

North-west of the city of Ballaarat, lower Palaeozoic rocks (500--400 million years) form the rugged hills of Mount Cole--Mount Langi Ghiran; rocks of similar age form the more subdued landscape extending south from Creswick to Rokewood Junction. The rest of the study area is dominated by Cainozoic rocks and comprises a vast volcanic plain with extinct volcanoes and monadnocks rising above it.

From these broad outcrops, together with isolated outcroppings of rocks, bore data, and mine information, we can construct a general geological history, as shown in Figure 1.

Geological History

During the Cambrian period, some 550 million years ago, a large north--south marine trough known as the Tasman Geosyncline extended from Tasmania to New South Wales. Volcanic activity within this unstable trough resulted in eruptions of basic lavas, which formed, along with some sedimentation, the initial filling of the trough. Volcanicity stopped during the Cambrian, and marine sediments continued to infill the slowly subsiding trough throughout the Cambrian and early Ordovician periods. The volcanic rocks and sediments were folded and faulted, probably during the early Silurian, then later uplifted and eroded.

These marine deposits now form a large part of the Ballarat area. Remnants of the volcanics and interbedded sediments outcrop in a narrow strip running south from Stavely. The younger Cambrian and lower Ordovician sediments outcrop over broad areas to the north-west and around Ballarat itself.

During the Silurian period, renewed earth movements and down-warping resulted in extrusion of acid lavas over the land surface that had developed on the older sediments and basic volcanics. An elongated north-south trough developed into which non-marine sediments were deposited during the Silurian and early Devonian. Occasional incursions by the sea resulted in thin interbedded marine sediments. The trough probably stabilized during the early Devonian when deposition ceased and the sediments were gently folded. Remnants of these rocks

Table 4

GEOLOGICAL TIME SCALE

Era	Period	Epoch	Age in millions of years
Cainozoic	Quaternary	Recent	0.015
		Pleistocene	1.8
	Tertiary	Pliocene	5
		Miocene	22.5
		Oligocene	36
		Eocene	55
		Palaeocene	65
Mesozoic	Cretaceous		136
	Jurassic		195
	Triassic		225
Palaeozoic	Permian		289
	Carboniferous		367
	Devonian		416
	Silurian		446
	Ordovician		509
	Cambrian		575
Precambrian			

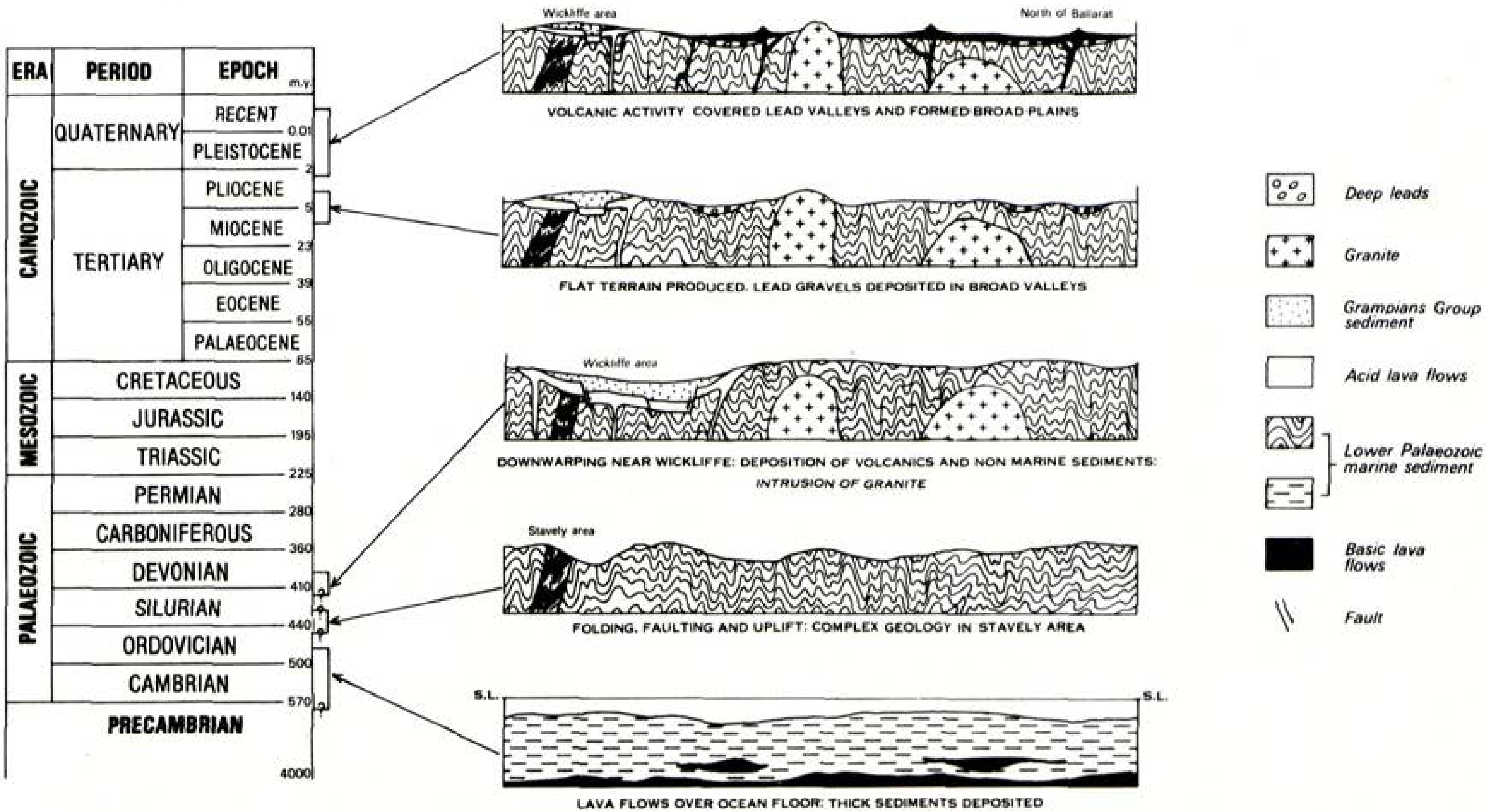


FIG. 1 SIMPLIFIED GEOLOGICAL HISTORY: BALLARAT STUDY AREA

- known as the Wickliffe Rhyolites and the Grampians Group - now outcrop south of Willaura.

During the early Devonian, granitic magma was intruded into the older Cambrian--Ordovician and Silurian--Lower Devonian sediments several kilometres beneath the surface of the earth. Subsequent erosion of the overlying sediments exposed the granites that now outcrop at numerous localities in the Ballarat area.

For the following 250 million years - the remainder of the Palaeozoic and the bulk of the Mesozoic - there is an almost complete break in the geological register in this area, apart from occasional dykes of Jurassic age. If any rocks were laid down during this period, they have since been removed by erosion.

During the late Mesozoic, the large east--west trending Otway Basin - associated with the breaking apart of the Australian and Antarctic continents - had developed south-west of the Ballarat area. On the mainland during the middle to late Eocene, alluvial deposits were being laid down (Eastern View Formation) and basalt (Older Volcanics) extruded near Cressy. During the late Eocene, the sea advanced towards the south-eastern corner of the Ballarat area, depositing marine sediments at the basin margins (Demons Bluff Formation). During the late Oligocene, the sea advanced strongly towards the basin margins, inundating this south-eastern corner. Calcarenite, rich in Bryozoal fauna (Maude Formation) was deposited in the shallow water, and calcareous silt and marl (Gellibrand Marl) laid down in deeper water.

The sea began to retreat from the study area in the middle Miocene, but at the end of the Miocene it advanced from the Port Phillip Basin in a narrow neck as far north-west as Shelford, depositing shallow-water sands (Moorabool Viaduct Sand). On the mainland, both north- and south-flowing river systems laid down coarse gravels (deep leads).

Towards the end of the early Pliocene the sea retreated completely from the study area, followed by volcanicity associated with mild earth movements (Kosciusko Uplift). Much of the Ballarat area had been undergoing continued erosion from as far back as the Mesozoic, which had produced a plain-like topography over broad areas. The vast outpourings of fluid lavas in the Cainozoic inundated much of this plains area, disrupting the drainage system and infilling some of the larger deep lead valleys north of Ballarat. The Dividing Range, which had passed through the Smythesdale area, was moved 25 km northward by a combination of this volcanic activity and earth movements. In many places on the lava plains the present drainage system has had little time to readjust and is still in its interrupted state.

Stratigraphy

This section describes the geological sequence in detail, beginning with the oldest rocks.

Cambrian (575--509 million years ago)

Rocks of Cambrian age are the oldest recorded in Victoria and represent the initial phase of rock accumulation in the Tasman Geosyncline. They outcrop in a narrow belt running south from Stavely. Mount Stavely is composed of chert with medium-grained greenstone (basic lavas) adjoining to the south. The occurrence of fragments of *Protospongia* sp. in the interbedded cherts testify to the extrusion of lavas under marine conditions. The eastern boundary of this belt of rock is a high-angle fault bringing greenstone against younger greywacke and mudstone of Cambrian--Lower Ordovician age.

Cambrian--Lower Ordovician (about 520 to 480 million years ago)

By the early Ordovician, a thick sequence of greywacke, slate, and siltstone was being deposited by marine turbidity currents in the subsiding Stawell and Bendigo troughs. These sediments were tightly folded, probably during the early Silurian, into north--south trending dome and basin-like anticlinoria and synclinoria. The folding has produced slaty cleavage in the fine-grained rocks.

The boundary between the Stawell and Bendigo troughs runs north--south roughly through Staffordshire Reef and Haddon. These two marine troughs were segments of a larger trough, the Lachlan Geosyncline, which in turn formed the southern part of the Tasman Geosyncline.

Large-scale faults disrupt major folds and cause interruptions in the fossil sequence. The most important to be recognized in the study area is the Muckleford fault, which runs north from Mount Egerton and has been traced for more than 130 km. It is a high-angle thrust fault bringing zones of early graptolite fossils in the west next to later graptolite zones on the eastern side - for example, in the Barkstead area. Upthrust on this fault totalled 1,200 m, and movement continued into the late Tertiary. Faulting on a smaller scale is recorded from the mines at Ballarat, with vertical and horizontal displacements up to 20 m and 200 m respectively.

Silurian (446--416 million years ago)

During the Silurian, down-warping recommenced and volcanics were extruded over a land surface consisting of tightly folded Cambrian--Ordovician sediments and volcanics. Further down-warping led to the development of a large continental depression into which non-marine sediments were deposited. The acid lavas, which are known as the Wickliffe Rhyolites, consist of 60 m of banded rhyolites, porphyritic rhyolite, and tuff. North of Wickliffe, the lavas and non-marine sediments unconformably overlie the older rocks.

Unfossiliferous Grampians Group sediments known as the Willaura Sandstone conformably overlie the volcanic rocks. They consist of basal conglomerate, quartzose sandstone, red siltstone, and sandstone deposited in association with lakes and rivers. The sequence, which extends to a depth of 960 m, is folded into a broad south-easterly plunging syncline. In the Grampian Ranges to the west, thin beds containing marine fossils indicate that the sea occasionally inundated this predominantly continental basin.

The Grampians Group sediments and the underlying volcanics lie between early Devonian and Silurian age.

Devonian (416--367 million years ago)

Numerous granitic plutons of varying sizes intrude the Cambrian--Lower Ordovician sediments of the study area. The Mount Cole Cupola - including Mounts Cole, Buangor, and Langi Ghiran - forms prominent uplands standing above the surrounding sediments. Several granitic masses have weathered out, forming basin-like features surrounded by ridges of contact metamorphic rocks (for example, the hornblendic granodiorite at Mount Lonarch, and a grey granodiorite at Granite Hill south-west of Lexton).

On the volcanic plains, isolated hills of granitic rocks protruding through the basalt cover indicate more extensive plutons beneath. The coarsely porphyritic biotite granite at Mount Bolton, the pink medium and even-grained granite north-west of Learmonth, and Mount Misery are all probably continuous beneath the basalt cover. This pluton probably extends even further south, as evidenced by tuffs at Lake Burrumbeet that contain boulders of granite. Blocks of granite are also included in the scoria at Bowens Hill near Smeaton, indicating buried granite in this area. Likewise the granitic rocks in the Mount Bute--Chepstowe--Nanima Hill area are probably continuous with the cream biotite granite at Mount Emu and are collectively called the Mount Emu Cupola. South of Pittong this pluton is deeply weathered and is a source of kaolin.

Outcrops of granodiorite along stream lines from Lismore to Mount Kinross may be a single pluton at depth. The Gong Gong--Lal Lal Cupola, east of Ballarat, is a biotite granodiorite, which is medium-grained at Gong Gong and porphyritic at Lal Lal. At Lal Lal this deeply weathered pluton is a source of kaolin.

Dykes, probably associated with the final stages of pluton emplacement, are numerous in the study atea. They are predominantly aplite, pegmatite, quartz porphyry, feldspar, porphyry, and diorite. Some of the dykes are highly altered, forming predominantly kaolin, and have been mined in the past at Mount Doran east of Lal Lal, and at Mount Egerton. It is thought that kaolinization has occurred by hydrothermal action rather than surface weathering, as the alteration continued to the lowest depths worked at Mount Egerton.

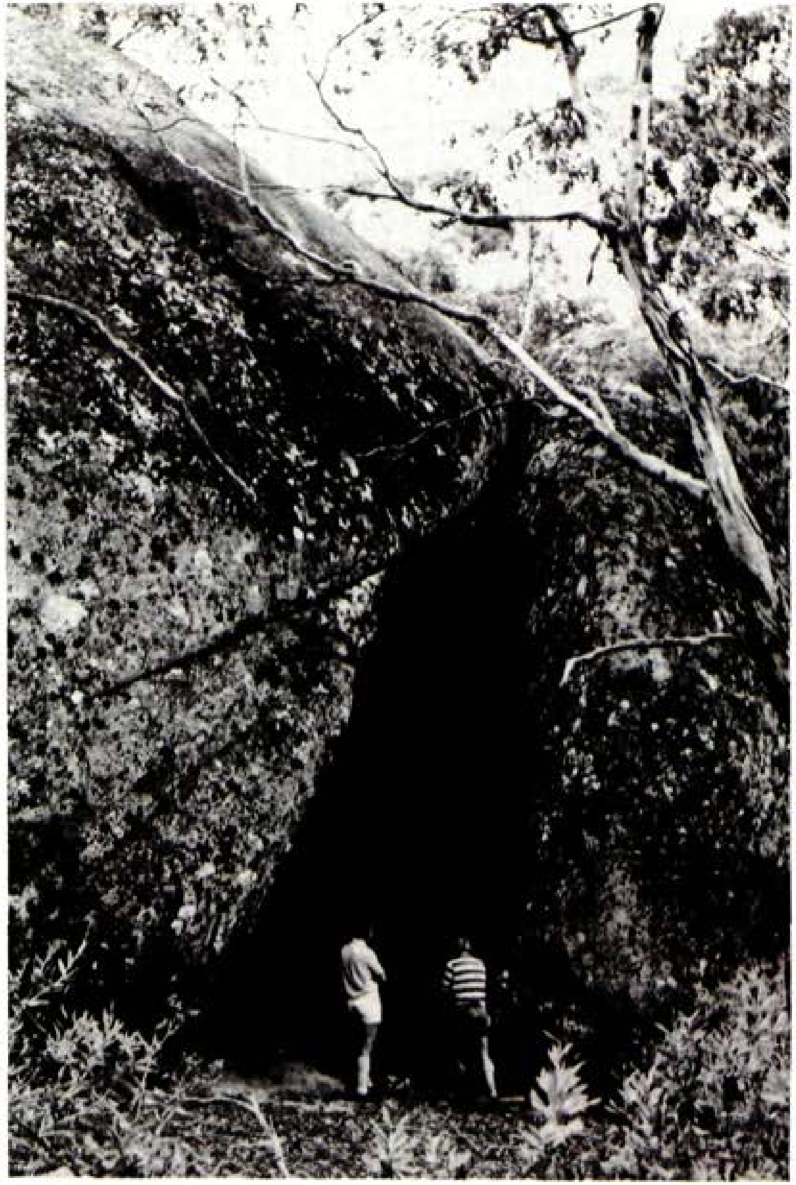
Veins of aplite and graphic pegmatite intrude the granite at Mount Bolton. Just north-west of Learmonth this pluton is intruded by dykes of coarse biotite pegmatite containing iron-bearing black garnets. At Mount Emu the granite contains aplite and biotite pegmatite.

These 'acid dykes' in the Ballarat area have a general north--south trend.

Ages of granitic rocks

Granitic rocks in central and western Victoria have been dated by the potassium--argon (K--Ar) isotopic method and the sphene dating method. It is apparent that two major periods of granite emplacement have occurred in the Ballarat area, separated by approximately 30 million years. Granites north and north-west of Beaufort have yielded sphene ages of early to middle Devonian periods.

To the south and east of the area, combined sphene and K--Ar dates indicate that the intrusions are around 360 mill-



Gigantic granite boulders at Mount Langi Ghiran ion years in age - that is, close to the Devonian--Carboniferous boundary. It is likely that the plutons at Mount Kinross and at Gong Gong--Lal Lal fall into this younger category. Until further dating is carried out, it is unclear whether the granitic rocks at Mounts Bolton, Misery, Emu and Bute are early to middle Devonian or late Devonian.

Table 5

SPHENE DATES OF GRANITIC ROCKS IN THE BALLARAT STUDY AREA

	age (million years)
Ararat	385 $\pm$ 12
Langi Ghiran	407 $\pm$ 22
Mount Cole	393 $\pm$ 17
Mount Direction	393 $\pm$ 14
Granite Hill, Lexton	384 $\pm$ 12
	374 $\pm$ 11
Lismore	369 $\pm$ 18

Source: Gleadow and Lovering 1978

Late Devonian--Early Tertiary

From the late Devonian (370 million years) to the early Tertiary (40 million years) - more than 300 million years - there is an almost complete break in the geological record in the Ballarat area. During this time erosion continued, with kilometres of sediment stripped away exposing more of the granitic plutons. Sediment may have been laid down and lavas extruded from time to time, but if so they have been entirely removed by erosion. For example, glacial sediments were deposited over a wide area of the State during the Permian (260 million years).

They were often encountered in deep lead mines just north of the study area and it is likely that some may have occupied the northern part of the study area. Jurassic dykes (150 million years) indicate that lava flows may have covered part of the surface during the late Mesozoic, but, as with the Permian glacial sediments, no outcrops are present to confirm such assumptions.

Jurassic (195--136 million years ago)

A series of dark-coloured dykes that have been intruded into Ordovician sediments outcrop in the Ballarat area. K--Ar determinations of similar rocks in the Bendigo area yield Late Jurassic ages (150 million years). The dykes are predominantly monchiquite and mainly contain the minerals augite and olivine. They have general east--west strikes, and were possibly feeders of lava flows that have since been eroded.

Tertiary (65--7 million years ago)

During the Mesozoic, the large Otway Basin developed across south-western Victoria; the north-eastern part, the Port Campbell Embayment, extended into the Ballarat area. Sediments deposited in this basin during the Tertiary period outcrop or extend below the relatively thin Quaternary sediments and volcanic rocks around the Yarrowee River near Shelford.

The sequence of Tertiary sedimentation within the study area was a response to a major marine transgression into the Port Campbell Embayment. Inundation by the sea, which started to influence sedimentation during the Eocene, reached a maximum in the early Miocene, inundating the south-eastern corner of the study area. The middle Miocene saw retreat of the sea, followed by a minor advance to Shelford from the Port Phillip Basin at the close of the Miocene. The sea finally retreated in the early Pliocene and widespread volcanic activity followed this retreat.

Several sedimentary formations were laid down in the study area by Tertiary seas. The Eastern View and Demons Bluff Formations are now subsurface. The Maude Formation, Gellibrand Marl, and Moorabool Viaduct Sand outcrop in the south-eastern corner of the study area.

Maude Formation

During the late Oligocene the sea advanced strongly towards the basin margins, laying down the Maude Formation in a littoral to shallow-water high-energy marine environment. The Formation outcrops in the study area at the junction of Woodbourne Creek and the Yarrowee River. It consists of a 15-m layer of sandy bryozoal calcarenite of late Oligocene to early Miocene age resting on Ordovician slate, and forms part of a sequence of sedimentary accumulations known as the Torquay Group.

Gellibrand Marl

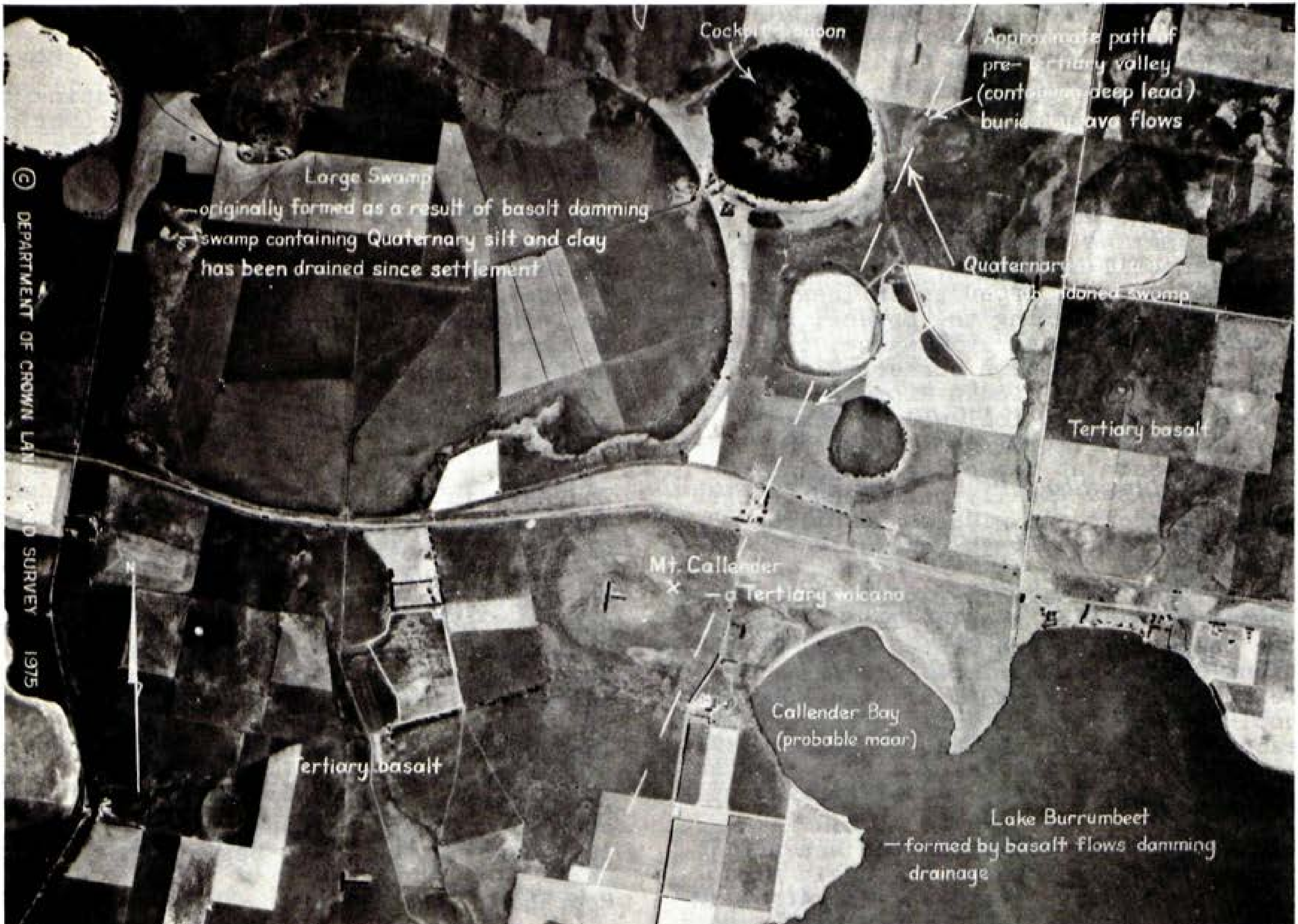
While the Maude Formation was being deposited in a shallow-water high-energy environment, the calcareous silt, clay, and marl of the Gellibrand Marl accumulated in deeper water. As the sea continued to advance, the Gellibrand Marl eventually conformably covered the Maude Formation.

The Marl is well exposed along the Yarrowee River from Inverleigh to north of Shelford as a result of the river cutting through overlying sediments. On the eastern bank of the Yarrowee, 5 km north of Shelford, it is 50 m thick. Small, isolated outcrops of marl and bryozoal calcarenite occur to the west between Cressy and Rokewood.

The Gellibrand Marl, which is late Oligocene to middle Miocene in age, forms part of the Heytesbury Group - a complete sequence of sedimentary rocks laid down in the Otway Basin.

Moorabool Viaduct Sand

The sea began to retreat from the basin margins during the middle Miocene;



Surface geology of an area adjacent to Lake Burrumbeet however, a minor oscillation (from Port Phillip Basin) at the end of the Miocene reached the area of Shelford, depositing the Moorabool Viaduct Sand. Calcareous sand and calcarenite were deposited in an east--west strait in subtidal and intertidal waters less than 5 m deep. The Sand forms part of the Brighton Group, consisting of ferruginous sand and gravel formations.

Deep leads

While the Moorabool Viaduct Sand was being laid down, widespread continental deposition was taking place on the mainland. Major stream systems, both north- and south-flowing, laid down coarse gravels known as deep leads, back-filling part of their valleys. Most of the major leads were subsequently buried beneath lava flows and their positions have been accurately located from gold-mining.

Where back-filling was extensive, broad areas of sand and gravel were laid down. Such surface outcrops, particularly around Ballarat, were among the first deposits to be worked for gold in the 1850s, and now provide a valuable source of sand and gravel.

Late Tertiary--Quaternary

During the Pliocene the highlands of Victoria were arched along an east--west axis, and is believed such earth movements initiated volcanism. This volcanic sequence is referred to as the Newer Volcanics.

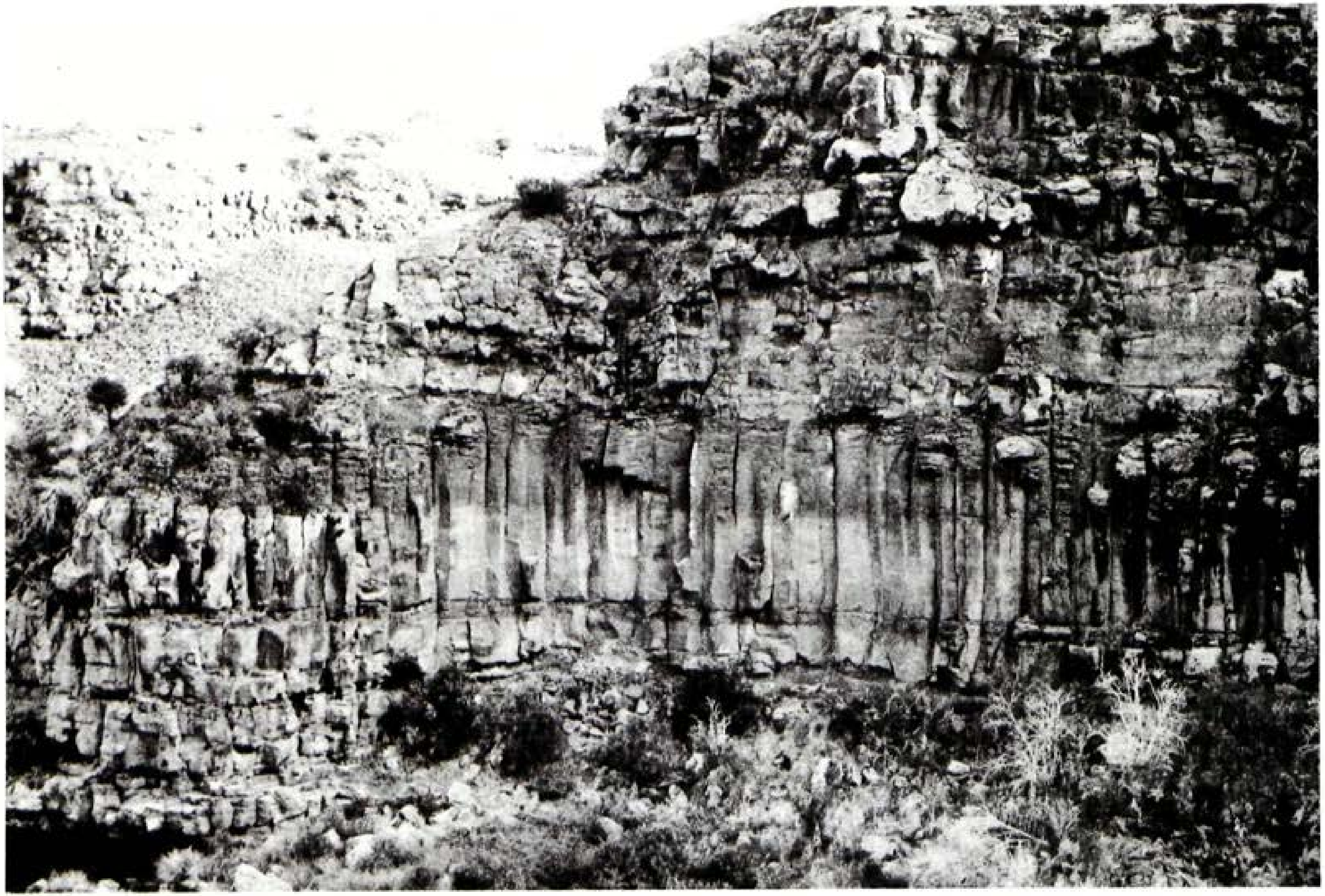
Newer Volcanics

The Newer Volcanics form an almost continuous lava field from east to west across the study area. In the south-east they rest on Tertiary sediment, while over the rest of the study area they lie on Lower Palaeozoic basement or Pliocene continental deposits (including deep leads).

The most outstanding characteristic of the field is that it is built up from a great number of outpourings of fluid lavas from many vents. During deep-lead mining in the Ballarat district, up to four main basalt sheets were intersected. Locally, sediment between sheets is up to 18 m thick, but generally the interflow sediments are quite thin, indicating only a brief time span between eruptions. The Newer Volcanics are normally less than 60 m thick, with local maxima of 120--150 m. Individual flows rarely exceed 30 m. The most abundant rock types are alkali olivine basalt and olivine tholeiite.

The relative youth of the lava field has meant it is still relatively intact from erosion. Only in the south-east along major streams such as Yarrowee River has dissection progressed to any extent.

An older and a younger phase have been distinguished. The older flows, notably



Lava flows exposed in the valley of Smythes Creek at Piggoreet west; note columnar jointing of basalt in the lower flow

those in the west of the study area, are often lateritized. On the other hand the lavas of the younger phase, north-west of Skipton, still display original flow structures, showing a subdued 'stony rises' topography in places.

Stratigraphic and geomorphic evidence indicates that most Newer Volcanic activity took place during the late Pliocene and Pleistocene. Isotopic K--Ar datings on the Newer Volcanic Province as a whole yield dates ranging from 4.5 million years to 0.6 million years, confirming the stratigraphic estimation. Table 6 shows K--Ar dates within the study area.

Table 6

K--Ar DATES, NEWER VOLCANICS

locality	age (million years)
Council quarry (now rubbish tip), Alfredton, Ballarat	*2.49 ± 0.02 *2.53 ± 0.03 2.87 ± 0.06
West Berrys Consols Mine, about 2 km west of Smeaton	*2.11 ± 0.003
Mount Rowan	2.90 + 0.06

* Source: Azia-Ur-Rahman and McDougall (1972)

Volcanoes occur in the greatest concentration to the north of Ballarat. They range from the more predominant and conspicuous scoria cones and lava domes, through lava discs, to the often indistinct lava cones. Five areas have been identified as possible maars (also called tuff rings). These are at Stockyard Hill and Callender Bay (both of which have associated basalts), Hepburn Lagoon (surrounded by tuffs with Kangaroo Hill defining the northern perimeter), Hardie Hill, and Lake Learmonth. Types of volcanoes and the geomorphology of the field are described in the preceding chapter.

Fluviatile--lacustrine sediments

Following the accelerated alluvial deposition associated with the deep leads, continental deposition has continued at a reduced level up to the present. As mentioned earlier, sediments were often encountered during deep-lead mining between basalt flows and some of these sediments may range down into the late Pliocene.

The surface alluvial and lacustrine outcrops are divided into the older terrace and lake systems shown on the Geology Map as Qpa - for example, south of Mount Misery, Mount Bolton, and Napoleons. Deposits associated with the most recent stream and lake activity are shown as Qra and Qrm. Such deposits are relatively thin. In the north of the study area - for example, Mena Park, Langi Kal Kal, Mannibadar, and north of Lake Burrumbeet - lava flows blocked many watercourses flowing from the highlands, causing damming of water and subsequent deposition of sediment. Such areas include both younger and older alluvial sediment.

Lava flows associated with younger and explosive volcanic phases resulted in a disruption of the former drainage system and in certain cases dammed back stream flow. Examples of former swamps and lakes are areas of Recent alluvial and lacustrine sediments north of Lake Wongan and north-west of Skipton.

In the areas of Lower Palaeozoic rocks, most streams contain Recent alluvial deposits of varying thickness - often overlying, but incised into, the older alluvial material. It was gold contained in such sediments that first brought miners to the Ballarat district in the early 1850s.

Glossary

Acidic. Applied loosely to any igneous rock composed predominantly of light-coloured minerals having a low specific gravity and less than 65% silica (for example, granitic rocks). It does not imply properties that would be used by a chemist.

Alkali (mineral). Refers to a feldspar or group of feldspars containing alkali metals (sodium, potassium), but little calcium.

Alluvial. Pertaining to or composed of alluvium, or deposited by a stream or running water.

Anticline. A fold that is convex upward. (Antonym: syncline).

Anticlinorium. A composite anticlinal structure of regional extent composed of lesser folds. (Cf. synclinorium.)

Aplite. A light-coloured igneous rock with a fine- and even-grained texture, free from dark minerals, usually found as dykes.

Augite. A greenish black mineral of the clino-pyroxene group found in many basic igneous rocks.

Basalt. Dark-coloured, fine-grained extrusive igneous rock.

Bedded fault. A fault that parallels the bedding of a sedimentary sequence.

Biotite. An important rock-forming mineral of the mica group. It is generally black or dark brown, and occurs in igneous rocks of all kinds and abundantly in metamorphic rocks.

Bryozoan. An invertebrate of the phylum Bryozoa, characterized chiefly by colonial growth and a calcareous skeleton. Stratigraphic range is Ordovician to present.

Calcarenite. A consolidated calcareous sand.

Calcareous. Implies that a considerable percentage (up to 50%) of the rock is calcium carbonate.

Carbonaceous. Refers to a sediment containing organic matter.

Chert. A hard, extremely dense, indistinctly crystalline sedimentary rock consisting predominantly of silica. Flint is essentially synonymous.

Clastic rock. A consolidated sedimentary rock composed of broken fragments of a pre-existing rock transported mechanically (by water, etc.) to its place of deposition.

Cleavage. Property of a rock of splitting along planar structure, produced by deformation or metamorphism.

Conformable. Refers to an unbroken sequence of strata in which the layers are laid down one above the other in parallel order by regular uninterrupted deposition.

Conglomerate. A coarse-grained, clastic rock composed of fragments larger than 2 mm set in a finer-grained matrix.

Contact metamorphism. Alteration of existing rocks in contact with or near an igneous intrusion, by heat.

Continental (deposit). A sedimentary deposit laid down on land, or in bodies of water not directly connected with the ocean.

Cupola. In the context of this report, the same as pluton.

Diorite. A group of plutonic rocks intermediate in composition between acidic and basic rocks, characteristically composed of dark-coloured amphibole acid plagioclase, pyroxene, and a small amount of quartz.

Dyke. A tabular igneous rock that cuts across the structures of the surrounding rock.

Feldspar. Feldspars are the most widespread of any mineral group and constitute 60% of the earth's crust, occurring in all kinds of rocks. They are aluminous silicates of potassium, sodium, and calcium, and are divided into alkali feldspar and plagioclase.

Ferruginous. Pertaining to or containing iron. Refers to a rock having a rusty colour due to the presence of ferric oxide.

Fission-track dating. A method of calculating an age in years by determining the ratio of the spontaneous fission-track densities to induced fission tracks. Fission tracks, which can be measured in minerals (for example, sphene) are the result of spontaneous (or induced) nuclear splitting.

Fluvial. The results of river action.

Foraminifer. Any protozoan found in marine to brackish environments from the Cambrian to the present. A planktonic foraminifera drifts in surface layers of water.

Garnet. Refers to a group of minerals commonly found as regular crystals in metamorphic rocks, and as an accessory in a wide range of igneous rocks. It is usually red, but is recorded in most other colours.

Geosyncline. A mobile down-warping of the crust of the earth - either elongate or basin-like, and measured in scores of kilometres - that is subsiding as sedimentary and volcanic rocks accumulate to thicknesses of thousands of metres.

Granite. A light-coloured plutonic rock in which quartz constitutes 20 to 60% of the light-coloured minerals and in which the ratio of alkali feldspar to total feldspar is between 35 and 90%.

Granodiorite. Similar in appearance to a granite, but contains more plagioclase feldspar at the expense of alkali feldspar.

Graptolite. Any colonial marine organism belonging to the class Graptolithina. Its known stratigraphic range is middle Cambrian to Carboniferous.

Graphic. See Pegmatite.

Graywacke. A dark coarse-grained sandstone of poorly sorted fragments of quartz and feldspar plus finer-grained material. Thinner layers show marked graded bedding. It generally requires an environment in which erosion, transportation, deposition, and burial are so rapid that complete chemical weathering does not occur, as in an orogenic belt, where sediments derived from recently elevated source areas were 'poured' into a geosyncline.

Greenstone. Basic igneous rocks, predominantly lavas.

Hornblende. The commonest mineral of the amphibole group, dark in colour. It is present in many granitic rocks, and common in metamorphic rocks.

Hydrothermal alteration. Alteration of rocks or minerals by the reaction of heated water (hydrothermal), with or without demonstrable association with igneous processes.

Igneous. A rock or mineral that has solidified from molten material. 'Igneous' rocks constitute one of the three main classes into which rocks are grouped (that is, igneous, metamorphic, sedimentary).

Isotopic dating. Method of calculating an age in years for geologic materials based on nuclear decay of natural elements. With the potassium--argon method the presence of a long-life radioactive (K-40) element plus its decay product is measured (Ar-40).

Kaolin. A group of clay minerals generally derived from alteration of alkali feldspars and mica. Used for the manufacture of porcelain fittings and fine porcelain and china, and as fillers in paper, rubber, and paint manufacture.

Lacustrine. Pertaining to, produced by, or formed in a lake

Lava. A general term for a molten extrusive - also for the rock that is solidified from it.

Littoral. Pertaining to the ocean environment between high water and low water.

Maar. A low-relief coneless volcanic crater formed by a single explosive eruption.

Marl. Applies to a soft deposit consisting chiefly of a mixture of clay and calcium carbonate in varying proportions, formed under either marine or, especially, fresh-water conditions.

Microcline. $KAl\ Si_3O_8$; it belongs to the group of alkali feldspars containing alkali metals - potassium (K) and sodium - but little calcium.

Monadnock. A hill of resistant rock rising conspicuously above the general level of a plain.

Monchiquite. A dark-coloured dyke rock containing divine, pyroxene, and usually mica or amphibole phenocrysts in a groundmass of glass.

Olivine. Olivine is $MgFe\ SiO_4$, a green mineral common in basic ignous rocks such as gabbro, basalt.

Pegmatite. Exceptionally coarse-grained igneous rock, usually found as irregular dykes especially at margins of plutons. Its composition is generally that of a granite. Pegmatites represent the last and most hydrous portions of a magma to crystallize and hence contain high concentrations of minerals present only in trace amounts in granitic rocks. Where there is a regular intergrowth of quartz and feldspar crystals, the texture is said to be graphic.

Pluton. An igneous intrusion

Porphyritic. Said of the texture of an igneous rock in which larger crystals (phenocrysts) are set in finer groundmass.

Porphyry.	An igneous rock of any composition that contains conspicuous phenocrysts (for example, quartz, feldspar) in a fine-grained groundmass.
Protospongia.	Primitive genus of the phylum Porifera. Sponges are many-celled aquatic invertebrates with an internal skeleton of opaline silica, and less commonly of calcium carbonate.
Pyroclastic.	Pertaining to a rock composed of broken fragments derived from a pre-existing rock by volcanic explosion or aerial explosion from a volcanic vent.
Rhyolite.	A group of extrusive igneous rocks generally porphyritic and exhibiting flow textures (bands) with phenocrysts of quartz and alkali feldspar in a glassy groundmass; the extrusive equivalent of granite.
Scoria.	Vesicular or cindery basic lava, the vesicular nature of which is due to the escape of volcanic gases.
Shale.	A fine-grained, indurated, detrital sedimentary rock formed by the consolidation of clay, silt, or mud and characterized by fine laminae approximately parallel to bedding.
Similar fold.	Successive folds resemble each other, with the limbs thinner than the axes.
Slate.	A fine-grained metamorphic rock, formed from such rocks as shale, which are fissile along planes independent of the original bedding (slaty cleavage).
Sphene.	Calcium titanium silicate. Small wedge- or lozenge-shaped crystals occurring as an accessory mineral in granitic rocks.
Stony rises.	A confused topography of hummock depressions, channels, and ridges, caused by differential drainage of lava from beneath a skin of partly congealed lava followed by partial collapse of that skin.
Stratigraphy.	Systematic arrangement of the sequence of rock strata of the earth's crust into units.

Tholeiite. A group of basalts primarily composed of plagioclase, pyroxene, and iron oxide minerals as phenocrysts in a glassy groundmass, or intergrowth of quartz and alkali feldspar. Little or no olivine is present.

Tuff. A compacted pyroclastic deposit of volcanic ash.

Turbidity current. A bottom-flowing current laden with suspended sediment, moving swiftly (under the influence of gravity) down a subaqueous slope and spreading horizontally on the floor of the body of water.

Unconformity. A substantial break or gap in the geologic record where one rock unit is overlain by another that is not in stratigraphic succession. It results from a change that caused deposition to cease for a considerable time.

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CLIMATE

Rainfall

In the study area, rainfall is closely related to the major geomorphic features - the basalt plains and the midlands - discussed in an earlier chapter. Moist air blows over the plains in a south-westerly stream and is lifted as it nears the ranges.

This results in lower rainfalls on the plains and higher falls on the windward side of the ranges. A north-westerly stream of moist air produces low rain-falls on the northerly plains and high falls about the northern side of the Dividing Range.

Meteorological stations in the vicinity of the Great Dividing Range receive rainfall in excess of 700 mm per annum. For example, at the Moorabool Reservoir, in the north-east of the study area, rainfall is 941 mm per annum. Few formal records are kept in the high-rainfall areas that lie on the Divide north of Beaufort. A station at Lookout Hill, north of Mount Cole, recorded an annual average rainfall of 1,193 mm between 1963 and 1977. (It should be noted, however, that climatological records require some 30 years of data collection to be statistically significant.)

Low falls are most pronounced in the south-west of the study area: the average annual rainfall is 544 mm at Willaura and 524 mm at Lake Bolac. The plains south of Rokewood also receive less than 550 mm annually.

Rainfall averages for stations within and adjacent to the study area are contained in Table 7. Rainfall distribution in relation to topography is shown on Map 7 - Water Resources, Water Utilization and Topography.

Temperature

Temperature-recording stations representative of conditions in the Ballarat area are located at Ballarat, Creswick, Ararat, Clunes, and Lismore. Table 8 shows monthly and annual maxima and minima. The 14 and 86 percentiles, which allow greater use of the temperature data, have been included for three stations.

The 14 percentile represents 1 day in 7. Thus the maximum temperature percentile

Table 7

AVERAGE ANNUAL RAINFALL (MM)

Years	Station	Bureau of Meteorology number	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Elevation (m)
76	Amphitheatre	79000	32	35	37	44	57	65	66	70	64	57	45	42	614	318
76	*Crowlands	79009	27	29	33	39	49	57	56	61	51	51	39	35	527	
67	Elmhurst	79013	31	29	34	52	56	66	74	76	63	60	49	43	633	
91	*Avoca P.O.	81000	27	37	30	41	51	60	60	61	53	50	38	36	544	
75	*Bannockburn P.O.	87009	29	37	39	42	45	43	43	47	52	51	48	42	518	120
93	Bungaree (Kirks Reservoir)	87014	47	49	52	69	83	85	84	94	87	83	69	58	860	511
30	Lal Lal	87028	37	53	53	57	65	65	68	74	79	72	62	52	737	
66	Meredith (Wattle Vale)	87044	35	43	45	47	55	48	52	59	64	60	56	53	617	335
62	Moorabool Reservoir	87045	49	58	50	75	93	86	100	108	97	91	73	61	941	605
118	Scotsburn (Mount Boninyong)	87046	42	47	51	67	73	70	71	79	82	78	63	58	779	488
96	*Clunes	88015	30	40	35	44	57	61	59	63	55	55	45	40	584	310
93	Smeaton Weir	88016	30	40	36	47	62	66	63	65	60	58	47	44	618	390
54	Creswick	88018	34	48	46	52	68	80	74	74	72	69	50	49	716	439
72	Lexton	88038	32	43	33	43	59	61	68	69	61	59	46	39	612	305
75	*Talbot P.O.	88056	26	39	32	38	52	57	60	60	54	52	40	36	546	250
61	Newlyn Reservoir	88101	32	38	46	56	74	91	72	80	75	66	49	53	732	536
107	Ararat P.O.	89000	31	34	39	44	60	67	64	68	62	61	48	38	616	332
92	Ballarat (Wendouree)	89002	37	50	47	57	70	63	69	77	73	68	56	52	719	460
83	Beaufort	89005	37	42	42	57	64	68	65	71	69	68	55	48	686	387
65	Cressy	89010	30	35	35	45	48	45	48	52	52	52	47	43	532	119
97	*Glenthompson	89013	34	34	40	54	68	66	74	74	79	73	59	47	702	296
61	Lake Bolac P.O.	89016	29	34	35	44	46	43	50	58	53	51	49	39	531	220
74	Linton P.O.	89017	38	45	48	60	70	64	69	77	75	70	63	52	731	375
41	Mount Mercer	89021	40	49	42	61	66	55	62	74	71	75	69	51	715	335
75	Rokewood	89024	33	35	41	48	50	49	46	52	59	58	51	43	565	168
77	Skipton P.O.	89025	34	41	41	52	59	54	58	64	64	61	55	47	630	289
68	Smythesdale P.O.	89028	37	49	47	58	72	61	71	79	75	73	64	53	739	354
64	Streatham	89029	30	40	41	47	50	46	51	61	59	54	55	41	575	210
86	Trawalla	89030	38	42	42	58	65	63	65	73	70	68	56	49	689	415
41	Westmere Station	89032	28	34	34	48	48	43	52	60	50	57	53	35	542	238
95	Wickliffe	89033	29	33	37	46	52	53	53	59	59	50	47	37	561	248
72	Willaura	89034	29	38	37	44	50	46	50	56	55	52	49	39	546	248
30	Inverleigh	89041	34	43	35	42	47	40	44	54	47	52	45	38	521	
53	Ballarat (Mount Pleasant)	89049	44	36	45	59	69	70	60	67	69	68	53	46	686	526
30	Ballarat (Survey Office)	89050	36	37	50	59	64	73	66	74	73	64	55	52	703	526
62	Moorabool Reservoir	87045	48	57	51	73	93	88	100	109	98	92	74	61	941	605
	Lismore	89018	34	40	37	53	56	52	59	69	60	62	57	46	625	158
5	Lookout Hill		81	72	72	102	119	92	143	126	125	99	94	68	1193	

* Station located outside the study area.

Table 8

MONTHLY AND ANNUAL TEMPERATURES ($^{\circ}$C)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Ararat (08900)*													
Daily maximum temperature													
Mean	27.7	26.4	23.9	19.3	14.6	12.5	11.1	12.7	15.3	18.6	21.6	23.9	19.0
86 percentile	35.0	33.3	30.0	23.8	18.3	14.4	13.2	15.6	18.3	25.0	28.3	30.6	
14 percentile	21.1	20.0	17.8	14.9	11.1	10.0	8.9	9.5	11.7	13.6	15.6	17.3	
Daily minimum temperature													
Mean	11.9	12.6	11.0	8.4	6.7	5.1	4.0	4.7	6.0	7.5	8.8	10.4	8.1
86 percentile	17.2	18.3	15.6	12.2	10.0	8.3	6.1	7.2	8.3	11.7	11.7	16.0	
14 percentile	8.3	8.3	7.2	5.0	4.4	1.7	1.7	2.2	3.3	3.9	5.6	6.3	
Ballarat (089002)*													
Daily maximum temperature													
Mean	25.5	24.6	21.9	18.0	13.3	11.3	9.9	11.4	13.6	16.6	19.3	22.1	17.2
86 percentile	32.8	31.2	27.8	22.8	16.8	13.8	12.1	14.3	17.3	22.1	25.8	29.3	
14 percentile	18.9	18.4	16.3	13.4	10.0	8.8	7.8	8.8	10.0	12.2	13.8	15.6	
Daily minimum temperature													
Mean	11.4	11.8	10.2	8.0	5.8	4.3	3.2	3.8	4.8	6.7	7.9	9.8	
86 percentile	16.6	16.7	14.4	11.7	8.9	7.2	5.8	6.4	7.8	10.6	11.9	14.2	
14 percentile	7.3	7.9	6.2	4.4	2.5	1.1	0.3	1.1	1.4	3.1	4.2	5.9	
**** Lismore (09018)***													
Daily maximum temperature													
Mean	26.9	26.1	23.7	19.9	15.5	13.4	12.2	13.4	15.5	18.2	21.0	23.5	19.1
86 percentile	35.0	33.3	30.3	25.1	18.9	15.6	14.3	15.8	18.9	23.6	27.0	30.7	
14 percentile	20.2	20.0	18.2	15.6	12.2	11.1	10.0	11.1	12.2	14.0	15.6	17.2	
Daily minimum temperature													
Mean	11.6	12.3	10.9	8.9	7.0	5.2	4.4	5.0	5.9	7.2	8.5	10.3	
86 percentile	15.6	15.9	14.4	12.2	10.0	8.3	7.0	7.5	8.6	11.0	11.7	13.9	
14 percentile	7.8	8.9	7.2	5.6	3.9	1.7	1.1	2.2	3.1	3.9	5.0	6.7	
Creswick (088019)*													
Daily maximum temperature	27.0	27.3	23.3	18.7	13.5	11.3	10.2	11.7	14.0	18.0	20.5	23.5	18.3
Daily minimum temperature	11.0	11.9	9.2	6.9	4.7	2.6	2.2	2.8	3.8	5.7	7.2	9.0	6.4
****Clunes P.O. (088015)***													
Daily maximum temperature	27.8	27.6	24.2	20.2	15.0	12.4	11.4	12.8	15.1	19.0	21.4	24.8	19.3
Daily minimum temperature	11.1	11.8	9.3	6.1	4.2	1.9	1.6	2.4	3.5	5.0	6.9	8.7	6.0

* Bureau of Meteorology number ** Station located outside the study area

for Ararat in January can be interpreted as follows - on the average, one day per week the temperature is lower than 21.1°C and on one day per week the temperature exceeds 35.0°C.

Wind

The Bureau of Meteorology has tabulated information on wind speed and direction for a number of stations in the study area. At Ararat (8 years of records), winds tend to come from the south and south-west, particularly during summer. Northerlies dominate during the winter months. Winds from the east and south-east are infrequent. At Ballarat (21 years of records), winds come mostly from the north throughout the year, with south to south-easterlies gaining strength in the summer months. Limited data for Warrambine Basin, on the basalt plains indicate that north and north-west winds predominate.

Evaporation

Evaporation is determined by measuring the loss from a free water surface exposed in a standard tank, in this case a class 'A' evaporation pan. This measurement, which is strictly the potential for evaporation, depends chiefly on temperature, humidity, and wind speed. Figures refer to evaporation from open water surfaces, where saturated surface conditions are maintained. Evaporation from soil, pasture, or forests will be less than from open water, due to limitations on availability of water at the evaporating surface. Records are scarce for rural Victoria and data from only two stations are available (see Table 9 below).

Climate and plant growth

Climatic factors interact with other environmental conditions (physiographic,

Table 9

CLASS 'A' PAN EVAPORATION (MM.)

Year	No. of observations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1. Warrambine Basin (089099)														
1978	364	173.6	146.2	106.2	58.0	49.8	20.8	29.8	31.2*	46.2	84.6	93.8	109.6	949.8
1979	90	177.4	130.2	108.4	0.0*	0.0*	0.0*	0.0*	0.0*	0.0*	0.0*	0.0*	0.0*	416.0*
2. Moorabool Reservoir (087045)														
1977	31	0.0*	0.0*	0.0*	0.0*	0.0*	0.0*	0.0*	80.8	0.0*	0.0*	0.0*	0.0*	80.8*
1978	212	0.0*	0.0*	122.2	68.4*	0.0*	29.0	32.8*	37.8	57.4	123.2	0.0*	0.0*	470.8*

Source: Bureau of Meteorology

* True total of evaporation may be greater than this

Table 10

PROBABILITY OF RECEIVING EFFECTIVE RAINFALL

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lexton	.14	.30	.30	.63	.87	.97	.99	.96	.87	.69	.40	.30
Buangor	.16	.21	.40	.78	.94	.97	.98	.98	.98	.81	.47	.43
Trawalla	.19	.33	.45	.79	.95	.98	.98	.98	.98	.88	.57	.46
Learmonth	.20	.36	.39	.83	.94	.99	.98	.97	.95	.87	.55	.47
Creswick	.22	.44	.47	.91	.93	.97	.99	.97	.97	.91	.57	.45
Ballarat	.28	.35	.53	.87	.96	.99	.99	.98	.99	.92	.65	.49
Mount Buninyong	.33	.47	.57	.90	.99	1.0	.99	.99	1.0	.96	.73	.54
Streatham	.15	.32	.41	.71	.90	.96	.99	.97	.98	.74	.60	.41
Skipton	.23	.31	.47	.78	.90	.98	1.0	.98	1.0	.87	.60	.51
Linton	.20	.36	.53	.85	.93	.98	1.0	.98	.98	.80	.62	.54
Smythesdale	.22	.38	.47	.81	.93	1.0	1.0	.98	.97	.87	.69	.51
Rokewood	.23	.28	.49	.72	.92	.96	.96	.99	.94	.85	.49	.41
Elmhurst	.16	.13	.29	.75	.88	.98	.98	.97	.92	.77	.46	.34
Yalla-y-poora	.18	.21	.42	.76	.95	.97	.98	.97	.98	.78	.46	.40
Wickliffe	.14	.24	.38	.71	.92	.96	.97	.95	.99	.75	.43	.27
Willaura	.09	.29	.32	.69	.89	.97	.99	.94	.96	.68	.44	.34

Source: Resources Survey, Central Highlands Region; Glenelg Region

edaphic, and biotic) to affect plant growth and distribution. The principal climatic influences on plant growth are precipitation, soil moisture, temperature, humidity, sunlight, and wind. Interrelations also exist between these influences - for example between soil moisture and soil temperature.

Measurement of climatic elements can be used in various ways - to determine the extent of the growing seasons for various areas or the distribution limits for various crops. Effective rainfall is the amount of rain necessary to start and sustain plant growth. It is a theoretical figure calculated from the relation between rainfall and evaporation. The growing season (in terms of effective rainfall) is defined as the *number of months during which the probability of receiving the effective rainfall equals or exceeds 50%.*

Table 10 lists the probability of receiving effective rainfall for various stations in the Ballarat area. It can be seen that growing conditions are restricted to the cooler months, generally April to October, when the bulk of the rainfall occurs, soil moisture levels are adequate, and water losses due to evaporation are minimal. The period of flush growth occurs in spring - and into later months at some stations - when adequate soil moisture coincides with rising temperatures.

Drought frequency, in an agricultural sense, amy also be inferred from this table - the likelihood of drought being the probability of receiving less than the effective rainfall. Estimates of effective rainfall are useful for agricultural planning, but they do not necessarily indicate the effects of dry spells on deep-rooted plants, which are more able to resist drought.

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WATER RESOURCES

The Great Dividing Range, which traverses the Ballarat area in an east--west direction, forms the upper reaches of a series of important catchments. Major watercourses flow northwards from the Divide discharging to inland lakes and to the Murray River, while south-flowing rivers discharge to the sea and inland lake systems. North-flowing streams with their headwaters in the study area are the Wimmera River, the Avoca, and tributaries of the Loddon. South-flowing rivers include the Hopkins, Woady Yaloak, Yarrowee, and West Moorabool.

Surface Water Resources

Although the catchments compare poorly with those to the north-east of Melbourne with respect to the important factors promoting stream flow, such as topography and rainfall, the study area constitutes practically the whole of the useful catchment area for the numerous streams that have their source within its boundaries.

The study area, which makes up 3.6% of Victoria, contributes only about 2% of the flow in the State's river systems. About 27% of its water yield enters those streams flowing north from the Great Dividing Range towards the Murray River system (with a catchment area equivalent to 20% of the study area), with the remaining 73% forming south-flowing streams. The value of these supplies in terms of existing and potential utilization for urban, industrial, and agricultural use is outlined in Chapter 20.

Climate varies considerably; topography exerts a marked control over the meteorological elements. The estimated annual mean rainfall is 685 mm in the area south of the Divide and 730 mm to the north of it.

Stream flow

The highest average monthly flows for most major streams in or originating from the study area occur during the period July to October, as indicated by the long-term measurement of stream discharges shown in Appendices 1 and 2.

Being numerous, these streams are small, with no rivers capable of sustained or regular flows. The combination of low average rainfall with a highly absorptive catchment, characteristic of most of the study area, prohibits sustained run-off to them. Nevertheless, short-term stream-flow characteristics are important, producing extreme flow variations related to rainfall intensity, duration, and soil-moisture condition of the catchment at the time. Reactions of streams to storm rainfalls are immediate and often violent, the nature of the catchments permitting little or no retention or delayed discharge. Daily flows of all streams are extremely variable, and many streams cease to flow during the summer and autumn months.

The mean annual run-off for catchments within the study area is of the order of 72 Ml per sq km for north-flowing streams and 58 Ml per sq km for south-flowing streams. Comparable figures for the highlands to the north-east of Melbourne are four to ten times greater.

Analysis of run-off figures indicates that between 8.8 and 10% of rainfall appears as stream flow, taken at the gauging station closest to the border of the study area. This means that more than 90% of precipitation is retained by or lost within the area. Appendix 3 gives a complete summary of stream-gauging data.

Water quality

Water quality is an important factor governing the potential use of the water resource, whether for domestic consumption or agricultural or industrial use.

Water quality monitoring under the Australian Water Resources Council monitoring program was introduced in Victoria in 1975. The aim is to monitor the general level of physical and chemical parameters of waters within the State, and testing is carried out on a regular basis at 300 gauging stations. Stations monitoring water quality of streams flowing in and from the study area are shown on Map 7, Topography, Water Resources, and Utilization.

Total dissolved solids

The suitability of water for domestic use, including drinking water, is affected by such factors as hardness, turbidity, colour, organic content, and the concentration of total dissolved solids.

Of these, total dissolved solids (T.D.S.) - a measure of salinity or the total concentration of ionic constituents - is the most convenient single parameter. Limiting salinities are listed in Table 11. According to these criteria, both the Hopkins and Woady Yaloak Rivers, at the lowest gauging station, have brackish to saline water.

Streams to the north-east of Ballarat have reasonably low total dissolved solids, giving them marginal salinity. It should be understood, however, that the area of catchment above the gauging

Table 11

LIMITING SALINITIES

Salinity (mg T.D.S. per l)	Use
Below 1,500	Domestic and industrial purposes, livestock, irrigation
1,500--3,000	Brackish water suitable for most livestock, irrigation under favourable conditions, some domestic use, limited industrial use
3,000--6,000	Brackish water suitable for some livestock and very limited domestic and industrial use (poultry 3,500, pigs 4,500, horses 6,000, cows in milk 6,000, ewes in lamb 6,000 mg per l)
6,000--15,000	Salty water; beef cattle will tolerate up to 10,000 mg per l; sheep on green feed can drink water up to 15,000 mg per l
above 15,000	Unsuitable for livestock
35,000	Sea water (world average)

Source: Department of Minerals and Energy.

stations is considerably less than the gauged catchment area for south-flowing streams.

Land-use changes, such as the conversion of farming land to urban residential areas, can have a marked effect on the rate and quantity of run-off, which is significantly increased where there are extensive paved and other hard standing surfaces such as in residential, commercial, and industrial areas.

In addition, pollution levels in run-off are increased by contaminants such as oil, bacteria, and nutrients. Pollution levels are particularly evident where no sewerage facilities are available, and affect not only surface water but groundwater in situations where run-off enters aquifers.

Most dissolved material in water results from the leaching of soils and weathered rock masses. Suspended material originates mainly from soil erosion.

The water quality of a stream in its natural state may vary considerably. Evaporation from streams and lakes results in concentration of the dissolved solids, with the reverse occurring during high river flows and flooding. In the latter case, reduced salinity may be accompanied by significant increases in suspended sediment concentration, bed load, and turbidity. Suspended materials may be subsequently deposited downstream - where velocities are lower - forming flood plains.

Agricultural chemicals, particularly fertilizers, may cause degradation of water quality and algal growth in rivers and lakes as a result of the increased level of nitrates and phosphates. Such waters may be difficult to treat to ensure suitability for human consumption, particularly with respect taste, odour, and colour requirements.

Catchment Basins

The upper reaches of seven major catchment basins are located in the study area. These are shown on Map 7, and may be divided into those discharging to the north of the Great Dividing Range and those discharging to the south. Appendix 4 summarizes the characteristics of these catchments.

Basins Discharging North

Wimmera catchment basin

The catchment basin includes the Wimmera River and Mount Cole Creek, and approximately 402 sq km, or 2% of it lies within the study area. The Wimmera River rises near Mount Buangor and terminates in Lake Hindmarsh in the Mallee. Mount Cole Creek rises on the cleared undulating plains that separate Mounts Buangor and Langi Ghiran.

The catchment has a mean annual discharge rate of 138 Ml per sq km. Stream flow is fairly unreliable during the summer, with only 11% of the mean annual discharge being contributed from December to May. At Eversley, T.D.S. readings indicate a mean salinity of 730 parts per million (p.p.m.), which increases to 2,500 p.p.m. during low flows. Consequently water quality rises to a reasonable standard only during the wetter months. (In the middle reaches of the Wimmera River, water is diverted for use in the Wimmera--Mallee Stock and Domestic Water Supply System.)


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Avoca catchment

The Avoca River, and tributary, Glenlogie Creek, rise in the Ben Major--Mount Lonarch area south of Amphitheatre and terminate in the Mallee at Lake Bael-Bael. Approximately 166 sq km, or 1%, of the catchment is situated in the Ballarat area. Stream-flow records indicate that rainshadow conditions affect the area to some extent. Run-off is approximately 50 Ml per sq km. The Avoca River has a generally unreliable stream flow during the summer; however, within the study area, water quality is generally acceptable.

Loddon catchment

Approximately 7%, or 1,050 sq km, of the Loddon River catchment occurs within the study area. Major tributaries of the Loddon originating in this part of the catchment are Bullarook or Birch Creek (rising near Newlyn North), Creswick Creek (south of Creswick), Middle Creek (Smeaton area), Joyces Creek (Eaganstown), McCallum Creek (Waubra, Mount Bolton), Doctors Creek (south-east of Lexton), Bet-Bet Creek (Ben Major), and Burnbank Creek (Granite Hill). The Loddon River enters the River Murray near Swan Hill.

Generally, T.D.S. readings for these streams are in the region of 700 p.p.m., although levels of 2,000 p.p.m. may be recorded during periods of low flow. Mean annual discharges for Adekate Creek, a tributary of Creswick Creek (167 Ml per sq km) and Bullarook Creek (124 Ml per sq km) indicate high catchment productivity. Discharge is only 9% of the total between December and May, however, and drops lower than 4% in January--March.

The Cairn-Curran Water Supply Catchment proclaimed under the *Soil Conservation and Land Utilization Act* 1958 lies partly within the study area in this catchment.

Catchments Discharging South

Moorabool catchment

The eastern and western branches of the Moorabool River rise in the ranges around Barkstead and Korweinguboora.

The two branches combine just outside the Ballarat area to form the Moorabool River, which eventually flows into the Barwon River near Geelong. A major portion of the western branch lies within the study area, with a catchment area of 355 sq km or 16% of the total Moorabool catchment.

Two storages - the Moorabool Reservoir and the Lal Lal Reservoir - are situated along the course of the Western Moora-

Opposite: *Lal Lal Reservoir is a major storage on the West Moorabool River, part of the Barwon catchment.*

bool - and one, the Korweinguboora Reservoir, on the Eastern Moorabool. Portions of both these catchments have been proclaimed as water supply catchments under the *Soil Conservation and Land Utilization Act* 1958.

Note: A discussion of proclaimed water supply catchments, under the provisions of this *Act* and the *Land Conservation Act* 1970, has been included in Chapter 20.

Barwon catchment

The part of this catchment included in the study area contains the headwaters of the Leigh or Yarrowee River (rising to the east of Ballarat) and a major tributary, Warrambine Creek (rising around Mount Mercer). At Inverleigh, the Leigh discharges into the Barwon River, which enters Bass Strait south of Geelong.

The 1,310 sq km or 36% of the Barwon catchment within the Ballarat area returns more than 90 Ml per sq km annually. The Leigh is more reliable than most other rivers, and approximately 18% of the annual discharge is recorded in the December - May period.

Water quality in the Leigh River has been a problem in past years, partly because of the discharge of effluent from the Ballarat South treatment works, which serves two-thirds of the population of Ballarat. The provision of maturation ponds has resulted in a dramatic improvement in the bacteriological quality of the effluent and of the Leigh River downstream, ensuring compliance with the conditions of the E.P.A. licence. All major industries in Ballarat discharge their liquid wastes to sewers under agreement, so it has been necessary to place limits on the discharge of heavy metals, total nitrogen and phosphorus, ammonia, and Biological Oxygen Demand (B.O.D.) to ensure the discharge of effluent to the Leigh River meets the required standard. The mean T.D.S. content at Mount Mercer gauging station is 824 p.p.m., indicating a relatively low-quality water.

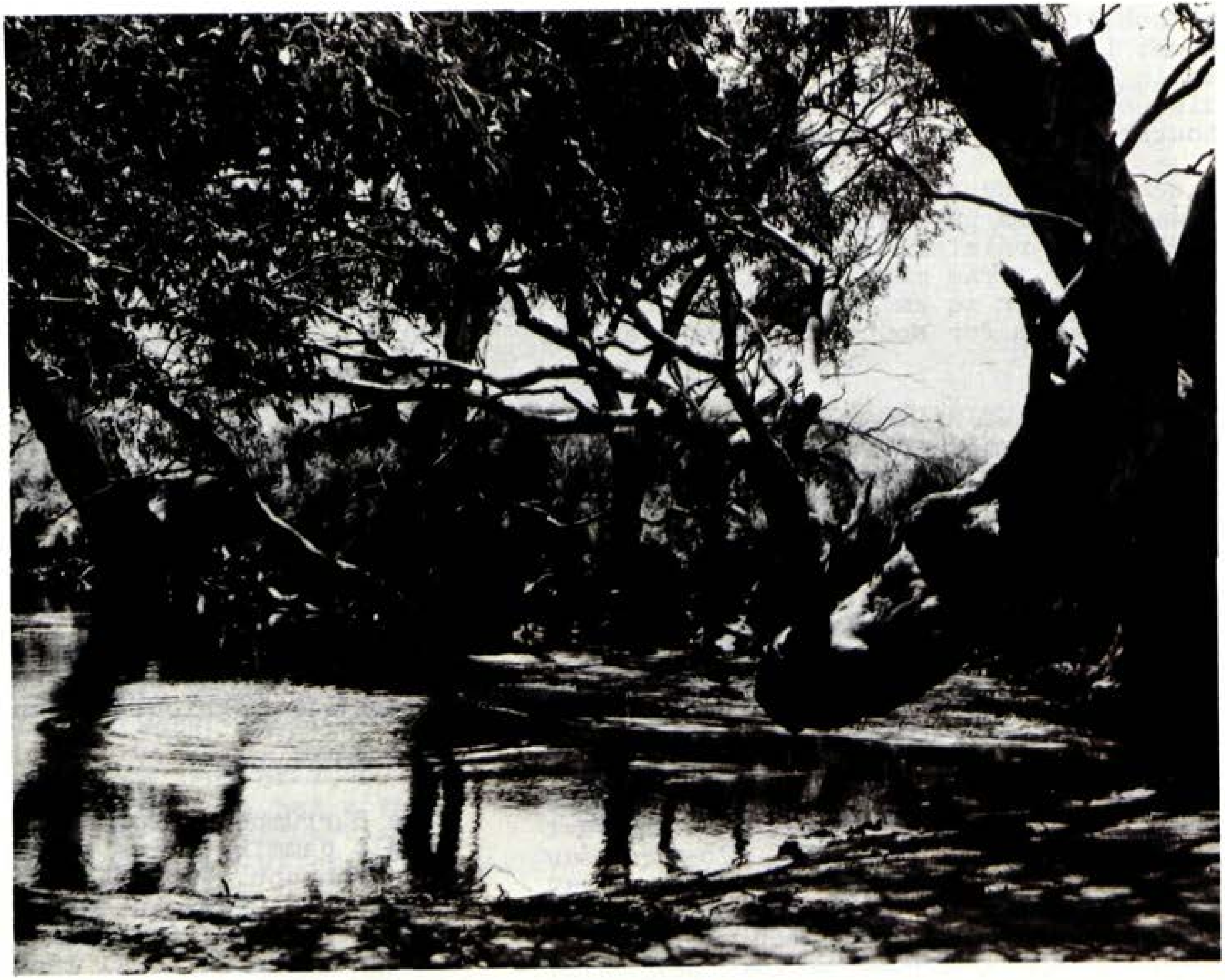
Corangamite catchment

The main watercourse in this basin is the Woady Yaloak River--Smythes Creek, which rises in cleared land south-west of Ballarat and flows mainly through cleared farmland to Lake Corangamite. It is fed by a number of tributaries, many of which rise in forested public land. Tributaries include Naringhil Creek (Pittong--Mount Bute), Little Woady Yaloak and Illabarook Creek (Berringa), and Kuruc-A-Ruc and Ferrers Creek (Dereel). Gnarkett Ponds Creek also discharges to Lake Corangamite.

The Woady Yaloak has a number of saline tributaries. At Cressy, T.D.S. readings in summer and autumn are high and may reach 5,000 p.p.m. Mean T.D.S. is 2,560 p.p.m. About 1,200 sq km, or 28%, of the Corangamite catchment is included in the study area. The catchment discharge rate is 54 Ml per sq km, with 13.5% of the annual rate discharging between December and May.

Hopkins catchment

Approximately 3,747 sq km, or 38%, of the total Hopkins catchment occurs with-



Fiery Creek - a major watercourse in the Hopkins catchment in the Ballarat area. The Hopkins River rises in cleared farming country between Mount Langi Ghiran and Ararat, and its tributaries - Fiery Creek and Mount Emu Creek - have their headwaters in forested public land in the Mount Cole--Mount Lonarch region. These streams drain large areas of the basalt plains, discharging via the Hopkins into the Southern Ocean at Warrnambool.

Catchment productivity is comparatively lower in this part of the Ballarat area due to low rainfall and gently sloping topography. The mean annual discharges are 26 Ml per sq km for the Hopkins, 53 Ml per sq km for Mount Emu Creek, and 40 Ml per sq km for Fiery Creek. During the 6 months December to May, the catchments of these streams yield about 10% of total discharge. At Wickliffe, T.D.S. observations for the Hopkins River indicate a mean salinity of 3,713 p.p.m., ranging from 9,396 to 430 p.p.m. Mount Emu Creek at Skipton and Fiery Creek at Streatham similarly have higher salinities, with mean annual values of 1,833 and 1,587 p.p.m. respectively.

The proclaimed Trawalla Creek Water Supply Catchment is located in the upper reaches of Mount Emu Creek, and is used primarily for the provision of domestic and stock supplies.

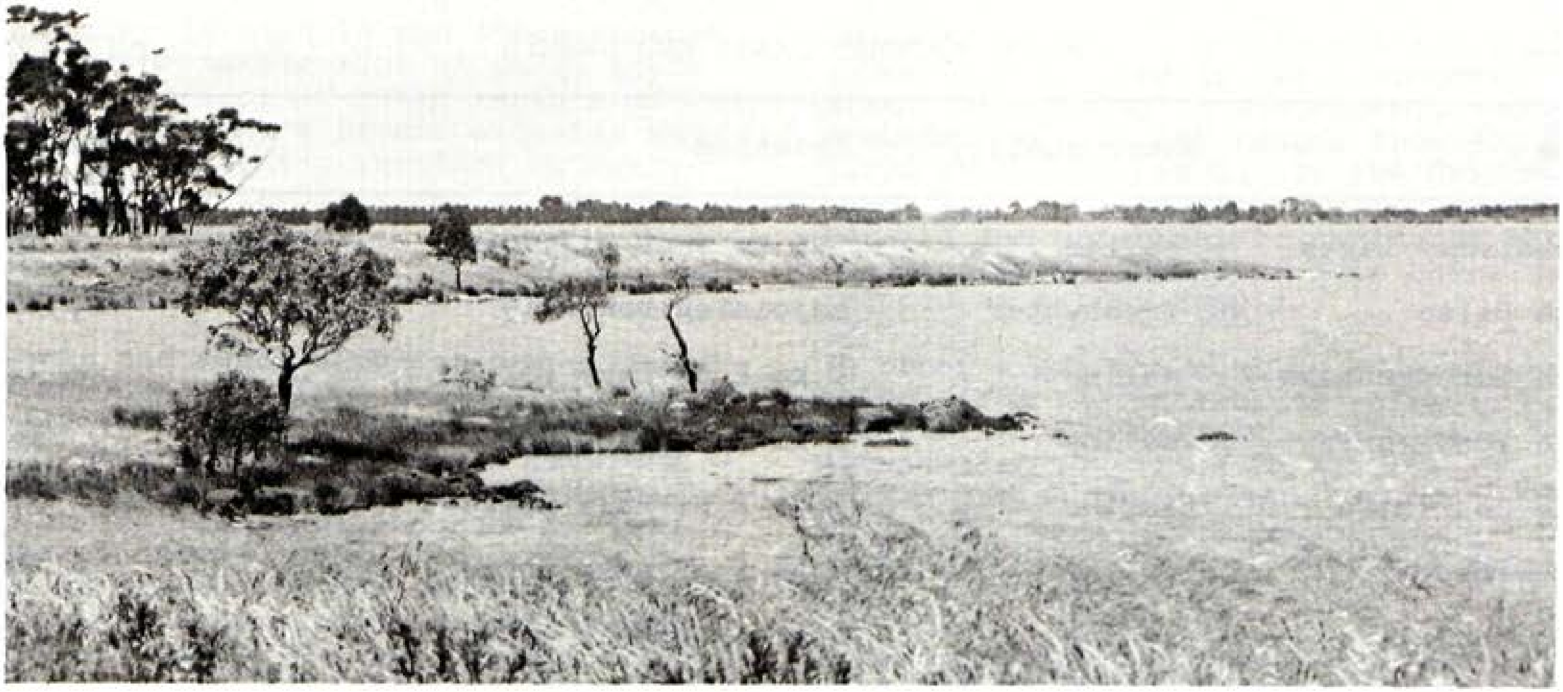
Lakes and Swamps

Lakes within the study area occur almost exclusively on the basalt plains. They were formed as a result of altered topography and drainage following late Tertiary volcanic activity. All have relatively high T.D.S. levels and most of the small lakes are saline (having a T.D.S. greater than 8,500 p.p.m.). Salts, naturally occurring in run-off waters, tend to be concentrated in lakes as a result of limited or non-existent outflow from the lake coupled with high evaporation rates. Table 12 lists the major lakes and some of their physical characteristics.

Nutrients may similarly be concentrated in lake waters. Large amounts of nutrients - particularly nitrogen and phosphorus (derived from fertilizer application, sewerage effluents, and household detergents) bring about a marked increase in lake productivity, particularly algae. This process, termed eutrophication, may reduce the suitability of the water for domestic or recreational uses and is particularly evident in cleared catchments that drain areas developed for agriculture and settlement.

Lake Burrumbeet

Lake Burrumbeet, formed as a result of basalt damming, lies in the Hopkins River catchment. Its major input stream is Burrumbeet Creek but water enters intermittently from Canico Creek and channels draining agricultural land. Overflows



Lake Bolac - important for recreation, fisheries and water supply

from Lake Learmonth may also enter Burrumbeet via a drain connecting to Burrumbeet Creek. The outlet is via Ballies Creek, which flows into Mount Emu Creek, but a sill restricts water outflow.

The lake, which has an area of 2,400 ha and an average depth of 3 m, has a variety of uses - recreation, commercial fishing, agriculture (stock-watering and crop-watering), and drainage.

In past years blooms of *Microcystis*, a species of blue-green alga, have led to stock deaths and unsightly accumulations of dead algae along the shoreline.

Studies of the physical and biological characteristics of the lake and sources of nutrient input, undertaken by the Environment Protection Authority in 1975, showed that the lake is highly productive due to nutrient input from agricultural run-off and because Burrumbeet Creek conducts effluent from Ballarat Sewerage Works. Concentrations of nutrients are enhanced by high evaporation rates and limited flushing of the lake.

Table 12

MAJOR NATURAL LAKES AND SWAMPS

Name	Water quality	Location	Approximate area (ha)
Cockajemmy Lakes	saline	3.5 km S of Willaura	67
Lake Bolac	freshwater	adjoining township	1,350
Lake Turangmoroke	saline	2 km E of Lake Bolac	93
Lake Yuangmaria	saline	2 km E of Lake Bolac	56
Lake Gnarimara	saline	2 km E of Lake Bolac	7
Lake Parupa	saline	2 km E of Lake Bolac	5
Lake Gunjal	saline	2 km E of Lake Bolac	15
Lake Wongan	saline	10 km NE of Streatham	208
Black Lake	brackish	14 km N of Skipton	76
Lake Goldsmith	brackish	12 km S of Beaufort	696
Bittern Lagoon	freshwater	Langi Kal Kal	30
Lake Burrumbeet	freshwater	18 km W of Ballarat	2,400
Lake Learmonth	freshwater	19 km NW of Ballarat	480
Dereel Lagoon	freshwater	adjoining Dereel Township	56
Winter Swamp	freshwater	adjacent to Ballarat common	33
Flax Mill Swamp	freshwater	adjacent to Ballarat common	6

Groundwater Resources

Groundwater is held in and flows through bodies of permeable rock known as aquifers. The groups of rocks capable of supplying water are Recent alluvial and colluvial sediments, Tertiary volcanic rocks, and the Tertiary sediments and associated deep leads.

Shallow supplies

Domestic and stock supplies are obtained in some instances from wells, which are usually shallow but range up to 15 m deep. This water is found in Tertiary or recent fluvial and colluvial deposits, on the basalt plains, and on the flanks of scoria cones. An example is water in gravels on the northern slope of Mount Bolton, with a salinity range of 170--550 mg T.D.S. per litre. In other areas shallow water may be quite saline and only suitable for stock purposes.

Volcanic rocks

Joints, fissures, flow contacts, and sands and clays between lava flows can contain good-quality water. The water is suitable for stock and often for irrigation, but is generally a little hard for domestic use. It can be fit for human consumption.

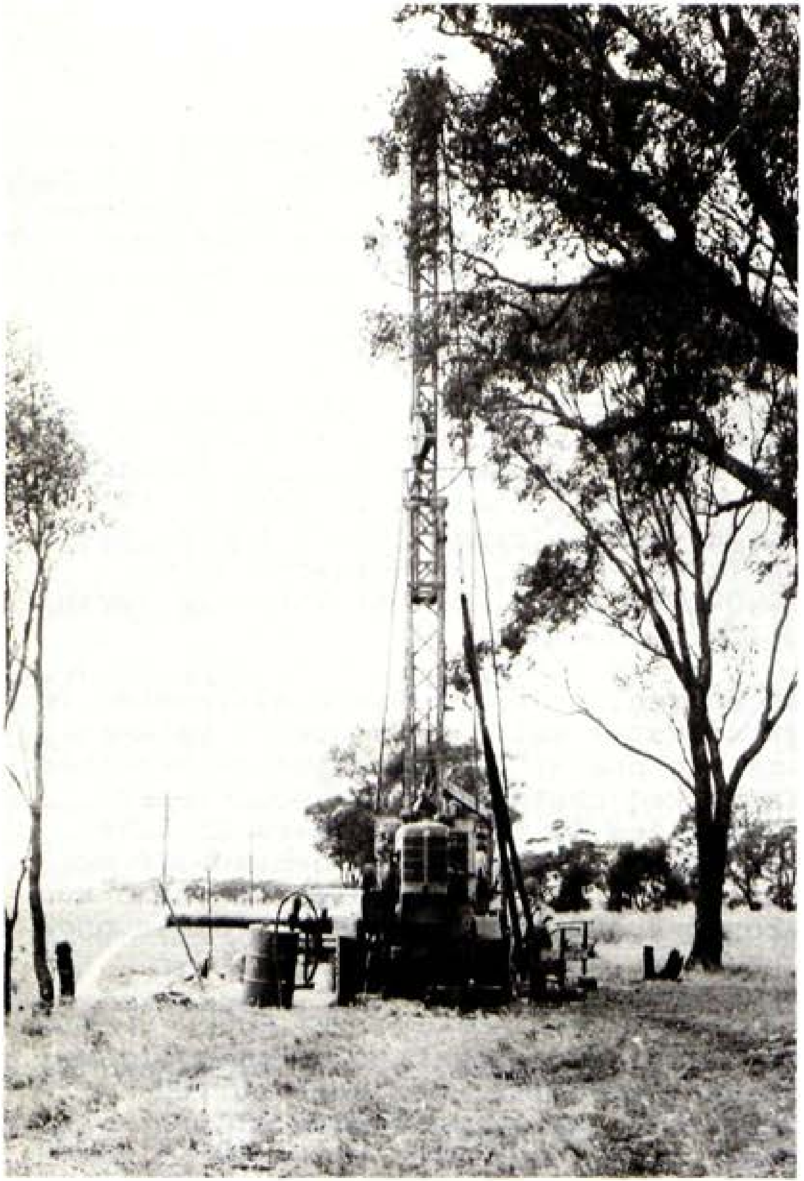
Salinities are often less than 500 mg T.D.S. per l from depths up to 100 m. Such waters - with a salinity range of 280--360 mg per l, and from a depth of 30 m - are located in the Learmonth area. In basalts at Windermere, the groundwater salinity ranges from 300 to 1,200 mg T.D.S. per l. In the Gordon--Mount Egerton area, groundwater from basalts and sub-basaltic sediments with a salinity of 520 mg per l is being developed as a town supply.

In other areas the quality of water obtained from the basalts is suitable only for stock. For example, salinities in groundwater contained in basalts in Wongan parish range from 1,400 to 5,000 mg T.D.S. per l, at Rokewood up to 10,000 mg per l, and at Tatyoong North up to 8,000 mg per l.

At Wongan, no appreciable difference in groundwater salinities occurs between the two phases of volcanics represented. In marked contrast, the groundwater salinities in the two phases at Lake Goldsmith differ, being around 370 mg per l in the younger volcanic phase and around 4,400 mg per l in the older one.

Deep leads

The deep leads are Late Tertiary river channel deposits that were buried beneath basalt, Quaternary alluvium, or both. The leads were extensively mined underground for gold from the 1850s to World War I. From the onset of mining, groundwater was the biggest obstacle to



Drilling for groundwater on the basalt plains

overcome as the gravels provided major flow paths for water.

The major regional groundwater drainage from the Central Highlands flows through these coarse-grained aquifers. The leads drain to the north into the Avoca --Loddon deep lead system towards the Riverina plain. Other leads flow south, beneath the Leigh and Woady Yaloak river systems and at Langi Logan.

Sand and gravel in the deep lead system have the potential to supply large quantities of good-quality water. In the study area, lead waters would generally be expected to contain salinities less than 1,000 mg T.D.S. per l. Levels of T.D.S. in lead groundwater are 160--280 mg per l around Learmonth, 600 mg per l at Windermere, 900 mg per l at Cardigan, and 850 mg per l at Rokewood. Such waters are generally fit for human consumption, but a little 'hard'. (Hardness refers to the presence of calcium and magnesium ions, causing the formation of an insoluble residue when used with soap.)

Tertiary sands and gravel

There are numerous deposits of Tertiary sediments resting on Palaeozoic rocks between Ballarat and Rokewood. Aquifers within these sediments can yield good-quality water. Those at Dereel can yield water with a salinity ranging from 270 to 1,200 mg T.D.S. per l from depths of 20 m.

Middle Tertiary sediment

Beneath the plains south of Rokewood, Middle Tertiary bryozoan limestone beneath the basalts and sediment have the potential to yield large quantities of high-quality groundwater.

Palaeozoic sediment

The Palaeozoic sediment generally contains saline water only suitable for stock purposes. Yields are generally low and T.D.S. levels are generally well in excess of 2,000 mg per l. For example, bedrock groundwater salinities are around 4,000 mg per l at Haddon, 3,500--11,400 mg per l south-west of Beaufort, and around 11,500 mg per l north of Caralalup.

Mineral Water

Mineral water is water found in nature impregnated with a mineral substance. The area in which it occurs extends just into the north-east of the study area near Eganstown. The waters in the mineral springs here are characterized by the presence of carbon dioxide, which effervesces when the water rises to the surface, making it a natural soda water. The waters also contain up to 10,000 mg of dissolved mineral salts per litre in solution. They are similar to the well-known mineral waters of Europe, such as Vichy water.

The mineral water aquifer occupies fissures and fractures in Ordovician sediments and has an average salinity of about 2,500 mg per l, but ranges from 600 to 10,251 mg.

Mineral springs in the vicinity of Daylesford have been analysed and investigated since late last century. Early this century recommendations were made to improve and protect the resource for tourist purposes.

The Hepburn Springs area is very sensitive to prolonged pumping from bores and there is a risk of permanent damage to the resource. There is also a possibility of pollution from effluent being drawn down into the groundwater system.

Recent pump tests of bores, carried out by the Department of Minerals and Energy south-east of Daylesford, concluded that total yields would approach a litre per second. It was also estimated that, for natural recharge to adequately replenish the aquifer, extraction would have to be limited to 89,000 litres per day.

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SOILS

Soils are formed by the weathering of rock or unconsolidated material near the earth's surface. Formation is influenced by several factors, notably the chemical and physical nature of the parent materials, and by climate and topography. Soil profiles develop by processes such as leaching and by the action of organisms in the soil.

In order to discuss the soils of a region, it is necessary to have a broad classification. In this chapter, soils are classified according to the morphology of the profile and are further discussed under a set of descriptive headings. Soil distribution has been mapped indirectly, according to parent material and topography.

The primary profile forms in the study area are:

* Uniform soils: profiles showing small, if any, texture differences throughout, such that no clearly defined textural boundaries are to be found

* Gradational soils: profiles showing increasingly finer (more clayey) texture grades on passing down the soil, such that the texture of each successive horizon passes gradually from the one above to the one below

* Duplex soils: profiles showing a sudden increase in clay content (that is, a marked texture change) between the A and B horizons

Table 13 shows the soils of the Ballarat area, and gives their approximate location. The soils are described below.

Uniform Soils

Black cracking clays have developed on alluvial material derived from basalt and are located in the drainage lines and creek flats. Although small in area, they are found throughout the basalt plains. They are very sticky when wet and deeply-cracking when dry. The soils are prone to waterlogging and have a minor salinity problem. They tend to be used for grazing rather than cropping because of unfavourable moisture characteristics.

Grey clays occur in low-lying situations

Table 13

SOILS - CLASSIFICATION, NOMENCLATURE AND LOCATION

Profile form (Northcote 1979)	Descriptive name	Classification according to Stace *et al.* 1960	General location
Uniform	Black cracking clays	Black earths	Drainage lines and creek flats on the basalt plains
	Grey clays	Grey clays	Low-lying and swamp areas on the basalt plains
	Coarse sands	Siliceous sands	Steep slopes and scarps of granite hills
	Calcareous sodic clays	Grey clays	Upper terrace of river alluvium
	Leached sands	Podzols	Lunettes of lakes and swamps
Gradational	Red-brown shallow stony soils	Chocolate soils	Rises and scarps on the basalt plains
	Finely structured red gradational soils	Kraznozems	Cones and higher rises of basalt plains; gentle slopes of Palaeozoic sediments
	Finely structured brown gradational soils	Brown earths	Volcanic cones of scoria and ash
	Shallow stony gradational soils	Lithosols	Upper slopes and crests of Palaeozoic sediments and metamorphosed sediments
	Stony red-yellow gradational soils	Lithosols	Mid slope and outwash fans of metamorphosed sediments

Profile form (Northcote 1979)	Descriptive name	Classification according to Stace *et al.* 1960	General location
Gradational	Yellow gradational soils	Weisenboden	Drainage lines of most steep areas
Duplex	Coarsely structured yellow brown sodic calcareous duplex soils	Solodic soils	Plains and scarps of the basalt plains
	Coarsely structured yellow sodic duplex soils	Solodic soils	Basalt plains; lower slopes of granite on Palaeozoic sediments
	Stony red sodic duplex soils	Solodic soils	Mid slope of metamorphic aureoles
	Mottled duplex soils with ironstone	Lateritic podzolic soils	Slopes on granite and Tertiary gravels
	Yellow sodic duplex soils	Solodic soils	Drainage lines and creek flats on granite and sediments, and alluvial terraces
	Red duplex soils	Red podzolic soils	Gentle slopes on granite and sediments, and alluvial terraces
	Yellow duplex soils	Yellow podzolic soils	Upper mountainous slopes on granite and lower drainage lines on sediments
	Coarsely structured red sodic duplex soils	Solodic soils	Lower slopes of granite and Palaeozoic sediments
	Red sodic duplex soils	Solodic soils	Gentle crests and lower slopes of sediments, and alluvial terraces

throughout the basalt plains and on the lower terraces formed from river alluvium. Profiles have very low permeability and are prone to waterlogging. Salinity problems also occur, particularly on the basalt.

Coarse sands occur on the steep slopes and the outwash fans of granitic hills. Profiles have high permeability but low fertility and water-holding capacity. They are prone to sheet erosion and, when eucalypt vegetation is removed, landslips may occur. Coarse sands on the footslopes are prone to moderate gully erosion.

Leached sands - off-white acidic sands with yellow subsoils - occur on the lake or swamp lunettes. Permeability is excessive, water-holding capacity is low, and fertility particularly low. Wind erosion occurs where vegetative cover is inadequate.

Calcareous sodic grey clays are found on the upper terraces of river alluvium. They have very low permeabilities, crack deeply, and develop a large crab hole or gilgai micro-relief. Pastures are more suited to these soils than crops because of the low available water capacity.

Gradational Soils

Red-brown shallow stony gradational soils are generally associated with the basaltic country known as the 'stony rises'. Their fertility is high and permeability moderate, but their water-holding capacity is low. Land use is restricted to grazing because of the surface rock. Similar soils are found on the scarps throughout the basalt plains.

Finely structured red gradational soils are found on the volcanic cones, on the higher basaltic plains, and also on gentle slopes on Palaeozoic sediments in high-rainfall areas. In profiles on basalt the fertility and permeability are favourable for agriculture, and here the land use is predominantly cropping. Forestry is the dominant land use of the less-fertile profiles on Palaeozoic sediments.

Finely structured brown gradational soils are restricted to basaltic cones with surfaces of scoria and ash. Fertility, permeability, and available water capacity are all favourable for agriculture. Cropping is the main form of land use.

Shallow stony gradational soils occur on the crests and upper slopes of the Palaeozoic sediments and on the aureoles formed from contact metamorphosed sediments. Steep slopes, low water-holding capacities, and weak soil structure create a high sheet-erosion hazard, particularly in the drier areas where vegetative cover is more difficult to maintain. Land use is grazing or protection forestry.

Stony red-yellow gradational soils occur on the mid slopes and on the outwash fans of metamorphic aureole hills. Permeability and available water capacity are moderate, but the high run-off from the adjacent hills often causes very serious gully erosion. Land use is mainly grazing.

Yellow gradational soils are found in the drainage lines of steep granite areas, Palaeozoic sediments, and Tertiary sediments in the higher-rainfall areas, and also on some of the higher river terraces. Permeability, water-holding capacity, and fertility are moderate, and land use is mainly grazing or forestry.

Duplex Soils

Coarsely structured yellow-brown sodic calcareous duplex soils have formed on the extensive areas of relatively flat basalt plains. Micro-relief is gilgaied and prominent cracks develop in the dry season. The soils are deep, but most have low permeability, resulting in seasonal waterlogging. Grazing is the main form of land use; however, in the drier south-western region cropping is practicable.

Coarsely structured yellow sodic duplex soils - similar to those of the previous group but in a higher-rainfall zone and lacking free lime in the profile - occur on basalt, the lower slopes of granite, and the lower slopes of Palaeozoic and Tertiary sediments. Land use is mainly grazing.

Stony red sodic duplex soils occur on the mid slopes of contact metamorphic aureoles in the lower-rainfall zone and are used mainly for grazing. The permeability, fertility, and water-holding properties are moderate, but sites are prone to deep gully erosion because of the high run-off from the hills above and the unstable colluvial parent material.

Mottled duplex soils with ironstone are highly leached and acidic. They occur on the gentle upper slopes underlain by granite or Tertiary gravels. Although their physical properties are favourable for agriculture, fertility is particularly low. Grazing is the main use, and heavy dressings of fertilizer are required to maintain growth.

Yellow sodic duplex soils occupy drainage lines in the drier areas on granite, Tertiary sediments, Palaeozoic sediments, and on river terraces. They have low permeability and dispersible subsoils prone to gully erosion and salting.

Red duplex soils are found in the higher-rainfall areas. They occupy the gentler slopes on granite, Palaeozoic sediments, and also occur on river terraces, and are used mainly for grazing. Permeability and water-holding properties are moderately favourable for agriculture.

Yellow duplex soils occur in the higher-rainfall areas on the upper slopes of granitic outcrops and in the lower drainage lines of Palaeozoic and Tertiary sedimentary areas. Land use is forestry and grazing. In the drainage lines there are hazards of gully erosion and salting on cleared land.

Coarsely structured red sodic duplex soils of low permeability occur on the lower slopes of granite and Palaeozoic sediments in the lower-rainfall zone. Surfaces are hard-setting and seasonal waterlogging is a problem, so land use is grazing rather than cropping.

Red sodic duplex soils predominate in the drier areas on the gentle crests of the Palaeozoic sediments used mainly for grazing, and on alluvial terraces used for alternate cropping and grazing. Permeability and fertility are moderate and water-holding capacity is favourable.

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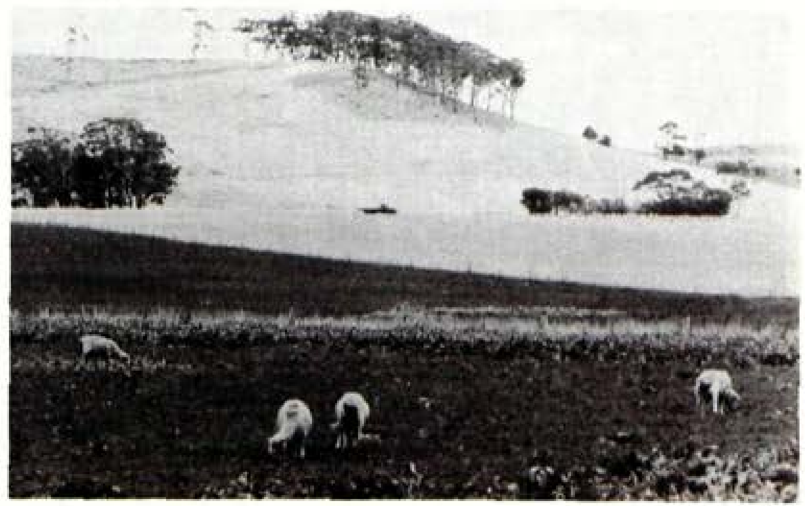
VEGETATION

A general picture of the vegetation of the Ballarat area at the time of European settlement can be obtained from contemporary accounts, particularly the writings and collections of Major Thomas Mitchell and the Colonial Botanist, Dr. Ferdinand Mueller.

The basalt plains originally supported tussock grasslands of kangaroo and wallaby grass, containing many other herbaceous plants, often ephemeral, most of which belong to the family Asteraceae.

The basalt plains were never as rich in species as the adjacent and older physiographic regions. The family Myrtaceae was poorly represented except for red gums and swamp gums, which occurred along watercourses and on the sediments of former lakes. Black wattle and black she-oak occurred as individual shrubs and sometimes in small groups. The family Epacridaceae (heaths) was entirely absent. As the plains were among the first areas to be taken up, they have been modified such that most of the grassland species have been replaced with pasture; however, many of the trees lining watercourses remain. Most of the basalt plains are in private ownership, and only small water reserves, stream frontage reserves, and roadside reserves have been retained as public land.

Areas subsequently cleared for agriculture include the undulating regions of volcanic origin to the west of Ballarat. The vegetation remaining on the volcanic cones of Mount Buninyong gives an indication of the original forests. The foothills of the Palaeozoic midlands have also been cleared for agriculture,



Remnants of the original vegetation on undulating volcanic country near Dean.

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Featherheads and kangaroo grass found along a road reserve on the basalt plains

leaving the areas of poorer agricultural quality and those set aside for timber production, water production, and other public uses. During the gold-mining era, large portions of these forests - since regenerated, - were felled for building purposes, for mine-shoring timbers, and for firewood. Around Ballarat and Creswick large areas of coppice-regenerated forests remain as evidence of this past activity.

Remnants of the original vegetation occur throughout the study area, mainly on small blocks of public land and on roadside reserves. In some areas, these remnants are the only indicators of the original vegetation.

Importance of vegetation

Natural vegetation is particularly important when considering possible uses of land. It integrates and quite sensitively reflects subtle changes in environmental factors. For this reason, and because its main components can be mapped in the field or from aerial photos, it provides a convenient way of assessing site factors, which by themselves would be difficult to measure directly.

Moreover, the vegetation itself often provides for many of Man's needs such as timber and recreation, protects other values such as soils and water quality and yield, provides habitats for animals, and constitutes much of what we regard as scenery or naturalness.

Classification and Mapping

Vegetation on public land in the Ballarat area has been classified into 33 floristic units according to the commonly occurring dominant tree species. This floristic framework includes a number of structural forms, based on the height and form of the tallest stratum, and on the percentage projective foliage cover (see Table 14). It should be noted that the floristic units are not the result of detailed study of species associations, but are determined by interpretation of aerial photographs and field inspections. They are, however, readily recognizable in the field.

The most closely related floristic units have been loosely grouped into six alliances, listed in Table 15, named after the most characteristic dominant species. The first six sections below describe these alliances and list the floristic units they contain, using the numbering system that indicates their distribution on Map 9. For example, the messmate--peppermint--gum alliance com-

Table 14

STRUCTURAL FORMS OF VEGETATION IN THE BALLARAT AREA
(Modified from Specht *et al.* 1960)

Life form and height of tallest stratum		Projective foliage cover of tallest stratum Dense (70--100%)	Mid dense (30--70%)	Sparse (10--30%)
trees	>40m	-	Open forest IV	-
	28--40 m	-	Open forest III	-
	15--28 m	-	Open forest II	Woodland II
	5--15 m	-	Open forest I	Woodland I
Grasses	0--2 m	-	Grassland	-

prises seven related floristic units (2a to 2g).

It should be emphasized that many small vegetation units have been combined with adjacent larger units because of diff-iculties of scale. Also depicted on the vegetation map are softwood plantations, areas of cleared public land, and wet-lands, which are classified in the range fresh-water to saline.

Additional information from sample plots distributed among selected floristic units has been collected and is present-ed in Appendix 5. The floristics are also discussed in more detail in the block descriptions.

Snow gum

Open forest II (1a)

Snow gum forests occur as a small and separate community on some of the high-er elevations of the Mount Cole Range, including Mount Buangor and Lookout Hill. The understorey is predominantly scattered silver wattle over a dense sward of tussock grass. The granite parent rock has produced coarse sand soils.

Messmate--Peppermint--Gum

Open forest IV (2a)

This category embraces forests with a top height greater than 40 m. They occ-ur on yellow gradational soils derived from granitic rocks on the Mount Cole plateau where rainfall is in excess of 700 mm per annum. The dominant tree is messmate stringybark and is associated with brown stringybark, blue gum, and manna gum. This structurally diverse forest has a dense understorey tree layer of blackwood and silver wattle and a shrub layer containing prickly moses, common cassinia, austral bracken, and forest wire-grass. The eucalypts form an important timber resource, which has been utilized since the middle of last century.

Open forest III (2b, 2c)

These forests fall into the height cat-egory 28--40 m. They are located in high-rainfall areas on granitic soils on the Mount Cole range and on areas of Palaeozoic sediments along the Great Dividing Range in the east of the study area near Barkstead and Creswick. The forests consist of messmate stringybark with associated candlebark and narrow-leaf peppermint. Brown stringybark and blue gum also occur in this association, but are confined to areas on the Mount Cole range. Understorey plants are sim-ilar to those found in open forest IV. These forests are also important hard-wood timber resources.

Open forest II (2d, 2e, 2f, 2g)

Messmate stringybark-dominated forests are distributed both north and south of

Messmate stringybark and southern blue gum in the Mount Cole forest - map unit 2b, open forest III.

the Great Dividing Range over a large portion of the Palaeozoic midlands. They tend to occur on gentle ridges and slopes where the soils are red gradational or duplex and yellow gradational or duplex. (The steeper spurs and ridges have poorer skeletal soils and are dominated by red stringybark--box forests.) Associated eucalypts include scent-bark, swamp gum, candlebark, and the peppermints. Large areas of forests around Enfield and north of Linton contain brown stringybark. Understorey species form sparse to moderately dense strata and variously comprise blackwood, silver myrtle, and black wattle, golden bush-pea, narrow-leaf bitter-pea, bracken, and tussock grass.

On the scoria cones of Mounts Warrenheip and Buninyong, messmate forests occur in conjunction with manna gum and a sparse understorey of blackwood over tussock grass and austral bracken. In

Manna gum with understorey of black wattle and bracken fern in the Mount Cole forest - map unit 4b, open forest II.

the former crater of Warrenheip, the formation reaches open forest III height. Soils, derived from volcanic parent material, are red and brown gradational.

Scent-bark--Peppermint

Open forest II (3a, 3b); open forest I (3c)

These forests predominate on drier sites and ridges on Palaeozoic sediments around Creswick, north of Chute, and around the Lal Lal Reservoir. They often occur in a mosaic with messmate--peppermint--gum forests where they occupy sites with shallow stony gradational soils.

Gum--Peppermint

Open forest II (4a, 4b, 4c, 4d, 4e)

Gum--peppermint forests grow in high-rainfall areas in the north-west and in drainage lines throughout the study area - often containing species typical of surrounding alliances. They occur on the foothills and outwash fans of Mounts Cole and Buangor, where manna gum, blue gum, and candlebark dominate. Within most forested areas, small flats along permanently flowing creeks support manna gum forests. Broad gullies, typical of many of the Palaeozoic foothills, contain swamp gum (*Eucalyptus ovata*) and/or its close relative *E. Yarraensis*. This species, once thought to be confined to areas along the Yarra River headwaters, east of Melbourne, has now been located at Smythesdale and north Chute. The flats that constitute drainage lines in the Ben Major, Waterloo, and Trawalla areas carry almost pure stands of

TABLE 15 : VEGETATION CLASSIFICATION

Alliance	Map unit	Typical structural form at maturity	Major eucalypts in the association	Associated tree species	Common understorey species
SNOW GUM	1a	OPEN FOREST II	*Snow gum*		*Silver wattle (<5m), Tussock grass, Mother shield-fern, Austral bracken, Bidgee-widgee*
MESSMATE–PEPPERMINT–GUM	2a	OPEN FOREST IV	*Messmate stringybark*	*Brown stringybark, Blue gum, Manna gum*	*Dense understorey of: Blackwood (<15m), Silver wattle (<15m), Prickly moses (<5m), Common cassinia (<5m), Large-leaf bush-pea (<4m), Austral bracken, Forest wire-grass*
	2b	OPEN FOREST III	*Messmate stringybark, Brown stringybark, Blue gum*	*Manna gum, Narrow-leaf peppermint, Candlebark*	*Dense understorey of: Blackwood (<15m), Silver wattle (<15m), Prickly moses (<5m), Common cassinia (<5m), Large-leaf bush-pea (<4m), Austral bracken, Forest wire-grass*
	2c	OPEN FOREST III	*Messmate stringybark*	*Narrow-leaf peppermint, Candlebark*	*Blackwood (<10m), Silver wattle (<10m), Prickly moses (<5m), Common cassinia (<3m), Narrow-leaf wattle (<2m), Golden bush-pea (<1m), Tussock grass, Austral bracken, Common heath, Forest wire-grass*
	2d	OPEN FOREST II	*Messmate stringybark, Brown stringybark*	*Broad-leaf peppermint, Scent-bark, Narrow-leaf peppermint, Red stringybark, Swamp gum, Candlebark*	*Understorey of low shrubs: Golden bush-pea (<2m), Small grass-tree, Narrow-leaf bitter-pea (<1m), Tussock grass, Austral bracken, Common heath, Myrtle wattle (<2m)*
	2e	OPEN FOREST II	*Messmate stringybark*	*Narrow-leaf peppermint, Scent-bark, Broad-leaf peppermint, Candlebark, Swamp gum*	*Blackwood (<10m), Silver wattle (<10m), Golden bush-pea (<1m), Austral bracken, Tussock grass, Small grass-tree, Common heath*
	2f	OPEN FOREST II	*Messmate stringybark*	*Manna gum, Narrow-leaf peppermint*	*Moderately dense: Black wattle (<10m), Wedge-leaf hop-bush (<3m), Austral bracken, Tussock grass*
	2g	OPEN FOREST II	*Messmate stringybark*	*Manna gum*	*Blackwood (<15m), Tussock grass, Austral bracken*
SCENT-BARK–PEPPERMINT	3a	OPEN FOREST II	*Broad-leaf peppermint, Scent-bark*	*Messmate stringybark, Narrow-leaf peppermint, Candlebark*	*Open understorey of: Golden bush-pea (<1m), Small grass-tree, Common heath, Tussock grass, Narrow-leaf bitter-pea (<1m)*
	3b	OPEN FOREST II	*Scent-bark*	*Narrow-leaf peppermint, Candlebark*	*Open understorey of: Blackwood (<10m), Black wattle (<10m), Prickly tea-tree (<2m), Silky tea-tree (<2m), Common cassinia (<3m), Austral bracken, Small grass-tree, Tussock grass, Black-anther flax-lily*
	3c	OPEN FOREST I (15m mature height)	*Broad-leaf peppermint*	*Scent-bark*	*Understorey of low shrubs (<1m): Golden bush-pea, Austral bracken, Common heath, Prickly broom-heath, Pink beard-heath*
GUM–PEPPERMINT	4a	OPEN FOREST II	*Candlebark*	*Yellow box, Narrow-leaf peppermint*	*Open understorey of: Blackwood (<10m), Black wattle (<10m), Silver wattle (<10m), Tussock grass, Austral bracken, Common heath*
	4b	OPEN FOREST II	*Eurabbie, Manna gum, Candlebark*	*Narrow-leaf peppermint, Messmate stringybark*	*Open understorey of: Black wattle (<10m), Wedge-leaf hop-bush (<3m), Austral bracken, Tussock grass*
	4c	OPEN FOREST II –WOODLAND II	*Manna gum*	*Narrow-leaf peppermint, Swamp gum, Radiata pine*	*Blackwood (<15m), Common cassinia (<4m), Cherry ballarat (<8m), Austral bracken*
	4d	OPEN FOREST II	*Swamp gum*	*Scent-bark, Narrow-leaf peppermint*	*Open understorey of: Blackwood (<10m), Black wattle (<10m), Prickly tea-tree (<2m), Tussock grass*
	4e	OPEN FOREST II	*Manna gum (rough-barked)*	*Black wattle, Messmate stringybark*	*Silky tea-tree, Common heath, Austral bracken*
RED STRINGYBARK –BOX	5a	OPEN FOREST II	*Red stringybark, Broad-leaf peppermint*	*Scent-bark*	*Understorey of low shrubs (1m tall): Golden bush-pea, Hedge wattle, Small grass-tree, Tussock grass, Narrow-leaf bitter-pea, Austral bracken, Common heath*
	5b	OPEN FOREST II	*Red stringybark*	*Broad-leaf peppermint, Red ironbark, Yellow box, Rough-barked manna gum*	*Understorey of low shrubs: Golden wattle (<2m), Golden bush-pea (<1m), Gold-dust wattle (<2m), Tussock grass*
	5c	OPEN FOREST II	*Red stringybark, Blue gum*	*Yellow box, Long-leaf box, Messmate stringybark, Candlebark*	*Open – sparse: Hedge wattle (<2m), Spreading wattle (<2m), Grey everlasting (<3m), Gorse bitter-pea (<1m), Narrow-leaf bitter-pea (<1m), Tussock grass, Common heath*
	5d	OPEN FOREST II	*Red stringybark, Long-leaf box*	*Scent-bark, Yellow box, Broad-leaf peppermint, Candlebark*	*Sparse: Hedge wattle (<2m), Spreading wattle (<2m), Grey everlasting (<3m), Gorse bitter-pea (<1m), Narrow-leaf bitter-pea (<1m), Tussock grass, Rock fern*
	5e	OPEN FOREST I/II	*Manna gum, Red stringybark, Long-leaf box*	*Broad-leaf peppermint, Yellow box*	*Sparse – open understorey of: Black wattle (<8m), Hedge wattle (<3m), Varnish wattle (<3m), Rock fern, Tussock grass*
	5f	OPEN FOREST I/II	*Red stringybark*	*Red box, Yellow box, Long-leaf box, Yellow gum*	*Sparse and open: Golden wattle (<2m), Grey everlasting (<1m), Narrow-leaf bitter-pea (<1m), Tussock grass*
	5g	OPEN FOREST I	*Red stringybark, Long-leaf box*	*Red box*	*Sparse understorey of: Grey everlasting (<1m), Wedge-leaf hop-bush (<1m), Tussock grass, Rock fern*
	5h	OPEN FOREST I	*Red stringybark, Red box*	*Long-leaf box*	*Golden wattle (<4m), Hedge wattle (<3m), Gold-dust wattle (<1m), Spreading wattle (<2m), Tussock grass*
	5i	OPEN FOREST I	*Broad-leaf peppermint*	*Red stringybark, Red ironbark*	*Sparse understorey of: Golden bush-pea (<1m), Golden wattle (<1m), Tussock grass, Common heath*
	5j	OPEN FOREST I	*Long-leaf box*		*Silver banksia (<5m), Yacca, Austral bracken, Hedge wattle (<4m)*
GUM–BOX	6a	OPEN FOREST II	*Yellow gum*	*Yellow box, River red gum, Scent-bark*	*Sparse and open: Golden wattle (<4m), Hedge wattle (<2m), Black wattle (<4m)*
	6b	OPEN FOREST II –WOODLAND II	*Grey box*	*Red box, Red stringybark, Long-leaf box, Yellow box, Yellow gum, Red ironbark*	*Golden wattle (<4m), Hedge wattle (<3m), Gold-dust wattle (<1m), Tussock grass*
	6c	OPEN FOREST II /WOODLAND II	*Yellow gum*	*Yellow box, Red stringybark, Grey box*	*Open understorey of: Blackwood (<10m), Black wattle (<10m), Hedge wattle (<3m), Varnish wattle (<3m), Spreading wattle (<2m), Wedge-leaf hop-bush (<3m)*
	6d	WOODLAND II	*Yellow gum*	*Yellow box, Red river gum, Scent-bark*	*Sparse and open: Golden wattle (<4m), Hedge wattle (<2m), Black wattle (<4m)* *Grasses: Kangaroo grass, Variable spear-grass*
	6e	WOODLAND I/II	*Yellow gum, Long-leaf box*	*Yellow box, Red stringybark*	*Sparse and open: Golden wattle (<4m), Black wattle (<4m)* *Grasses: Variable spear-grass, Kangaroo grass*
	6f	WOODLAND II	*Yellow box, River red gum*	*Manna gum*	*Open understorey of: Black wattle (<10m), Hedge wattle (<3m), Wedge-leaf hop-bush (<3m), Silver banksia (<8m)*
	6g	WOODLAND II	*River red gum*	*Blackwood, Silver wattle* *or*	*Common sedge, Bulrush, Spiny flatrush* *Pasture*
SOFTWOOD PLANTATION	7	OPEN FOREST III	*Radiata pine*		
CLEARED LAND –GRASSLAND	8	*Includes public land use for agriculture, gravel extraction and water supply; land purchased for softwood plantations; former goldmining areas. Vegetation includes native grasses and remnants of former forests, pasture species, gorse, spiny broom and blackberry.*			

Height and range of structural categories:
Open forest IV >40m
Open forest III 28-40m
Open forest II 15-28m
Open forest I 5-15m
Woodland II 15-28m
Woodland I 5-15m

candlebark. A rough-barked variety of manna gum (wherein the bark extends well above the bole of the tree and into the branches) occurs on relic Tertiary sand soils south of and surrounding Dereel lagoon, and at Mount Erip.

Red Stringybark--Box

Open forest II (5a, 5b, 5c, 5d, 5e); and Open forest I (5f, 5g, 5h, 5i, 5j)

Forests characterized by red stringybark in association with red and long-leaf box grow on both Ordovician sediments and Devonian granites. On the western side of the Mount Cole--Ben Nevis range, red stringybark occurs in association with blue gum and, to a lesser extent, with messmate--stringybark, yellow box, candlebark, and long-leaf box. A similar association, without blue gum, occurs on the Langi Ghiran granite massif.

Other major occurrences are on the sedimentary foothills surrounding Beaufort and Chute. Here red stringybark and long-leaf box predominate on the drier northerly aspects where soils are shallow, stony, and gradational. Around Berringa, red stringybark and broad-leafed peppermint occur on the dissected slopes surrounding the headwaters of Mount Misery Creek. In forests adjacent to Mount Erip, red ironbark appears as an associated species.

The drier habitat, characteristic of this alliance, produces a relatively

Elderberry panax and tree violet are commonly found on basalt escarpments and cliffs

Red ironbark, red stringybark and golden wattle at Mount Erip - map unit 5b, open forest II sparse and open understorey of wattles (gold-dust, hedge, spreading, varnish, black, and golden), bush-peas, (*Pultenaea* spp.), bitter-peas (*Daviesia* spp.), and tussock grass.

Open forest I tends to occupy the more extreme sites, where soils are skeletal or granitic slabs and tors prevent optimum growth. Examples are the rocky faces of Mount Langi Ghiran, Ben Nevis, Ben Major, and the rocky ridges associated with the Mount Erip forest.

Gum--Box Forests

Open forest II (6a, 6b); and woodland II (6c, 6d, 6e, 6f, 6g)

These areas are characterized by yellow gum, red gum, yellow box, and grey box - mainly as woodland, but also in an open forest formation. In the Dunneworthy forest, north of Ararat, yellow box, river red gum and scent-bark occur on yellow duplex soils on the lower slopes of a gently undulating plain. The yellow sodic duplex soils of the upper slopes support yellow gum and long-leaf box woodland. The sparse and open understorey contains golden, black, and hedge wattles. The ground layer has been extensively grazed.

Woodlands of yellow box and river red gum occur on granite sand soils west of Mount Langi Ghiran with an open understorey of black wattle, hedge wattle, wedge-leaf hop bush, and silver banksia.

Yellow gum in the Dunneworthy forest, north of Ararat - map unit 6d - woodland II

River red gum woodlands occupy Crown land frontages to the Hopkins River, Woady Yaloak River, and numerous tributaries, often with yellow box, blackwood and silver wattle, rushes, and sedges. River red gum also occurs as an open woodland associated with agricultural country (for example, at Langi Kal Kal Youth Training Centre). These woodlands are often associated with former lakes where quaternary alluvial deposits have resulted in the development of a mottled duplex soil.

Softwood Plantations

Softwood plantations of radiata pine *(Pinus radiata)* have been established around Creswick, Ballarat, Beaufort, Eganstown, and Spargo Creek by the Forests Commission, and by the Ballarat Water Commissioners. This topic is dealt with in Chapter 17.

Mount Cole grevillea - a semi-prostrate shrub found only on the eastern fall of the Mount Cole plateau

Cleared Land - Grassland

These areas of public land fall into two categories: land purchased by the government for special purposes (for example, Langi Kal Kal Youth Training Centre and farmland purchased by the Forests Commission for softwood plantations); and former gold-mining and grazing commons and mining reserves. The vegetation includes remnants of native grassland and tree species, pasture species, and noxious weeds such as furze, spiny broom, and blackberry.

Wetlands

Wetlands have been classified in the range fresh-water to saline. The locations together with lists of common aquatic plants, are shown on Map 9.

Significant or Unusual Species

The following list contains plants that are variously rare, uncommon, or localized within the study area.

Brachycome tenuiscapa - daisy. This species has a disjunct distribution - for example, Bogong High Plains, Ballarat; possibly extinct at Ballarat.

Thelymitra mackibbinii - brilliant sun orchid. Very rare in Victoria, where it has only been found on gravelly auriferous terrain at Smythesdale and Maryborough. (These are old records and some doubt arises whether the plant exists.)

Discaria pubescens - Australian anchor plant. Once common on the plains, now restricted to a few plants along Creswick Creek and Lal Lal Creek.

Grevillea sp. - Mount Cole grevillea. Un-named grevillea locally abundant in an area on the eastern slopes of the Mount Cole plateau. No other occurrence.

Grevillea sp. - Ben Major grevillea. Un-named grevillea locally abundant in forests south of Ben Major. No other occurrence.

Grevillea sp - Enfield grevillea. Un-named grevillea locally abundant around Little Hard Hills and Smythesdale. No other occurrence.

Eucalyptus globulus - southern blue gum. Common forest tree in the Mount Cole forest, at its most westerly occurrence.

Leptospermum nitidum - shiny tea-tree. Found at Mount Buangor and Mount Langi Ghiran; otherwise restricted to the Grampian Ranges.

Leucopogon neurophyllus - veined beard-heath. Found at Mount Langi Ghiran; otherwise restricted to the Grampian Ranges.

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FAUNA

A survey of mammals, birds, reptiles, and amphibians in the study area was carried out by the Fisheries and Wildlife Division. The information covers 42 mammal species (2 monotremes, 21 marsupials, and 19 placental mammals), 249 species of birds, 26 reptiles, and 12 amphibians. Other member groups of the fauna - such as arthropods (insects, spiders, and crustaceans) and annelids (worms and leeches) - are not reported on. These groups, which make up by far the largest numbers of species, are rarely the subject of detailed survey.

Habitats

Animal habitats, described by E.P. Odum as 'the place where an organism lives', can be broadly described in terms of vegetation formations. Four habitats - tall open forest, open forest, woodland, and grassland - have been selected, as these have major structural and floristic differences (see Table 16). Others - wetlands, urban areas, and softwood plantations - are also described.

This chapter does not discuss the reasons why species prefer a certain habitat, as the ecological niche concept includes complex physical, biological, and behavioural variables that are rarely well understood. It should be noted, however, that localized features such as dense shrubbery, hollow trees, rock outcrops, soils suitable for burrowing, or clumps of specific flowering plants may be more important than the broad vegetation formation in which they occur.

General forest habitat

Open forests and woodland cover most of the public land in the Ballarat area. Many animals are widely distributed and cannot be closely identified with specific forest types. They may be found in greater numbers in certain forests, which may be described as the preferred habitat, but also occupy a broad range of types. Such species, considered to be 'non-dependent' or 'marginally dependent', contrast with those restricted in their habitat preference to one forest type - which are termed 'dependent residents'. Species with known affinity for a particular forest habitat are discussed under that heading.

Wet open forest

Open forests IV and III, the wetter range of the messmate--peppermint gum

Table 16

RELATION BETWEEN HABITAT AND VEGETATION UNITS

	Habitat	Corresponding vegetation unit
General forest habitat	Wet open forest	2a, 2b, 2c, 2f, 4b
	Dry open forest	2d, 2e, 2g, 3a, 3b, 3c, 4a, 4c, 4d, 4e, 5a, 5b, 5c, 5d, 5e, 5f, 5g, 5h, 5i, 5j
	Woodland	6a, 6b, 6c, 6d, 6e, 6f, 6g
	Pine plantations	7
	Grassland	8
	Wetland	9a, 9b, 9c, 9d
	Urban	

and gum--peppermint alliances, are representative of this habitat, which covers approximately 20% of public land in the study area, on Mount Cole and surrounding Barkstead. The tall trees, dense shrub layers, and moist and often ferny gullies provide a variety of habitats.)

Dry open forest

Alliances characteristic of this habitat include scent-bark--peppermint and red stringybark--peppermint--box. Such drier forests have an understorey that may consist of low shrubs, sparsely distributed wattles, and open grassy areas. There are also small areas with a dense heathy understorey. This habitat covers large areas (approximately half) of public land in the study area.

Grassy woodland

Woodlands of red and yellow gum and red and yellow box cover about 2% of public land north of the Great Dividing Range. They are essentially dry, with an understorey of sparse shrubs and native grasses.

Grasslands

Relic patches of the original native grasslands occur along roadsides and watercourses, and occasionally on public reserves. The vast bulk of the original grassland basalt plains (now privately owned and developed for agriculture) has an important habitat role, but, while many of the fauna species have adapted to this modified grassland, others have not and have become extinct.

Wetlands

Aquatic habitats include saline lakes, fresh-water lakes and marshes, and temporary wetlands caused by periodic inundation of pasture. The saline lakes, found in areas of impeded drainage on the basalt plains and flooded craters, are characterized by a shallow nature, seasonal variation in salinity (as water levels fluctuate from full to empty), and a low surround of salt-tolerant plant species. Fresh-water wetlands generally have a greater range of marginal vegetation, including trees and reed-beds, which may extend into the water and so provide a greater diversity of habitats.

Other habitats

Urban habitat covers the areas more intensively occupied by Man. Many introduced mammals and birds are associated with this environment. A large number of native birds and mammals, however, have adapted to semi-natural surroundings of suburban gardens and municipal parks.

Introduced pine plantations provide a succession of habitats, beginning with a grassland type in the early phase of

Koala on brown stringybark near Mount Lonarch establishment. This becomes shrubland as the pines and other species (wattles, eucalypts, and shrubs) compete with each other, and eventually an open forest with minimal understorey as the plantation reaches maturity. As an adjunct, areas of native forest often regenerate along streamsides or are specifically retained for this purpose. Certain native mammals and birds (that is, those not totally dependent on eucalypt forests for their survival) have shown the ability to utilize certain of these successional stages. In the study area, plantations cover approximately 16% of public land.

Mammals and Birds

General forest habitats

A broad cross-section of mammals may be found in the general forested environment. These include the more common arboreals - such as the koala and brush-tailed and ring-tailed possums - and also the feather-tailed glider, a widely distributed small possum. Perhaps more prevalent in the open forests is the sugar glider, a nectar feeder and insectivore, and the black-tailed wallaby, which favours areas with dense undergrowth. The red-necked wallaby occurs as an isolated population in the Mount Cole forests. The brown antechinus is a common inhabitant of the forest floor and tree layer of open forests throughout the study area. It feeds on insects, crustaceans, and other invertebrates. The adult males of this species die off annually during August.

The brown antechinus forages on the forest floor, in hollow logs and trees. This mouse-sized marsupial is a common inhabitant of open forests

A number of insectivorous bats occur in open forests. Individuals belonging to the larger fruit bats of northern Australia occasionally stray into the area.

The eastern grey kangaroo is a common resident of the open forest fringes and woodlands throughout the study area. The echidna is widespread.

The success of the introduced mammals such as the fox, feral cat, rabbit, black rat, and house mouse throughout the forests indicates their adaptability.

Many bird species are widespread in forested areas. The red wattle-bird, white-naped honeyeater, yellow-faced honeyeater, striated thornbill, and spotted pardalote feed among the crowns of the trees; the crested shrike-tit and white-throated tree-creeper feed in the branches and along trunks of trees; the grey fantail feeds in the air beneath the tree canopy; the brown thornbill feeds in crowns of the understorey; and the superb fairy wren and white-browed scrub-wren feed in the shrubby ground cover.

Other species that frequent forest habitats include the southern boobook owl, sulphur-crested cockatoo, crimson rosella, and laughing kookaburra, all of which nest in hollows in trees. The golden whistler, eastern yellow robin, grey shrike-thrush, brown goshawk, white-eared honeyeater, eastern spinebill, common bronzewing, and Australian raven can also be considered general forest inhabitants. The blackbird is the only introduced species to have become well established in forest areas.

Wet open forest

This habitat occurs basically in two disjunct localities - the Mount Cole plateau and the area surrounding Barkstead and the Moorabool Reservoir. Three mammals - wombat, bush rat, and greater glider - occur only in the latter area, apparently at the western limit of their range in Victoria. (Wombats are recorded further to the southwest around the Lower Glenelg area.) The wet and ferny gully habitat at Mount Cole, is occupied by the swamp rat and Swainson's antechinus. Bush rats are not found here. The Mount Cole forests also contain the red-necked wallaby, which has a patchy distribution in Victoria. Sambar deer, thought to be progeny of a herd released from Ercildoun in the 1890s, are protected from hunting in this forest. There are unconfirmed sightings here of the bobuck or mountain possum, a close relative of the brushtailed possum.

Dry open forest

Mammals specific to dry open forests include the yellow-footed antechinus, which exhibits a preference for an open understorey. The tuan, a marsupial widespread but not commonly seen, feeds in open forest and woodland, generally seeking insects and spiders under bark and robbing nests. The mouse dunnart, a mouse-sized marsupial that feeds mainly on insects, is restricted and not often located. In the study area one pair were discovered under sheets of old iron in the Mount Erip forest. A small herd of red deer inhabit open forests and softwood forests south of Ballarat and forests around Ben Major.

The tiger cat, a marsupial predator about the size of a domestic cat, has been reported in this habitat. The last recorded sighting was around Rokewood in 1964 and it is probable that this spec-

The tuan - an infrequently seen inhabitant of dry open forests

The plains-wanderer, once common in basalt plains grassland, is now considered a rare species

ies is locally extinct. (The major population stronghold occurs in the wet forests of the Otways.)

The eastern pigmy possum, widespread but not generally encountered, lives in the dry scrubby forests, and is occasionally encountered by workers cutting dead trees for firewood.

The more open understorey and tussock-grass ground cover of the drier forests provide ideal habitat for the spotted quail-thrush and buff-rumped thornbill, which both frequently utilize the grass tussocks for nesting. Other characteristic species are the grey currawong, which feeds on insects, fruits, and the eggs of other birds, the white-winged chough, which lives in family groups with a well-organized social structure, and the scarlet robin.

Grassy woodland

The tuan and mouse dunnart also occupy the woodland habitat, as does the red deer. The quoll, common and widespread until early this century in woodland and grassland with piles of stones, seems to no longer exist in Victoria.

Grassy woodland areas carry a wide range of birds. The trees provide nectar, pollen, and insects for the fuscous, brown-headed, and yellow-tufted honey-eaters, the purple-crowned, musk, and little lorikeets, the striated pardalote, and the brown weebill. The varied sittella forages for insects on the trunks and branches of the trees, while the brown tree-creeper forages on the trunks and on fallen timber. Superb fairy wrens, buff-rumped thornbills, and speckled warblers inhabit the low bushes and ground cover. Horsfield's bronze cuckoo and the pallid cuckoo are common in the study area during the summer. Other common species are the eastern rosella, red-rumped parrot, jacky winter, rufous whistler, and Australian raven.

Grassland

Populations of birds and mammals characteristic of native grasslands have declined markedly or become extinct as these areas have been developed for agriculture. For example, Gunn's bandicoot, a grassland species previously recorded in the Ballarat area, is now restricted to a relict colony around Hamilton; the previously mentioned quoll also once occupied grasslands. Many native birds, however, have readily adapted to the agricultural habitat.

The fat-tailed dunnart is a widespread but infrequently recorded species. It occurs in drier native grasslands between rocks and logs. Its fat tail contains a store of food available for consumption during times of shortage.

The plains-wanderer is an endangered species and the most recent sighting was just outside the study area at Inverleigh in 1976. The Australian bustard, which once appeared in large flocks on the plains, is occasionally sighted south of Rokewood and Streatham. Little button-quail are rarely seen. Other species such as the stubble quail, Richard's pipit, Australian magpie and magpie lark, and Australian kestrel continue to thrive in this habitat.

Australian kestrel, a common raptor

Among the introduced species, the feral pigeon, spotted turtledove, European goldfinch, and starling are common.

Aquatic

Only two mammals occupy aquatic habitats - the platypus and eastern water-rat. Both nest on the banks of lakes and watercourses and forage for crustaceans, insects, and molluscs in the water. Neither species is found in the saline lakes.

Waterbirds require shallow waters for feeding (by diving or wading), as this is biologically the most productive zone. This means that deep lakes and water storages are unsuitable habitat, except those with surrounds shallow enough to support a fringing or emergent flora. Birds that dive after fish and aquatic invertebrates include the Australian pelican, the darter, the cormorant, and the grebe. The white-faced heron and the spoonbill wade through shallow margins to pick out frogs and invertebrates. Seasonally inundated pastures provide ideal habitat for large flocks of birds, including straw-necked ibis and sacred ibis.

Eastern water-rat, a common native rat found in lakes, swamps, and waterways throughout the study area

Brolgas prefer small shallow swamps for nesting. Drainage and alteration of swamplands for agricultural use has greatly reduced the number of swamps available for nesting and has been a major cause of the decline in this species since settlement.

Mudflats and reed-beds surrounding lakes and swamps provide nesting and feeding areas for dusky moorhen, coot, spotted warbler, and Australian crake.

A number of waders, of significance because they migrate from summer breeding grounds in the Northern Hemisphere to the southern continents, are seen on shallow mudflats. Included are the wood sandpiper, greenshank, curlew sandpiper, red-necked stint, and Latham's snipe. Saltmarsh areas (mud-flats and salt-tolerant plants) are frequented by these species as well as red-necked avocets, banded stilts, and silvergulls.

Other habitats

Many species that are non-dependent or marginally dependent on their preferred habitat have been shown to occur in softwood plantations. The results of a study of pine plantations in north-eastern Victoria suggest that the foll-

Brolgas are uncommon but widespread. Their habitat is the larger swamps and lakes of the basalt plains.

owing mammals of the general forest habitat would be found - echidna, brown antechinus, Swainson's antechinus, brush-tailed possum, ring-tailed possum, eastern grey kangaroo, black-tailed wallaby, house mouse, black rat, rabbit, hare, fox, and feral cat. Those absent include the species wholly dependent on the forest trees themselves - for example, the gliding possums, which rely on eucalypt nectar and hollows for nesting.

The groups of birds best represented in pines were those that (in eucalypt forest) feed from the ground and understorey strata. Ground feeders that nest and feed in pines include White's thrush, spotted quail thrush, buff-rumped thornbill, scarlet robin, and grey currawong. The birds most poorly represented were those that feed in the canopy and boles of trees in eucalypt forests. The canopy feeders include honeyeaters, which feed on nectar, pollen, and nectar-seeking insects associated with eucalypt flowers.

A study in New South Wales found that species diversity and actual number of individuals were much lower in pine forests than in adjacent eucalypt forests. Also, breeding diversity was twice to three times as great in the eucalypt forest. Hole-nesting birds were found to be disadvantaged in pine plantations because of the lack of hollows.

In the urban habitat, most common mammals that occur are introduced. They

Three-lined skink

include black rats, house mice, cats and dogs. The grey squirrel, a North American native, was common in Ballarat gardens for many years and was last seen in 1966. The ring-tailed and brush-tailed possums are two native species found in urban areas.

Introduced species dominate the bird fauna. The starling, spotted turtle-dove, house sparrow, blackbird, song thrush, mynah, and goldfinch are all common. Many suitable gardens and open areas attract honeyeaters, wattlebirds, and wrens.

The distributions of birds and mammals in the study area are shown in Appendices 6 and 7 respectively.

Reptiles and Amphibians

Reptiles have three major ecological requirements: a suitable thermal area, as they rely on external factors to control body temperature; a suitable micro-environment, where they can remain inactive and sheltered during unfavourable conditions; and a warm dry egg-laying site for oviparous species.

Reptiles use two strategies to raise body temperature. One is basking in the sun, and the other is selection of the suitable temperature in shaded situations. Basking reptiles (heliotherms) such as black-rock skink and large striped skink are found on rock outcrops that have an exposed north-westerly aspect - for example, the rocky areas of Mount Langi Ghiran and the Mount Cole plateau. The non-basking reptiles or thigmotherms may shelter beneath rocks and logs; others - for example, Spencer's skink, - are found in shrinking gaps in dead trees or beneath granite exfoliations. The spinifex lizard is a non-basking reptile found in grassland areas.

Common heliothermic snakes include the eastern tiger snake and the eastern brown snake. The thigmothermic little whip snake is found beneath rocks in woodland and grassland. Appendix 8 lists the reptiles.

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LAND SYSTEMS

The preceding sections of this report have described the features of the land in the study area - geology, land forms, climate, soils, and vegetation.

These features are not distributed at random, nor do they occur independently. Rather, distinct environments consisting of characteristic patterns of geological material, land forms, soils, and vegetation can be recognized. These patterns often occur within a given range of climate, thus allowing large areas of land to be described in terms of 'land systems', each with a particular range of climate, topography, parent materials, soils, and original vegetation.

In this method of characterizing the land, each feature of the environment is considered in relation to the others, with more emphasis placed on interactions than in single-feature surveys - for example, soil or vegetation surveys. The approach allows other attributes of the land to be incorporated - such as problems of development, erosion hazard, and potential productivity.

An understanding of the nature of such areas of land, and a knowledge of their distribution, is a valuable base for land use planning.

The most-detailed unit for mapping and description is the 'land component', in which the climate, parent materials, soils, and vegetation are uniform within close limits. Land components are mapped at scales of 1:10,000 to 1:50,000. They usually occur in a limited number in a consistent repetitive sequence, and an area containing such a sequence is termed a LAND SYSTEM.

Land systems are mapped at scales of 1:100,000 to 1:250,000. They may be delineated as the first stage in the characterization of land for land use and management planning, and are therefore valuable where integrated information is required for large areas on a relatively broad scale.

Mapping of land systems in the State is being carried out by the Soil Conservation Authority; however, surveys have not been completed for all regions.

For this reason, the available information on land systems within the Ballarat area has been amalgamated into still broader groupings according to geomorphology (see Map 8). Environmental information has been similarly grouped, and Table 17 sets out the sequence of topography, rock type, rainfall, soils, and vegetation for each map unit.

Table 17

LAND SYSTEMS GROUPINGS OF THE BALLARAT STUDY AREA

Geomorphic groups of land systems	Topography and rock type	Soils (and topographic position)	Average annual rainfall (mm)
1 Alluvial plains	Terraced plains of Quaternary alluvium - silt, sand clay, and gravel	Red sodic duplex soils (plains & upper terraces); Yellow sodic duplex soils, coarsely structured (plains); Calcareous sodic duplex soils with columnar structure (upper terraces); Yellow gradational soils (upper terraces); Black cracking clays, (low terraces, basalt alluvium); Calcareous sodic clays (upper terraces)	500--750
2 Palaeozoic sediments I	Low hills of Palaeozoic sediments; interbedded slates, sandstones, quartz reefs	Shallow stony gradational soils (crests); Red sodic duplex soils (crests, slopes); Red sodic duplex soils, coarsely structured (slopes, crests); Yellow sodic duplex soils, coarsely structured (slopes); Yellow sodic duplex soils (swales);	500--625

Table 17 (continued)

3 Palaeozoic sediments II	Low and dissected ridges of Palaeozoic sediments; interbedded slates, sandstones, quartz reefs	Shallow stony gradational soils (crests, spurs); Red duplex soils (slopes); Yellow duplex soils (swales & fans); Yellow gradational soils (swales) Red gradational soils, finely structured (slopes)	625--750
4 Palaeozoic sediments III	Mountain range of Lower Palaeozoic sandstones and slates	Stony gradational soils (slopes); Shallow stony gradational soils (slopes); Yellow gradational soils (drainage lines).	625--750
5 Granite hills I	Low hills of Devonian granite and granodiorite	Mottled duplex soils with ironstone (slopes); Red and yellow sodic duplex soils, coarsely structured (slopes, swales); Yellow sodic duplex soils (flats); Coarse sands (hills); Yellow gradational soils (drainage lines).	500--625
6 Granite hills II	Mountains of Devonian granite and granodiorite	Coarse sands (scarps); Yellow duplex soils (upper slopes); Yellow gradational soils (drainage lines)	625--1,000

7 Metamorphic hills	Aureole ridge & fan of contact metamorphics; interbedded slates & sandstones	Shallow stoney loams (crests, slopes); Stony red-yellow gradational soils (slopes); Yellow gradational soils (fans)	
8 Basalt plains I	Undulating plains with volcanic cones of Tertiary basalt	Red gradational soils, finely structured (cones, slopes, drainage lines); Stony red gradational soils, finely structured (crests)	750--1,000
9 Basalt plains II	Stony rises of Quaternary basalt, scoria and ash	Red brown shallow stony gradational soils (rises); Black cracking clays, uniform texture (flat); Brown gradational soils, finely structured (cones)	500--625
10 Basalt plains III	Undulating plain of Tertiary basalt	Stony yellow-brown sodic calcareous duplex soils, coarsely structured (plains & scarps); Black cracking clays (drainage lines); Grey clays (swamps)	500--625
11 Basalt plains IV	Undulatinng plains with volcanic cones on Tertiary basalt	Red gradational soils, finely structured (cones); Red-brown shallow stony gradational soils (scarps); Black cracking clays (flats); Yellow sodic duplex soils, coarsely structured (slopes)	500--750

Table 17 (continued)

12 Tertiary	Undulating plains on Tertiary sediments, gravels and clays	Mottled red and yellow-red duplex soils, with ironstone (plains, slopes); Yellow sodic duplex soils, coarsely structured (slopes); Yellow sodic duplex soils (plains); Yellow duplex soils (drainage lines); Leached sands (crests)	500--750

PART III

LAND USE

LAND USE HAZARDS

Interacting systems of soils, vegetation, fauna, and water evolve as a result of geological and climatic change operating over millions of years. In their natural state, these systems tend to exist as a dynamic equilibrium. Since European settlement, however, they have been substantially altered to provide for the requirements of Man - forests have been cleared for agriculture or intensively managed for forestry and land has been mined and used for recreation and settlement.

Inevitably, changes in land use are associated with hazards such as accelerated soil erosion, salting, flooding, fire, and increases in populations of unwanted plants and animals. The type and severity of the hazard varies with the land's capability to adapt to the changed land use and according to the type of management applied. This chapter concentrates on known hazards associated with major land uses in the Ballarat area.

Physical Hazards

Soil deterioration

The soils of the area vary greatly in the extent to which they can withstand disturbance by land uses such as cultivation, grazing, burning, extraction of timber, construction of roads and reservoirs, mining and quarrying, and recreational activities such as trail-bike riding or trampling by people. Soil deterioration affects not only the productivity and aesthetic appeal of the land, but also the quality and flow rate of water in streams.

An important factor governing the occurrence of erosion is the geology of the country - the basalt areas are much less susceptible to erosion than the land on Ordovician slates, shales, and sandstones. For example, the gold-mining activities of prospectors and sluicers working the beds of many of the smaller streams and natural gullies in the Ordovician sediments left behind a raw and ravaged landscape open to the attack of storm waters: the resultant scours often extended into unworked country beyond.

Areas of high run-off and high erosion hazard depend on vegetative cover for stability. Retention of native vegetation provides the best conditions for soil conservation, for a sustained yield of high-quality water, and for flood mitigation.

Water erosion

In granitic soils, sheet erosion is a common form of soil deterioration because any form of land disturbance exposes the loose and often deep A horizon to the forces of water flow. Deep rilling on unprotected road batters and dams is also a serious form.

Gully erosion is the more spectacular form of soil deterioration in these soils, as the damage and volume of soil removed are immediately apparent. Increased run-off from cleared hills or overgrazed paddocks concentrates water flow in the drainage lines, where (in many instances) relatively unstable yellow gradational and yellow sodic duplex soils are found. Mass movement of soil may occur in the form of landslips on steep hills, particularly when the trees are cleared.

On the hill crests and upper slopes of the Palaeozoic sediments, including the metamorphic aureole ridges, shallow stony gradational soils have a high incidence of sheet erosion. This hazard decreases towards the higher-rainfall zone, where a protective vegetative cover is more easily maintained. On the gentler slopes, sheet erosion is also significant because of the slow rate of entry of water into the subsoils of the predominant red sodic duplex soils.

On the outwash fans from the metamorphic aureole ridges, the unconsolidated colluvium has a high gully erosion and a moderate sheet erosion hazard. When large quantities of water drain off the aureole and channel across the fan, gullies form very quickly where there is soil disturbance. A high gully erosion hazard also exists on the yellow sodic duplex soils that predominate in the drainage lines on Palaeozoic sediments.

Soils derived from basalt cover approximately half the study area. The gently undulating plains have a minimal water erosion hazard. On the rises and scarp sections of the landscape, however, a moderate sheet erosion hazard does exist. The black cracking clays in the alluvium along drainage lines have a low gully erosion hazard.

The light sandy A horizons of the mottled duplex soils on Tertiary sediments, supporting a heathy-woodland vegetation, have a moderate sheet erosion hazard if the vegetation is disturbed. A high gully erosion hazard exists in the drainage lines, where the yellow sodic duplex soils are very dispersible and unstable.

Most areas of alluvium are broad, flat, or gently undulating with low erosion hazards.

Wind erosion

Significant wind erosion is confined to sandy soils on Tertiary sediments. Wind erosion may also occur on lunettes east of swamps that have been cleared and left unprotected in a dry condition.

Stream erosion

Although the headwaters of numerous streams originate in the midlands, few large rivers flow through the study area. While stream erosion and flooding are by no means negligible, probably the most important and significant damage occurs as a result of sheet erosion and gullying, with the somewhat allied problem of bed erosion of the smaller streams.

Bed erosion is common in the upper reaches of many streams. In the Avoca River near Mount Lonarch, south of Amphitheatre, erosion has cut a trench several metres deep in the river bed. Other examples of erosion include scouring of a tributary of Fiery Creek near Raglan, and headward erosion on a number of streams such as on the Woady Yaloak Creek near Grenville, and on Burbank and other creeks in the Lexton Shire.

Flooding

The low annual rainfall of 760 mm or less throughout most of the Ballarat area provides little sustained surface run-off. After heavy falls, however, the geological features of the region have a marked effect on run-off rates.

Flood flow discharges are characterised by high peak flows of very short duration, brought about by the steep grades of those watercourses that originate in the highlands. Flood flows are generally contained in the river channels in the upper reaches, but more severe flooding occurs to the north and south where the river gradients are less. Flooding could also be expected to occur at the confluence of rivers and streams when peak flood discharges coincide. An example of such flooding occurred in 1978 in the township of Inverleigh, just outside the study area, when flood flows in the Barwon and Leigh Rivers spilled over the river banks onto the adjacent flood plain.

The plains south of the Divide exhibit little relief and have numerous swamps, small lakes, and slow-flowing small streams that flood widely after heavy rainfall. Sheet-flow flooding is common because of the lack of defined stream channels. Vast areas may remain swampy for considerable periods, retaining water or retarding run-off into the main streams flowing to the south. The waterlogged condition of these basaltic soils is, however, a limitation of the soil drainage rather than a sign of deterioration.

Salting

Subsoils (particularly in highly weathered lateritized soils) and underlying rocks contain relatively high concentrations of soluble salts - mostly sodium chloride. Removal of the native vegetation for agriculture has increased the amount of water percolating through the soils and rocks, resulting in movement of salts in seepage waters. When seepage waters approach the surface, salts become concentrated through evaporation, and may reach levels that inhibit the growth of conventional pastures and crops.

The early stages of salting cause a yellowing of herbage; then salt-tolerant grasses such as buckshorn, plantain (*Plantago corunupus*), and sea barley-grass (*Hordeum hystrix*) slowly replace pasture. If allowed to deteriorate, the topsoil erodes away, leaving bare subsoil on which rill and gully erosion may occur. Poorly drained salt-affected land frequently becomes infested with spiny rush (*Juncus acutus*).

Two types of salting occur: valley-floor salting and hillside salting, which are associated with rising water tables and seepage from perched water tables respectively.

Although instances of salting can be found in all land systems in the study area, they are widespread only on the alluvial plains to the north of the Great Dividing Range and on cleared Palaeozoic sediments to the south and south-west of Ballarat. On those parts of the basalt plains where drainage is impeded, swales are usually slightly salt-affected and salty swamps and lakes are frequently encountered. Occasional salting occurs in granitic areas, and this is believed to be associated with drainage from adjoining metamorphic aureoles.

Where soil salting is severe, it significantly limits land use. Salt concentrations in soil water above 2,000 mg per litre (0.2%) are too high for cropping and forestry, and grazing is significantly reduced unless salt-tolerant species are established. Farm dams and water supplies can also be affected. Overgrazing of salt-affected land can lead to sheet and gully erosion.

To manage salt-affected land, fencing-out is required so that special treatment can be given - for example, controlled grazing, mulching, and sowing salt-tolerant grasses and trees. Drainage works can help in some situations.

Prevention of salting is difficult, particularly in the case of valley-floor salting where large groundwater bodies have been building up for many decades before damage became evident. Also, groundwaters may originate several kilometres from the affected area. Methods of prevention vary according to circumstances. Poorly drained areas should be carefully observed for signs of deterioration so that remedial measures can be undertaken at an early stage.

Significant clearing of forested land for agricultural purposes should not be undertaken until the local hydrological effects can be evaluated in relation to salinity hazard. Increased use of water by deep-rooted vegetation throughout the catchments will help to prevent and reclaim salted areas, and trees may be required on a proportion of the land. The proportion of the catchment that should be treed will vary with locality, and studies into this aspect are required.

Stream pollution

Pollution of streams is potentially a problem in the study area, particularly downstream of those towns without reticulated sewerage. Domestic sullage and sewage waste disposal is always a problem where significant areas lack reticulated sewerage. Septic tanks require careful management to operate satisfactorily. Their effectiveness is governed by such factors as the soil type and the area of absorption field available. Groundwater pollution from septic tanks is a potential problem that, during periods of low stream flow, is likely to detrimentally affect water quality in streams with a baseflow sustained by groundwater recharge.

In agricultural areas, the application of fertilisers can lead to excessive plant growth in streams due to high nutrient levels in surface run-off.

Fire

In the early days of European settlement extensive areas of forest were burnt, in an uncontrolled manner, in operations associated with land clearing and gold-mining. Records show that particularly damaging fires occurred in the study area in 1851, 1877, 1896, 1912, 1920, and 1944, and more recently in 1962, 1967, and 1976/77.

Fires in the study area

The number of fires and the area burnt over any summer period vary substant-

Erosion following salting on farmland near Ararat ially, depending on seasonal weather conditions and the quantity of fuel. Pastures that have grown prolifically during a favourable spring and early summer dry off in summer to become a considerable hazard. The risk of severe fires becomes extreme on hot, dry, windy days, particularly when levels of litter in forests and grass on farmlands are high. Wildfires in the study area may occur in the period September to April, but are concentrated in the period December to February. Table 18 gives fire area statistics for public land during the 10-year period 1969/70 to 1978/79, and Table 19 shows the known or suspected causes.

The fires of February 1977

On 12 February 1977, some 68 fires started throughout the State under extreme weather conditions. The Board of Enquiry subsequently set up to enquire into 'The Occurrence of Bush and Grass Fires in Victoria' classified 12 of

Table 18

AREAS OF PUBLIC LAND IN THE BALLARAT AREA BURNT BY WILDFIRE (1969/70 to 1978/79)

Year	Area burnt (ha)		
	Reserved forest	Other public land	Total
1969/70	205	2	207
1970/71	22	3	25
1971/72	10	4	14
1972/73	2,680	6	2,686
1973/74	16	-	16
1974/75	12	1	13
1975/76	145	9	154
1976/77	3,221	202	3,423
1977/78	25	6	31
1978/79	194	-	194
	6,530	233	6,763

Table 19

CAUSAL AGENTS (KNOWN OR SUSPECTED) OF WILDFIRES ON PUBLIC LAND IN THE BALLARAT AREA (1969/70 to 1978/79)

Agent	Total number of fires over 10-year period	Percentage of total
Landowners, householders	35	15
Deliberate lightings	34	15
Sportsmen, campers, travellers	25	11
Licensees, forest workers	13	6
Lightning	14	6
Children	18	8
Rubbish tips	9	4
Power lines	4	2
Miscellaneous		
known	24	10
unknown	52	23
	228	100

these fires as major, of which four occurred in the study area, namely the Creswick, Cressy, Tatyoon/Streatham, and Waubra fires. The same Board classified as major a further four fires that burnt on different dates in the same fire season, and one of these, the Ross Creek fire, also occurred in the study area.

The five major fires mentioned above burnt mainly on privately owned farmland. Of the total of 52,000 ha they burnt, 3,500 were forested public land. They cost four lives, destroyed 90 houses and numerous other buildings, and killed 183,000 sheep and 3,000 cattle. The heaviest losses on public land involved the burning of 270 ha of softwood plantation in the Creswick fire.

These figures illustrate the potential threat of damage and destruction posed by wildfires under extreme weather conditions.

Bulldozers are used to rapidly form a firebreak to confine wildfire

Fire protection and suppression

The Forests Commission is responsible for fire protection in State forests and on private property within 1.5 km of those forests, except for such private property areas that have been excised from Commission responsibility. In areas managed by the National Parks Service, the Service and the Forests Commission share the responsibility for fire protection and suppression.

The Country Fire Authority is responsible for fire protection in the remaining rural private lands throughout the State. A high level of co-operation between the Forests Commission and this Authority is necessary because of the fragmentation of public land, and this

Burning back from roads, often at night, is a technique used to control wildfire

is maintained through well-established working arrangements between personnel of the two organisations.

In native forest on public land, programs of controlled burning are undertaken during mild weather to reduce readily flammable litter accumulations. Although areas recently burnt under such programs may burn again in summer, the intensity of any wildfire would be low. A well-organized and equipped fire-fighting force can control a wildfire burning in such areas even under severe weather conditions. In 1978/79, protective burning was carried out in 6,500 ha of forest in the study area.

The Forests Commission is conducting long-term studies into the effects of fuel-reduction burning on flora communities.

Successful control of wildfires depends on early effective initial attack. The keys to success are early detection, rapid access, and swift mobilization of personnel and equipment. Six fire towers in the study area are manned during the fire danger period. A network of access roads and tracks is maintained throughout the area and men and fire-fighting equipment are located at strategic centres. During the fire danger period, crews maintain constant radio contact with their headquarters and personnel are held on stand-by, ready for immediate call, on weekends and holidays. A network of 270 fire-protection dams on forested public land provides the water supply for fighting wildfire.

Fire protection in softwood plantations is assisted by the relatively intensive network of roads and tracks within plantation areas, by the maintenance of cleared fire-breaks, and by fuel-reduction burning in strategic native forest areas adjacent to the plantations. The substantial investment made in the establishment and maintenance of softwood plantations requires that a high priority be given to their protection from wildfires.

Biological Hazards

Although many insect pests and fungal diseases occur on public land in this area, only a few have been identified as being primary causes of damage to native vegetation or softwood plantations.

Insect pests

Native eucalypt forests and radiata pine plantations in the study area have not sustained permanent severe damage from insects during the past few decades, although various native insect pests inhabit them. The more important pests include the mottled cup moth, *Doratifera vulnerans*, which attacks eucalypt leaves. The indigenous moth *Lichenaula* sp. attacks radiata pine needles, while the introduced sirex wood wasp, *Sirex noctilio*, attacks pine stems and branches.

Outbreaks of the mottled cup moth during winter have caused widespread defoliation of peppermint--stringybark forests near Creswick. Affected trees have recovered in subsequent years. The outbreaks are normally only short-term and diminish when the larvae starve after consuming their food supply. This trend of outbreaks without lasting severe effects is likely to continue, provided fire damage in the summer following defoliation does not impair the vigour of the trees.

During the mid 1960s, following prolonged drought, the older larvae of *Lichenaula* sp. reduced the growth of killed or suppressed radiata pine in slow-growing 15- to 30-year-old plantations near Ballarat. The outbreak was successfully controlled during the late 1960s by felling and burning the infested and suppressed trees. No further outbreaks have occurred. This pest is

Damaged pine shoots caused by Lichenaula

unlikely to threaten pine plantations in the study area as the plantations are now healthy and vigorous.

Sirex wood wasp - which lays its eggs in pine trees that are suppressed or under stress - was detected in the study area in the late 1960s. Since that time detailed systematic surveys have been carried out by the Forests Commission in both private and State-owned plantations. Sirex has been located in softwood plantations around Creswick, Ballarat, and Mount Lonarch, and in farm windbreaks throughout the study area; however, no significant tree mortality has been detected. Control of sirex is effected by current management techniques, which involve the thinning of plantations to remove suppressed trees. Other control measures include the breeding and liberation of wasp and nematode species that parasitize the sirex larvae.

Fungal diseases

Two species of root rot fungi significantly affect native forests in the study area. Effects range from loss of vigour to 'dieback' of branches and may ultimately result in the death of the tree or shrub. Armillaria root rot attacks only the woody roots of trees; cinnamon fungus attacks the fine roots and infests the soil.

Armillaria root rot (*Armillaria luteobubalina*) is widespread in most native forests of the region and may cause decline or death of eucalypts such as messmate, manna gum, and Victorian blue gum as well as shrubs such as some species of *Acacia*. Some parts of the Wombat forest are affected, but the incidence of the disease is highest in the Mount Cole forest.

Moderate to severe dieback caused by *A. luteobubalina* affects about 1,200 ha (approximately 12%) of the Mount Cole forest. The severely affected areas occur in patches that range in size from 0.2 to 20 ha, with nearly all trees either dying or dead.

Management practices aim at controlling the disease by clear-felling severely to moderately affected areas to give a patchwork of coupes, which are regenerated with eucalypt species native to the area. Felling all the trees in a coupe is believed to reduce the food base available to the fungus. Infected stumps and roots, however, may provide a source of infection for up to 20 years. Consequently, research has been initiated to determine whether mechanical removal of stumps and roots from the soil during or soon after felling will satisfactorily control the disease. These methods have also been used on a small scale in normal forest operations.

Regrowth stands are also susceptible to the disease and, while current levels of mortality are not serious, there is potential for a serious loss of future timber production if the disease is not checked. Research on the disease and monitoring of its progress is undertaken by the Forests Commission in conjunction with the C.S.I.R.O. Division of Forest Research.

The cinnamon fungus (*Phytophthora cinnamomi*) is widely scattered in the region, but causes little damage to forests on public land in the study area, except on some infertile and poorly drained sites. These sites are characterised by species such as *Xanthorrhoea australis*, *Isopogon ceratophyllus*, *Hibbertia stricta*, and *Pultenaea pedunculata*, all of which are susceptible to the disease. At present, however, there is little evidence of damage to the associated overstorey trees.

Plant and Animal Pests

A number of plants and animals are proclaimed as noxious weeds and vermin resprectively under the *Vermin and Noxious Weeds Act*. In general, however, they are not widespread on public land and constitute localised problems only.

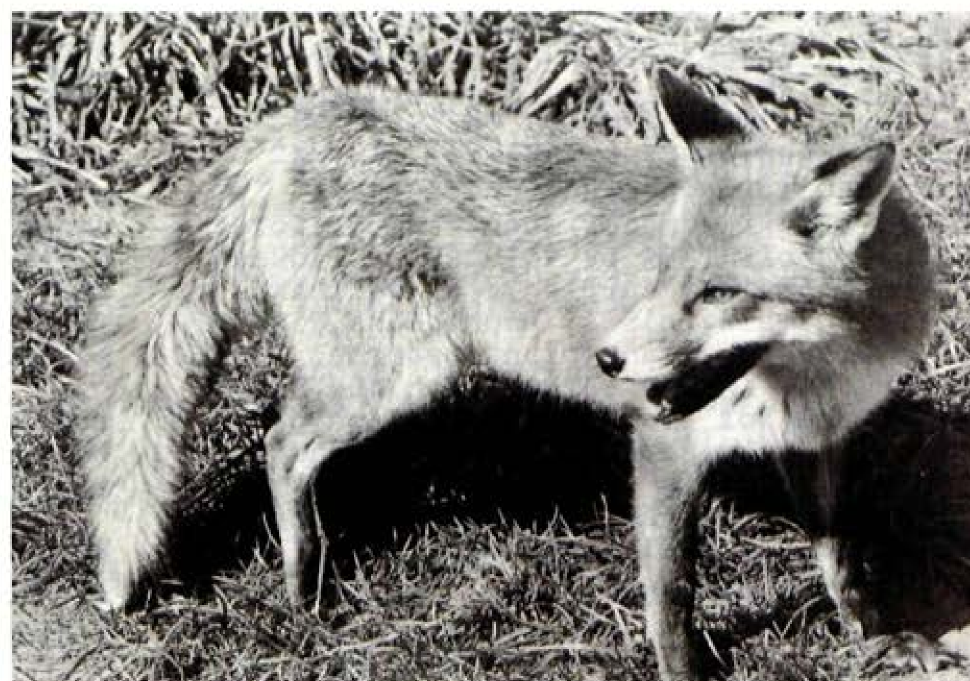
Animals proclaimed as vermin

Animal vermin, apart from birds, include rabbits, hares and foxes. Although not covered by the *Act*, feral cats have varying importance throughout the area, according to the effect of their predation on the smaller native mammals and birds.

Mice also breed up to plague proportions in some years and cause considerable damage to stored grain and fodder, particularly in the plains.

Rabbits - descendants of those that spread from the Winchelsea area in 1859 - show various levels of infestation. On agricultural land they compete with stock for pasture and cause damage to crops. Although present in relatively small numbers on land carrying a reasonable cover of native vegetation, rabbit populations rise to problem levels on recently cleared land. This is the case on areas cleared for pine plantations, where the combination of food (regenerating grasses and herbs) and cover in the form of windrows can lead to high local populations, with subsequent losses of planted seedlings.

On public land, the control of rabbits is carried out by the Vermin and Noxious Weeds Destruction Board using carrot bait poisoned with sodium monofluoro acetate (1080). Another technique involves fumigation and subsequent ripping of warrens. The establishment of the disease myxomatosis in wild rabbit populations in 1950 was a major breakthrough in biological control. This form of control is still used, and the rabbit flea, the vector in distribution of the



The fox - an introduced predator and opportunistic feeder - is declared vermin under the Vermin and Noxious Weeds Act myxoma virus, was released in areas of heavy infestation on the stony rises, on the southern slopes of the Divide, and around Beaufort and Ararat.

Hares are present on the plains portions of the study area and are comparatively rare compared with the heavy infestations present in the immediate post-war years. Organized shoots were responsible for this heavy reduction in numbers, and the hares' low reproductive rate and closer settlement have kept their numbers down.

Foxes (along with other introduced predators, the feral cat and wild dog), are opportunist feeders, as several studies have shown, and will generally eat or prey upon the most abundant form of food available at the time. Diet studies, carried out by the Keith Turnbull Research Station (a branch of the Department of Crown Lands and Survey) showed that the major food item of foxes is the rabbit (35% by volume), followed by sheep (mainly carrion), as well as native animals, birds, amphibians, insects, reptiles, and plant material. Of course this intake varies with the habitat of the fox - agricultural land or forest. Foxes were found not to carry hydatid tapeworms - a parasite that results in considerable loss of livestock production as well as being a threat to public health.

Control is carried out by shooting, poisoning with 1080, and secondary poisoning following the ingestion of rabbits poisoned by 1080. Bonuses are paid for fox scalps. The fox also provides considerable recreational value as a game animal, and winter pelts can realise quite high prices in the fur trade.

Birds

Sparrows and starlings are proclaimed as vermin because they can cause damage to crops and carry disease to poultry farms. They are of little importance on public land, and no official regulatory action is taken against them on either public or private land.

Damage by protected animals

Farmland adjacent to forested land is particularly susceptible to damage by kangaroos, which shelter in the forested land during the day and move out in the evenings and mornings to feed on crops and pastures. Kangaroos reduce productivity by direct competition with stock and by grazing or flattening crops. They also damage fences and allow stock to escape.

The Fisheries and Wildlife Division issues permits for culling native animals in problem areas.

Wallabies also shelter in bushland that adjoins farmland and can cause damage to pasture and fences. They also enter plantations and browse young plants, both eucalypts and pines. Eucalypt regeneration following logging at Mount Cole has been so heavily browsed in some isolated areas that ground application of 1080 has been a necessary part of the regeneration program. The aim of control measures is the short-term reduction of wallaby populations (black-tailed and red-necked wallaby) until the eucalypts are sufficiently advanced to resist browsing.

Noxious weeds

Noxious weeds proclaimed for the State of Victoria, excluding the metropolitan area, total 92; in addition, one weed, water hyacinth, has been proclaimed for the whole of the State. A survey carried out in 1970 indicates that 56 of these weeds occur in the Ballarat area; Table 20 lists them, together with their distribution on public and agricultural land. This indicates distribution but not density of infestation. A small number of the 56 species are endemic - for example *Acacia armata* and *Cassinia arcuata*. The remainder were introduced from overseas by various means, including impure seed, fodder, and packing, and as plant specimens, seeds, and cuttings.

Noxious weeds found in the study area are not established to any extent on sites that still maintain a reasonable cover of native vegetation. Most of them have established on areas that have suffered some soil disturbance, and this is particularly evident in old mining sites and on areas from which gravel has been extracted.

Three main problem weeds are discussed below. Other noxious species worthy of note that are found in the study area are cape broom, English broom, hawthorn (occurring mainly on red volcanic soils, such as those to the east of Ballarat), and boneseed (which grows, for example, at Nerrina and Dereel).

Furze is the most significant pest plant found in the study area, and is common on disturbed land and old mining areas. In areas where native vegetation is sparse, furze may grow in dense thickets up to 3 m tall and can be impenetrable because of its dense growth and prickly stems and foliage. As well as restricting access and suppressing native vegetation, it provides a harbour for vermin and can be a considerable fire hazard. This perennial shrub is permitted in existing hedges not exceeding 2 m in height and 1 m in width. It reproduces prolifically from seed.

Blackberry, a perennial with trailing prickly stems up to 6 m long, is present in the higher-rainfall portions of the area. It mainly occurs along streams, roadsides, and fencelines, and its prickly growth resists access to some areas of public land. Although blackberry is not considered a major problem species, it is distributed throughout the study area on moist sheltered sites.

Table 20

DISTRIBUTION OF NOXIOUS WEEDS

Botanical name	Common name	Distribution on public land (1)	Distribution on agricultural land (2)
Acacia armata	prickly acacia	29	Unknown
Ailanthus altissima	tree of heaven	-	10
Allium vineale	wild garlic	-	4
Amsinckia sp.	amsinckia	-	12
Asphodelus fistulosus	onion weed	-	1
Calycotome spinosa	spiny broom	-	13
Cardaria draba	hoary cress	-	20
Carduus tenuiflorus	slender thistle	19	104
Carthamus lanatus	saffron thistle	-	29
Cassinia arcuata	Chinese scrub	5	9
Centaurea calcitrapa	star thistle	-	10
Centaurea repens	hardhead thistle	-	2
Chondrilla juncea	skeleton-weed	-	3
Chrysanthemoides monilifera	boneseed	-	5
Chrysanthemum leucanthemum	ox-eye daisy	-	2
Cirsium arvense	Californian thistle	-	6
Cirsium vulgare	spear thistle	27	102
Conium maculatum	hemlock	-	33
Crataegus monogyna	hawthorn	2	37
Cynara cardunculus	artichoke thistle	-	1
Cyperus rotundus	nutgrass	-	4
Cytisus scoparius	English broom	2	45
Datura stramonium	thorn apple	-	11
Diplotaxis tenuifolia	sandrocket	-	Unknown
Dipsacus fullonum	wild teasel	-	7
Echium plantagineum	Patterson's curse	-	45

Table 20 (continued)

Foeniculum vulgare	fennel	-	17
Genista linifolia	flax-leaf broom	-	5
Genista monspessulana	cape broom	-	58
Homeria breyniana	cape tulip	-	15
Homeria miniata	cape tulip	-	5
Hypericum androsaemum	tutsan	-	3
Hypericum perforatum	St John's wort	1	16
Inula graveolens	stinkwort	-	27
Juncus acutus	spiny rush	-	43
Lavandula stoechas	topped lavender	-	1
Lycium ferocissimum	boxthorn	4	54
Marrubium vulgare	horehound	2	65
Onopordum illyricum	Illyrian thistle	-	3
Opuntia stricta	erect prickly pear	-	1
Oxalis pes-caprae	soursob	3	12
Physalis viscosa	prairie ground cherry	-	1
Proboscidea louisianica	devil's claw	-	1
Reseda luteola	wild mignonette	-	18
Rosa rubiginosa	sweet briar	12	85
Rubus fruticosus	blackberry	11	64
Rubus laciniatus	Italian blackberry	3	16
Salpichroa origanifolia	pampas lily of the valley	-	6
Scolymus hispanicus	golden thistle	-	6
Senecio jacobaea	ragwort	-	1
Silybum marianum	variegated thistle	3	96
Tribulus terrestris	caltrop	-	7
Ulex europaeus	furze	10	94
Verbascum thapsus	great mullein	-	20
Watsonia bulbillifera	wild watsonia	-	17
Xanthium spinosum	Bathurst burr	-	21

(1) Numbers refer to the number of occurrences on 44 discrete sites investigated during the botanical survey of public land in the Ballarat area.

(2) Numbers refer to presence by parish. The study area contains 107 parishes altogether.

It reaches its optimum development in particularly favourable conditions in isolated locations in the Mount Cole forest.

Sweet briar, an erect perennial commonly 2 m high with prickly stems, mainly grows on roadsides and stream frontages. Like blackberry, its seeds are spread mainly by birds eating the fruits.

Control of noxious weeds

Three main methods - chemical, mechanical, and biological - are used to control noxious weeds. Mechanical means include grazing, slashing, ploughing, and pasture improvement and are effective for small areas. Research in Europe into the biological control of blackberry has discovered two agents that

Team from the Department of Crown Lands and Survey spraying a heavy infestation of artichoke thistle show promise. These are the rust fungus *Phraginidium violaceum*, which causes premature defoliation in summer, and the stem borer *Hartigia* sp., the larvae of which cause total collapse of the stems. Research into the biology and specificity of these agents has to be carried out before they can be introduced into Australia.

The herbicides most frequently used are 2,4-D, 2,4,5-T, and picloram. Care in storage and handling of these chemicals is most important. Legal procedures relating to the disposal of unwanted or surplus are designed to minimize pollution and other adverse effects.

The herbicides 2,4-D and 2,4,5-T have been subject to much controversy in Victoria in the past 2 years, following the reporting of birth defects among newborn babies at Yarram and a suggested link with these chemicals. A Consultative Council appointed by the Minister of Health investigated this claim and concluded that the use of these herbicides could not be linked with the birth defects. Three countries have banned the use of 2,4,5-T - Holland, Italy, and more recently Sweden - and in Victoria, no sprayings by government departments are carried out in urban areas.

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NATURE CONSERVATION

Conservation is concerned with Man's relation to his environment. The need for conservation of economic resources is obvious because Man depends on these for many of the necessities of modern life. These aspects of conservation are considered in subsequent chapters under such headings as timber production, water use, and minerals and extractive industries.

This chapter deals with nature conservation (such aspects as native species, natural features, and landscapes of an area), and the conservation of archaeological and historic features. Conservation of these attributes is important for a number of land uses, including reference, conservation of species, recreation, and education. Often these conservation needs are compatible with each other or with commercially productive uses.

Uses of Conservation Areas

Reference

The solution to problems arising from our use of a particular land type is often helped by reference to an undisturbed example of the land type. Here the soils, vegetation, and fauna, and the processes linking them, can be studied under natural conditions. Knowledge of the basic relations operating within a land type is important when studying problems such as soil instability or falling productivity.

Reference areas, therefore, act as standards against which the progress and effect of human alteration and utilization of the land can be measured. They also provide a valuable gene pool of plant and animal species. Such genetic material is already being used, and will be increasingly used, to endow species with advantageous characteristics.

Reference areas must be carefully chosen and managed to permit natural processes to continue without disturbance. In common with standards used in other fields, they should not be tampered with; that is, access should be restricted, experimental manipulation should not be permitted, and they should be protected by a buffer zone.

Although all land types need to be represented in reference areas, the need is most urgent in those that have been extensively developed for uses such as agriculture. Few, if any, areas suitable for reference remain for some land types in the study area, such as those on the basalt plains. Conscious effort must be made to retain reference areas in suitable remnants to represent all land types.

Conservation of species

Each species of plant and animal makes a unique contribution to the richness and diversity of the environment. Each is an essential part of Man's natural heritage and, to many people, there is a moral responsibility to ensure that none of them should knowingly be lost or endangered.

Chemists, geneticists, physiologists, and scientists in many other fields place a special value on each individual species for its potential to provide the means of solving a research problem, or because it may be used in future as the stock for breeding essential plants or animals.

Conservation of the existing plant and animal species and associations in their natural habitats is therefore an important land use. The survival of some species may require certain precautions in an area because few individuals remain in existence. In other instances, particular species may be living in unusual habitats, or near the limits of their distributions, and it may be justifiable to devote the land expressly to their conservation.

Chapter 10 contains a list of significant and unusual plant species, and important fauna species are discussed in Chapter 11.

It is essential for the conservation of plants and animals to recognize the ecosystems they form (the inter-dependent complexes of soils, water, air, plants, and animals), and to conserve examples of each major one.

The range of different ecosystems in a region is reliably indicated by the vegetation. Plants express the various conditions of soil and climate, and they determine the types of food and shelter available for birds and animals. Conservation of a representative area of each distinct plant association or formation therefore ensures the protection of most of the different ecosystems of a region, and also most of the individual species.

Special natural values

Particular areas of land are often needed to preserve significant natural values such as distinctive geological features. A report, soon to be published, on the geological features of the National Estate has set out to record the known geological features of Victoria, and has made a selection of those that are most suitable for conservation. Many of these have scientific values, while others are valuable for education. Most of the more accessible and spectacular features also attract tourists.

Unlike historical or archaeological features, geological features have no legislation in Victoria designed specifically to protect them. It is therefore important that these features be satisfactorily preserved in suitable reserves.

Archaeological and historical features

As stated in Chapter 4, the study area contains a number of Aboriginal relics, mostly on private land. Although many of these sites are culturally and scientifically important, none are proclaimed archaeological areas. Some of the more significant sites on public land may require special protection.

Buildings of structures on Crown land or on land vested in any Minister are not listed in the Register under the *Historic Buildings Act* 1974. The National Trust of Australia (Victoria), however, records or classifies all historical buildings, landscapes, areas, objects, and sites that members consider worthy of preservation.

Recreation

Most Australians live in the artificial environment of large cities and towns, and many find that their lives are enriched by renewed contact with the natural world. Chapter 15 discusses the requirements of natural surroundings for many forms of outdoor recreation. Bird-watching, nature study, hunting, and bushwalking all require conservation of the native plants and animals; picnicking and driving simply require a background of trees or shrubs in the recreation areas. These requirements can all be filled in the study area.

Due to the fragmented nature of the vegetated land, and the accessibility of most parts of this region, there are few areas, if any, that people would regard as having any characteristics of wilderness. Smaller areas, however, can still have value by providing some degree of solitude and contact with nature, and by reducing the pressures on places more suited for conservation of particular natural features or species.

Education

Education is another important use of land in a natural or near-natural condition. Forests, rivers, and other natural landscapes have many applications in education - from primary to post-graduate levels - giving students opportunities to see, interpret, collect and monitor natural land forms and processes. In some circumstances laboratory facilities and associated accommodation are needed so that successive groups can undertake long-term studies. This may require land to be specifically set aside for education.

Productive uses

Some productive and commercial uses of land are achieved by conserving the natural ecosystems in varying degrees. The commercial product is obtained by harvesting a proportion of the population of a species or group of species at a controlled rate that the ecosystem can sustain. Examples include the sustained yield of hardwood timber and conservation of wetlands to produce game birds.

The continued success of such uses depends on maintaining many of the natural features of the ecosystem. Land under such management can also be used for education, recreation, and scientific purposes, and it may form a protective buffer around small areas specifically devoted to nature conservation.

Viability of Areas

The viability and effectiveness of conservation areas depend on a number of factors, including the size of the area, type of community, ecosystem, or feature to be conserved, and the degree to which the area can be managed to control influences that tend to upset the natural balance.

Large consolidated reserves have less perimeter relative to their area than small or irregular ones, and so tend to be better-buffered against the effect of intrusive factors.

Small areas can nevertheless contribute to nature conservation or the preservation of particular features. They include narrow reserves along streams, roadsides, and railways, and those originally set aside as gravel, water, cemetery, school, and camping reserves. Where these small areas retain native vegetation, and are surrounded by cleared and developed land, they can make a major contribution to the regional character of the landscape.

Narrow strips of native vegetation are important for migratory and nomadic birds and as wildlife 'corridors' for small animals. These may be particularly important in the study area because the areas of natural landscape are so fragmented.

Careful management may enable small areas to remain viable. Management may take the form of using controlled fires to change vegetation, culling animal populations, practising silviculture, strictly controlling the number of visitors, fencing to exclude introduced animals, or eradicating introduced species.

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RECREATION

Recreation can be defined as any activity (or planned inactivity) undertaken for personal pleasure during a person's leisure time. This chapter is concerned with outdoor recreation, one aspect of which is the wide range of activities carried out on public land. Recreational use of public land and conservation of ecosystems are major reasons for the retention of natural areas.

Resources for outdoor recreation include both natural and Man-modified landscapes such as forested and cleared lands, water bodies, and air space. The recreation resource itself is a combination of physical and biological features and the ability and desire of Man to appreciate or use it. The attributes that comprise the resource are often the same as those for other forms of land use such as forestry, agriculture, grazing, and mining. In many cases the recreational and other land uses may be complementary, but occasionally they compete and certain conflicts must be resolved.

Influences on recreation

Mercer in 'Leisure and Recreation in Australia' discusses a number of factors affecting outdoor recreation behaviour at the family and individual level. An important one is discretionary or uncommitted income, which is often linked with occupational and educational level. Together with other variables such as age, sex, and cultural and socio-economic background, these factors determine people's recreational behaviour.

Place of residence and degree of mobility are important in determining locations and patterns of recreational activity. In any consideration of recreation in the Ballarat area, precepts applying to residents of the provincial cities and townships in the area differ from those applying to inhabitants of metropolitan Melbourne, for whom the Ballarat area is about the limit of a day return trip.

The attractions of the Sovereign Hill Gold Mining Township and the annual Begonia Festival, however, tend to draw large crowds from Melbourne. Annual attendance figures at Sovereign Hill over 4 years - namely, 1978, 400,000; 1977, 418,000; 1976, 413,000; and 1975, 429,000 attest to its popularity.

The hinterland extending away from Ballarat and the highways is visited to a

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much smaller extent by Melbourne residents on a day-long pleasure drive to the region.

In contrast, residents of the study area do not have to travel long distances to use the recreation resources of its public land. Most areas are well within the limits of a day trip and, in addition, many areas of forest and natural landscape have a low intensity of use. The extent to which local resources are used by local communities, compared with travellers from Melbourne, remains unknown, however. No organized tours include public land of the study area in their itinerary. Local schools probably use local recreation resources to a large extent in their outdoor recreation--education courses.

Recreation demand

It could be expected that even if the popularity of various outdoor recreation activities remained constant, demand for recreation resources (much of which will need to be provided on public land) would increase as populations and their discretionary income and leisure time increase.

Advertising and media coverage can also have a major effect in generating a demand for certain, and sometimes fashionable, recreational activities. For example, usage of the Mount Cole and Mount Langi Ghiran forests has risen following the publication of a book and feature articles on bushwalking. Also, local demand for further motorcycle tracks has been generated following the establishment of a trial track south of Ballarat.

An organization aiding dissemination of tourist information is the Central Highland Regional Tourist Authority, a partnership between State government, local government, and the private sector.

The size, distribution, and age structure of the population have an influence on demand. In the Ballarat sub-region (City of Ballaarat, Borough of Sebastopol, and the adjacent Shires of Ballarat, Buninyong, and Grenville - see Map 2), statistics show that population growth is much lower there than in the State as a whole (7.6% compared with 19.5%). The sub-region (total population 70,000) also has a considerably higher proportion of people considered as dependents (under 15 and over 65 years of age), primarily composed of older people. Thus the potential for population growth in the sub-region without substantial inflow is declining.

It would appear that the local population will not have a major influence on increasing recreation demand in the short-term future. With a shorter working week and improved road access to the region, it could be expected that most of the future demand for its recreation resources will be generated by residents of metropolitan Melbourne seeking opportunities for nature-based recreation lacking on the northern and western sides of Melbourne.

Recreational Resources

Urban

Cities and townships in the study area offer facilities for formal activities such as tennis, golf, bowls, and football, as well as parks and playgrounds for more passive recreation. These are user-oriented resources, which are located close to the home base to enable ready access and a high frequency of use.

The urban environment also includes many tourist-oriented facilities - such as caravan parks, historic parks, museums, galleries, and ornamental gardens.

The Ballarat urban area covers the former Ballarat gold-field, and contains many remnants in the form of monuments, the site of the Eureka Stockade, historic buildings and streetscapes, and old diggings. The Sovereign Hill Gold Mining Township is an important recreation of the early gold-mining times around Ballarat.

Agricultural

A large proportion of the study area consists of treeless plains used almost exclusively for agriculture. As a recreational resource this open land-

Amateur prospectors pan for gold at Sovereign Hill scape does not generally have high appeal. North of Ballarat and around Creswick, however, the agricultural zone contains volcanic cones and heaps of mine tailings, which are visually attractive and form an interesting landscape. Similarly, the broad expanse of plains is broken by water bodies such as Lakes Goldsmith and Burrumbeet and the maar lake at Stockyard Hill. These landscape resources are often the major feature of a day or afternoon of pleasure driving.

Natural vegetation

The larger areas comprising this zone contain a range of recreation resources: geological, floral, faunal, and aquatic. Such resource-based areas are used for activities ranging from wilderness experience to rock-climbing, bushwalking, and camping. Generally some degree of planning is necessary for participation in these activities and some time is involved in actually getting there.

Often these natural vegetation zones form the venue for extended trips such as a week-end or annual vacation. For example, the Mount Cole and Mount Langi Ghiran forests are popular with week-end hikers, horse-riders, and campers.

The forests surrounding Ballarat to the north and south are an important part of the landscape and residents of the city use them intensively on a day-to-day basis. Visitors from Melbourne and other areas also use them, but to a lesser extent. Activities include picnicking, nature study, pleasure driving, riding motorcycles and horses, orienteering, jogging, fossicking, shooting, and walking. The same resource is used for forestry, collection of firewood, water production, mining, and bee-keeping.

Softwood plantations

Where plantations are close to population centres, as occurs at Ballarat, they become important recreation resources. For example, in the pines south of Ballarat a motorcycle course and jogging track have been established. Orienteering, an organized sport involving map-reading skills and physical fitness, is carried out extensively in these softwood areas.

Other activities include pleasure driving and picnicking - pines provide an important landscape backdrop to the popular St Georges lake at Creswick, the north-eastern edge of Lake Burrumbeet, and the southern part of Lake Learmonth.

Inland waters

The resources include fresh and saline lakes within the agricultural zone, and rivers, streams, and storages within various zones. Some of the larger lakes accommodate active sports such as powerboating, sailing, and swimming, while on others the activity may be picnicking or observation of waterfowl. Many lakes and streams are stocked with fish (see Table 21) and also provide maturation grounds for eels. On the larger lakes, camping grounds are established to take advantage of water-based recreational activities.

Recreational Activities

Bushwalking

Walkers can be divided into those groups preferring overnight camp-outs and those preferring short walks that have inter-

Table 21

ANGLING AREAS

Catchment	Site	Angling species	Comments
Loddon	Government Dam (Creswick)	rainbow trout brown trout tench	stocked occasionally
	Dean Reservoir	brown trout rainbow trout	stocked regularly bank fishing only (domestic supply)
	Newlyn Reservoir	brown trout redfin	stocked regularly bank fishing only (domestic supply)
	Hepburn Lagoon	rainbow trout brown trout redfin tench crucian carp	stocked regularly bank fishing only (domestic supply)
	Lake Learmonth	redfin eel tench brown trout rainbow trout	not stocked regularly

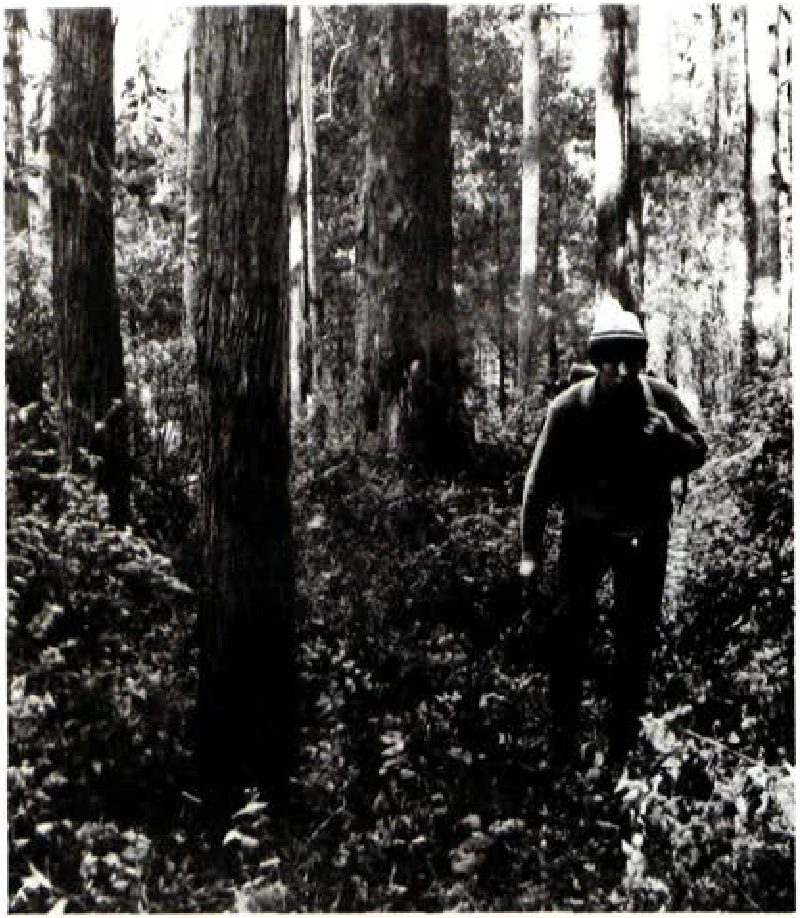
Table 21 (continued)

Catchment	Site	Angling species	Comments
Loddon	Talbot Reservoir	redfin brown trout rainbow trout	stocked regularly
Wimmera River	downstream Elmhurst	redfin tench	
Barwon River	Ballarat Water Commissioners storages	tench redfin carp eel	domestic supply: permits issued only to persons residing within 32 km of Ballarat P.O.
	Lake Wendouree	brown trout rainbow trout redfin tench carp	stocked regularly with trout
Corangamite	Woady Yaloak River (Cape Clear to Cressy)	brown trout eel redfin tench blackfish	stocked regularly with brown trout
Hopkins River	Beaufort Lake	brown trout rainbow trout	stocked occasionally
	Lake Bolac	redfin eel tench brown trout European carp	stocked regularly with brown trout

Table 21 (continued)

Catchment	Site	Angling species	Comments
Hopkins River	Lake Burrumbeet	redfin rainbow trout eel tench carp	stocked with rainbow trout
	Burrumbeet Creek	eel redfin tench	
	Dawsons Dam (Snake Valley)	brown trout redfin tench eel carp	stocked occasionally with brown trout
	Fiery Creek (Streatham)	rainbow trout redfin eel	
	Hopkins River (South of Ararat)	redfin eel tench brown trout	
	Mount Emu Creek (Skipton area)	brown trout	

Source: Tunbridge, B.R., and Rogan, P.L. 'A Guide to the Inland Angling Waters of Victoria.' 2nd ed. (Fisheries & Wildlife Division, Victoria: Melbourne 1977.)



Bushwalker in forest of messmate stringybark in the Mount Cole forest

pretive services provided. For walks involving overnight camping, the Mount Cole and Langi Ghiran blocks are the most popular areas.

At Langi Ghiran, bushwalkers tend to climb Mount Gorrin from the western side and then proceed, via the lagoon and saddle, to Mount Langi Ghiran. Within Mount Cole State Forest, a popular walk begins at the Ferntree waterfalls, climbs onto the plateau - visiting Mount Buangor, Mugwamp, and the Victoria Mill site and continues to either Ben Nevis or Mount Cole.

Signposted walking tracks are popular with day travellers and family groups. Examples are walks to the Ferntree waterfalls, Cave Hill, Victoria Mill picnic ground (Mount Cole Forest), old gold-mining sites around Slaty Creek, Koala Park (Creswick area), Berringa area, and the Lal Lal falls.

Shooting and hunting

Organized gun clubs operate shooting ranges at Ballarat and Beaufort. The Canadian Rifle Range, partly located in Canadian forest south of Ballarat, is operated at week-ends by rifle clubs and throughout the year by local military and cadet units. Beaufort Rifle Range is on Commonwealth land south-west of the township. Organized clay-pigeon shooting occurs on public land south of Sago Hill.

All locations are shown on Map 10.

Shooting of game takes place on a seasonal basis on game reserves (public land reserves) administered by the Fisheries and Wildlife Division and on private lakes, swamps, and farmland.

The season for wild duck is generally declared between late March and the end of May. Popular hunting grounds on public land are Lake Goldsmith (State Game Reserve), Lake Wongan, Black Lake, Lake Burrumbeet, and Flax Mill Swamp. Most swamps and lakes on private land would also be shot over.

Most of the grasslands of the basalt plains are used for hunting quail; the season extends from early May to the end of June.

Small numbers of red deer occur in the forests around Linton and Little Hard Hills and are hunted each year during the one-month open season. Sambar deer are protected on public lands surrounding Mounts Cole and Langi Ghiran, but some shooting takes place on private property adjacent to these areas.

Camping

Dispersed camping is permitted throughout the public land as long as precaut-

Duck-hunting at Lake Burrumbeet

ions relating to fire and waste disposal are met. Selection of a camp-site is left up to individual preference.

Sites, suitable for tent camping, that have minimum facilities such as toilets and fireplaces are shown on Map 10, Outdoor Recreation. Many of these are located in the Mount Cole forest. The Middle Creek and Ditchfields camp sites, both maintained by the Forests Commission, are becoming increasingly popular with school groups and scouts as well as family campers.

A number of organized camps, suitable for groups of people, occur in the study area. These usually have accommodation, catering, and toilet facilities for large numbers of people. They are variously administered by the Education Department, church groups, and youth organizations, and conduct recreational activities and environmental awareness programs. Many occupy leased public land. Table 22 lists these camps.

Camps run by the Education Department occupy the sites (and sometimes buildings) of old schools.

Camping grounds on public land that are managed by local committees, and commercial camping parks, are not specifically marked on the map. Commercial caravan parks provide approximately 1,000 sites in the study area, however, and a further 1,000 sites within 20 km of it. In addition, 25 motels and many hotels in the study area provide holiday accommodation.

Recreation driving

For many people, driving to an area is part of the recreational experience, while for others it simply provides access to areas where they will carry out some other activity. Pleasure drivers, the former category, look for diversity in scenery and natural history. Popular features visited include Lal Lal falls and the blast furnace, look-outs on Mounts Bute and Buninyong and Ben Major, and sites of early gold-mining ventures.

Pleasure driving is usually associated with picnicking, and there are a large number of suitable sites on public land. Those with picnic tables and fireplaces are marked on Map 10.

Car clubs use the Mount Cole--Ben Major forest roads up to six times a year for competitive car rallies and trials. The events are supervised by a co-ordinating body, and conflicts with other users are minimal. Social club car rallies occur at week-ends, often terminating at picnic grounds.

While most recreational driving is in conventional cars, many people own four-wheel-drive vehicles. Four-wheel-drive touring involves the use of minor forest roads, which in many cases can only be negotiated by this type of vehicle, and

Table 22

ORGANIZED CAMPS IN THE BALLARAT AREA

Camp	Location of nearest town	Private land	Public land
Adekate Fellowship Centre (United Churches of Ballarat and District)	Dean	X	
Eastern Hill Camp	Creswick		X
Allendale Camp (Education Department)	Creswick		X
Pax Hill (Scout Association, Ballarat area)	Ballarat East		X
'Linbogol' (Girl Guides Association)	North Creswick		X
Church of England Boys Club	Snake Valley		X
Broomfield (Education Department)	Broomfield		X
Glendaruel (Education Department)	Glendaruel		X
Illabarook (Education Department)	Rokewood		X

Sources: Education Department
National Fitness Council of Victoria
Department of Youth Sport and Recreation
'Directory of Youth and Family Camps in Victoria.' Melbourne 1975.

Picnicking facilities in a picturesque setting. This shows a portion of a small highway park beside the Hopkins River at Dobie may involve road repair and clearing of fallen trees. The activity is most popular in the Mount Cole forest, which contains a network of suitable roads. At present, use is low and track erosion is minimal.

Car trials are occasionally conducted using logging tracks and fire tracks in the Scarsdale and Enfield forests.

One of the clubs, at Ballarat, uses clay quarries near Creswick for adventure driving. This activity calls upon the full capacity of the vehicle and skill of the driver. Erosion is confined to the already highly altered quarrying area.

Trail-bike riding is extremely popular. This form of recreational riding may present certain problems to the land manager in terms of road damage and off-road activities, as well as those of unlicensed riders and unregistered vehicles. Under the *Land Conservation (Vehicle Control) Act* 1973, no vehicle (four-wheeled or two-wheeled) may leave a formed road, except with permission.

To cater for local demand, the Forests Commission at Ballarat has constructed a motor-cycle course in a pine plantation just south of the city. The course winds between large pines and over the mullock heaps and sluicing scars of a former mining area. This trial 'free access' area is immensely popular with young people living at Ballarat. Sound tests have shown that noise generated by normally muffled bikes is likely to be inaudible in adjacent residential areas. Without effective policing of the area, however, it may be difficult to ensure that bikes used here are properly muffled.

Orienteering

The popular sport of orienteering is well catered for by the large resources of public land close to population centres. For example, orienteers living in Ballarat, Bendigo, and Melbourne use Canadian forest, the White Horse Ranges, and Nerrina and Creswick forests. At Beaufort, the forest south of the highway is a popular orienteering area.

Joggers and cross-country runners also take advantage of the proximity of the forest to their homes. A jogging track with exercise bays and picnic areas has been constructed in the pine forest adjacent to the Golden Gate mining dam, south of Ballarat.

Water-based activities

The three largest lakes - Bolac, Burrumbeet, and Learmonth - are reserved for recreational purposes. Power-boating and water-skiing take place on these lakes in areas zoned to avoid conflict with sail-boats, canoeists, and swimmers. The lakes also form a focal point for picnics, camping, fishing, sightseeing, and nature observation. The

Angler's catch of redfin at Lake Burrumbeet

basalt cliffs (up to 10 metres high) and tuff in the north-western side of Burrumbeet are interesting geological features visited by sightseers.

Angling for eel and fish takes place in many lakes, storages, and watercourses. Table 21 shows the location of many areas as well as the popular angling species.

Nature study

While many people would visit public land specifically for nature study purposes, a far greater number incorporate nature study into other activities such as bushwalking, picnicking, camping, and recreation driving.

Popular bird-watching areas include Winter Swamp, Lake Goldsmith, and most areas of bushland close to population centres. Koalas may be seen throughout the public land and at Koala Park, an area of bushland at Creswick managed specifically for this marsupial.

Visits to wildflower features such as the orchid displays near Berringa and the holly-leaf grevillea at the Glut area, Mount Cole, are favourite activities.

Geological features associated with Recent volcanic activity - such as the basalt columns at Lal Lal Falls, the 'devils kitchen' at Piggoreet, and the numerous scoria cones (for example,

Trailer sailer at Lake Learmonth

Mount Warrenheip) - are of great interest to those who have some knowledge of these phenomena.

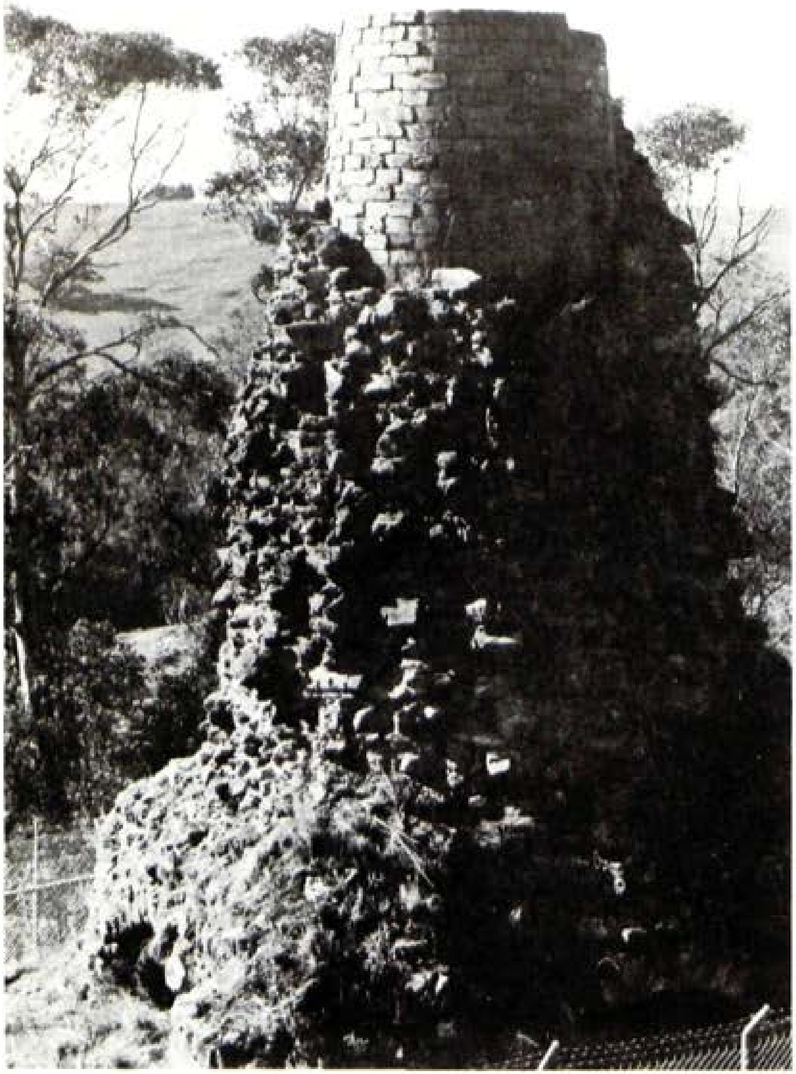
Fossicking and gem-collecting

A renewed interest in fossicking has developed in the past few years. This is related to an enormous increase in gold prices, and the availability of portable metal detectors. The Department of Minerals and Energy and various agents, for example, issued 5,000 Miners Rights in 1979 compared with 2,000 in 1978. This sort of activity has drawbacks, as indiscriminate use may well damage the integrity of historically significant areas.

Fossicking on a small scale using traditional techniques is practised by enthusiasts. Another popular activity is collecting gemstones and minerals.

Horse-riding

Many week-end riders make use of tracks in forested public land for horse-



Ruins of the blast furnace at Lal Lal - classified 'A; to be preserved at all costs', by the National Trust of Australia

riding. Organized trail rides, which include overnight camping are conducted through the Wombat forest, beginning at Creswick.

Historical study

A number of aspects of Australian history are strongly in evidence, attracting those with a major interest in the conservation of historical sites as well as others with a peripheral interest such as photography, fossicking, or picnicking.

Remnants of the gold-mining days can be seen in the large mullock heaps that dot the agricultural plains around Ballarat and Creswick, and in the sluiced areas, dams, and remnants of machinery found within the public land. Moreover, many monuments identify the site of important gold-fields, settlements, or events.

The remnants of iron-mining and smelting can be seen at Lal Lal.

Relics of the pastoral era include large homesteads such as 'Ercildoun' and 'Carngham', dating back to the 1840s. Cities and townships throughout the study area contain historical buildings, many of which are classified by the National Trust.

Water storage dams in the Mount Buangor and Mount Langi Ghiran areas provide the basis for historical interpretation of a service network.

The historical aspects of transport are exemplified by the railway station and water tank at Lal Lal and the Cobb and Co. changing station at Buangor.

Complementary to these *in situ* historical sites is the re-created gold-mining township of Sovereign Hill. This is a successful tourist project, run as a non-profit company and part-funded by the Victorian government. Operating profit, which is used to finance capital expansion, was $268,000 in the 1976/77 financial year.

Kryal Castle - a re-created mediaeval castle - attracts on average some 300,000 visitors annually and contributes an estimated $2 million to the local economy through wages and necessary supplies.

Recreation Studies

A bulletin published by the Department of State Development and Tourism summarizes the results of domestic travel involving at least one night away from home and involving a journey of at least 40 km. The survey is based on interviews of 68,000 people throughout Australia during the period April 1978--May 1979.

In the Central Highlands Region, which covers the study area and includes the Grampians, Avoca, and Bacchus Marsh, 60% of travellers originated from Melbourne and 26% from Victorian country areas. Occupations of travellers were tabulated as follows:

White collar worker	40.1%
Semi-skilled worker	18.5%
Skilled worker	18.1%
Farm owner	6.9%
Businessman	5.4%
Professional	4.4%
Small-businessman	2.5%
Other	

With regard to stage in life cycle, 37% were single and under 35 and 30% were couples older than 25 with children.

In January 1979, a visitor study of 485 people was conducted at the Sovereign Hill Gold Mining Township and Gold Museum at Ballarat, by the Department of State Development, Decentralization and Tourism. Respondents listed the following places of residence:

Melbourne	36%
Ballarat	6%
Rest of Victoria	11%
Other States	49%
Overseas	8%

More than half the sample lived in Victoria. Of those respondents who lived in Melbourne, two-thirds came from the eastern suburbs, despite the fact that Ballarat is more easily accessible from the northern and western suburbs. More than half the respondents were visiting the attractions while on a holiday (the survey was conducted during the Christmas holidays), and a further one-third were on a day trip from home. Most (93% of respondents) had come in private vehicles.

Occupancy rates

Occupancy rate of hotels, motels, and guest houses in the Ballarat urban area is maintained at a consistently high level. Figures from the Australian Bureau of Statistics show an average room-occupancy rate of 75.2% for 1978/79 (giving Ballarat the highest ranking for occupancy in the State). (The Victorian average is 58.9%.)

Major Conservation Reserves

At present, the Forests Commission is the only authority managing large areas on public land for active and passive recreation. Table 23 describes the various areas set aside under the *Forests Act* 1958.

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Table 23

RESERVES MANAGED BY THE FORESTS COMMISSION (UNDER SECTION 50 OF THE FORESTS ACT 1958)

Reserve	area (ha)	Description
St Georges Lake Scenic Reserve	23	Near Creswick township: formerly a mining dam now used for fishing, boating, and picnicking
Creswick Koala Park	9	Near Creswick township: sanctuary for koalas, with walking trails and adjacent picnicking area

Table 23 (continued)

Reserve	area (ha)	Description
Enfield Forest Park (includes Berringa Flora and Fauna Reserve and Mount Misery Gardens)	5,342	South of Ballarat in the head-waters of Mount Misery Creek: evidence of former mining activities associated with the Mount Misery and Berringa gold-fields, with walking trails and picnic and camping areas; three orienteering maps have been prepared for the area
Lal Lal Blast Furnace	30	Adjacent to the Lal Lal Reservoir: site of Victoria's only venture into mining of iron ore and production of pig iron; walking track to blast furnace working area; associated picnicking facilities
Mount Buangor Forest Park and Ferntree Waterfalls Scenic Reserve	2,098	North-west of Beaufort: forested southern fall of the Mount Cole plateau with waterfalls, rock formations, picnic and camping grounds, and walking tracks; includes Mount Buangor 1,090 m, and Ferntree waterfalls.
Victorian Mill Scenic Reserve	33	Within the Mount Cole forest; area adjacent to old mill site containing fine stand of messmate stringybark; picnic facilities
The Glut roadside reserve	12	Within Mount Cole forest; walking track through areas containing wildflowers, including an unnamed grevillea; picnic facilities
Langi Ghiran Forest Park	1,854	Adjacent to Northern Highway between Ararat and Beaufort: basically unroaded area encompassing the rugged Mounts Langi Ghiran and Gorrin; Aboriginal cave art; floral affinity to Grampian Ranges; walking tracks and picnic facilities

Ferntree waterfalls are a popular feature of Buangor Forest Park

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HARDWOOD PRODUCTION

Prior to European settlement, the midlands region of the study area carried either forest or woodland and the basalt plains supported savannah woodland and grassland. Since that time, about 90% of the land has been alienated, most of which has been developed for agriculture and settlement.

The forests generally have a history of heavy and uncontrolled cutting during the latter half of the 19th Century, when timber was essential for building, mining, and as a supply of fuel. Control of forest harvesting came with the *Forests Acts* of 1907 and 1918. Subsequent forest management has improved the condition and productivity of the remaining forests. The Victorian School of Forestry, established at Creswick in 1910, has played an important role in training foresters in the management of forests and continues to do so.

Today eucalypt forests cover about 80% of the remaining vegetated land in the study area. These forests generally have a moderate to low capacity for the production of hardwood timber, being constrained by low rainfall and impoverished soils. The most productive areas occur in the north-west on the Mount Cole plateau and in the north-east around Barkstead, where the forested public land comprises portion of the Wombat forest.

Productivity of Forest Types

Table 24 broadly categorizes forests in terms of their productivity.

Category A - high productivity

Mature stands in this category have heights in excess of 40 m and are restricted to an area of about 640 ha on the Mount Cole plateau. The predominant species are messmate stringybark, manna gum, and blue gum.

These forests provide sawn timber that is used for house-framing and a wide range of general construction purposes. Regeneration following harvesting is generally achieved by seeding onto ashbeds prepared by burning the logging debris.

Harvesting methods have been modified in recent years because of dieback caused by the root rot fungus *Armillaria* sp. All trees on a felling coupe are now removed, in contrast to the previous prac-

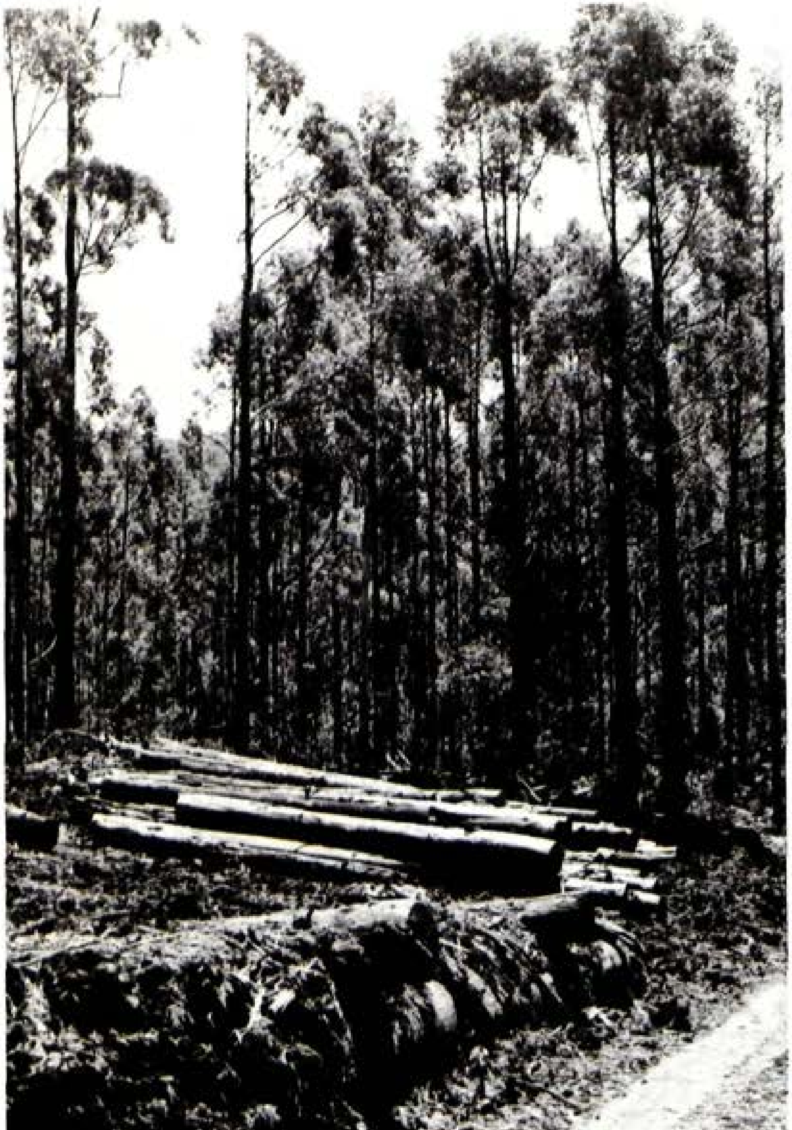
Table 24

HARDWOOD TIMBER PRODUCTION

Category	Structural form and map unit[1]	Main timber species	Productivity MAI[2] - cu.m per ha per annum
A - high productivity	Open forest IV 2a	messmate stringy-bark, manna gum, blue gum	estimated about 7--8; potential about 10--12; suitable for saw-logs and pulpwood
B - moderate productivity	Open forest III 2b, 2c	messmate stringy-bark, manna gum, candlebark, narrow-leaf peppermint, blue gum	estimated about 3--4; potential about 5; suitable for sawlogs and pulpwood
C - low productivity	Open forest II 2d, 2e, 2f, 3a, 3b, 4a, 4b, 4c, 4d, 4e, 5a, 5b, 5c, 5d, 6a	messmate stringy-bark, brown stringy-bark, candlebark, narrow-leaf pepper-mint	estimated about 1--3; potential about 3--5; suitable for sawlogs, pulpwood, and minor products
D - very low productivity	Open forest I and woodland I and II 3c, 5e, 5f, 5g, 5h, 5i, 5j, 6b, 6c, 6d	broad-leaf pepper-mint, red stringy-bark, scent-bark, long-leaf box, red box, yellow gum, river red gum, yellow box	very low; suitable for minor products only

[1]Refers to Map 9, Vegetation

[2]MAI (Mean Annual Increment) = total volume production to 10 cm small-end diameter under bark, divided by the age of the stand in years.



Log dump and loading ramp in moderate-productivity messmate stringybark forest at Mount Cole

tice of selecting individual or small groups of trees for felling. Regeneration techniques have also been modified. The extent of the disease is monitored and active research on fungal control is proceeding. Chapter 13 gives further information on the rootrot problem.

Category B - moderate productivity

The mature stands have heights in the range 28--40 m and occupy approximately 9,000 ha in high-rainfall areas along the Great Dividing Range. Messmate stringybark, candlebark, narrow-leaf peppermint, manna gum, and blue gum are the predominant species.

These forests are important timber-production areas. Harvesting and regeneration of stands in the Mount Cole area are carried out as for Category A stands. In the Wombat forest, stands are harvested under a partial-cut system that utilizes only portion of the stand. Regeneration is obtained by burning the logging debris and relying on natural seed-fall from the retained overstorey. At a certain stage of development of the regenerating crop the remaining overstorey is removed.

In the Ballarat--Creswick area, where stands adjoin the White Swan Reservoir, harvesting is by means of selection thinning - that is, only the poorer of the merchantable trees are selected for cutting. Seedfall from adjacent trees and the heads of logged trees provide satisfactory regeneration in the small gaps created in the stand.

Stands in this category produce both sawlogs and pulpwood. The sawlogs provide timber for house-framing and general construction, while the pulpwood is used for hardboard manufacture.

Category C - low productivity

These stands have mature heights of 15--28 m. They occupy 35,000 ha of public land in the study area, with messmate stringybark, brown stringybark, candlebark, and narrow-leaf peppermint as the predominant species.

The forests are generally found in areas receiving less rainfall than those supporting Category B stands. Both stand types are similar with respect to species composition of overstorey and understorey, but Category C stands have slower growth rates. They occur as foothill forests, predominantly on Palaeozoic sediments, both north and south of the Great Dividing Range.

Harvesting in such forests concentrates on the removal of the poorer trees and, because the residual crop occupies the site, regeneration treatment is seldom needed.

Stands in this category are presently utilized for sawlogs and, to a lesser extent, for pulpwood. The sawlogs provide timber for house-framing and gen-

Completion of partial-cut logging in the Wombat forest

Selection logging of messmate stringybark and candlebark stands adjoining White Swan Reservoir

eral construction, while the pulpwood is used in hardboard manufacture.

Category D - very low productivity

Stands in this category have top heights of less than 15 m. Broad-leaf peppermint, red stringybark, scent-bark, red box, long-leaf box, and red ironbark are the predominant species. The forests are generally unproductive for sawlogs, but do supply minor timber produce such as fence posts and firewood. The study area contains 6,100 ha of forest in this category, mainly in areas of lower rainfall and on exposed rocky slopes.

Present Supply Situation

Sawlogs

The Forests Commission is responsible for allocating sawlog supplies from

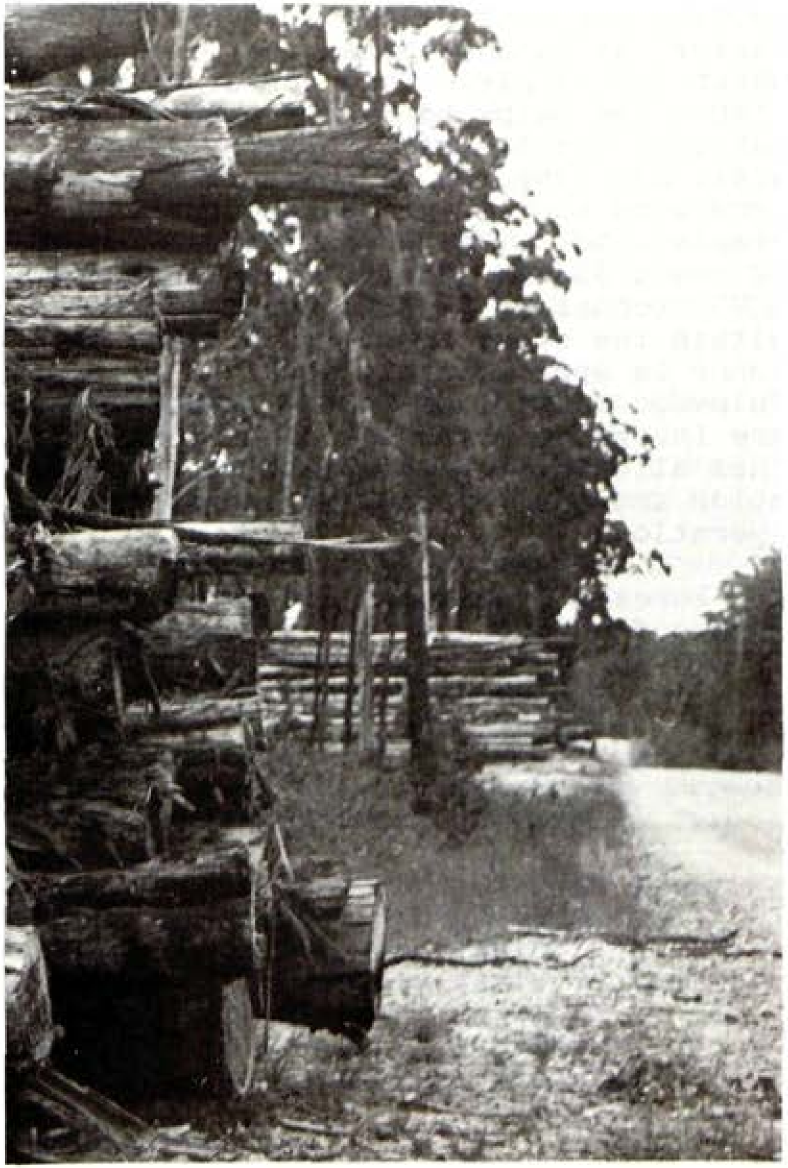
State forest. Hardwood forests in the Ballarat area have been carefully managed for a long period to match the volume of logs supplied to sawmills with the estimated volume that can be made available on a sustained-yield basis. It is expected that sawlog supplies can be sustained at a level of about 20,000 cu. m per year. This level closely approximates the present cutting rate.

In 1977/78, 21,600 cu.m of hardwood sawlogs were cut from public land in the study area, mostly from Beaufort and Daylesford Forest Districts. This represented about 2% of the Victorian output of hardwood sawlogs from State forest in that year. The logs were supplied to three mills at Ballarat, two at Daylesford, two at Beaufort, and one mill each at Enfield, Stawell, Ararat, Chute, Newlyn, Barkstead, Bullarto, and Korweinguboora.

Nine of these 15 sawmills are located within the study area and employ the equivalent of about 74 people full time, including bush operators and transport drivers. The sawn timber produced is used mainly within the study area. The six sawmills located outside the study area but supplied in part with logs from forests within the area employ the equivalent of about 66 people full time.

Pulpwood

An area of 3,600 ha within the study area, comprising part of the Wombat



Pulp-log dumps stockpiled beside road in the Wombat forest

forest, supplies pulpwood to a hardboard factory at Bacchus Marsh that employs about 223 people. This forest falls within the pulpwood supply area designated by the *Forests (Pulpwood Agreement) Act* 1959, which guarantees long-term wood supplies to Hardboards (Australia) Ltd. The current annual intake is about 50,000 tonnes, of which about 3,750 tonnes or 7.5% is supplied from within the study area. (Note that 1 tonne is approximately equal to 1 cu.m.) Pulpwood operations in the Wombat forest are integrated with sawlog harvesting, thus allowing more complete wood utilization and facilitating regeneration operations.

The Forests Commission estimated that hardwood pulpwood supplies could be maintained at a level of about 30,000 cu.m per year.

Other wood products

With the development of pressure impregnation treatments for applying preservatives to wood of low natural durability, a substantial demand for transmission poles developed in the 1950s and 1960s. The demand for poles has declined in recent years, but small numbers are still supplied from the forests in the north-east of the study area. Messmate stringybark is the preferred species.

There is a significant local demand for shed poles, fencing timbers, and firewood.

SOFTWOOD PRODUCTION

Plantings of introduced *Pinus* species began at Creswick in the 1880s, to provide employment for miners and to re-vegetate and stabilize sluiced and eroded gold-fields. Various softwood species were tried until 1900, but radiata pine, *Pinus radiata*, established its superiority as a commercial timber species. The Ballarat Water Commissioners also began softwood plantings in the 1880s around public land obtained for storages, channels, and other works.

An expanded planting program commenced in the 1960s under a plan to achieve self-sufficiency of wood requirements in Australia by the year 2020. Since 1966, State forest plantations have been extended at the rate of about 4,200 ha a year with financial assistance received under the *Commonwealth--States Softwood Forestry Agreements Acts*. In recent years the rate of plantation extension has been reduced to about 3,500 ha a year.

Plantation softwoods produce the raw material for a variety of end uses including light construction, flooring, weatherboards, joinery, furniture, veneers and plywood, particle board, paper pulp, and fencing material. The timber is suitable for pressure treatment with preservatives, enabling it to be used in situations of high insect and fungal attack.

Suitability criteria for radiata pine

Commercial production of radiata pine has the following basic requirements:

* mean annual rainfall should be greater than 700 mm

* soils should be acid, well drained, and have moderate fertility

* more than 0.5 m of topsoil should overlie any soil layer that may impede root development or water percolation

Certain other factors, however, deserve some consideration. Deep ripping to conserve moisture may result in a lower-rainfall site being suitable, especially if other site factors - such as slopes, proximity to markets, or proximity to other plantations - are favourable.

Productivity

The actual or potential productivity of an area of land used for growing radiata

Pine logs carted to the Creswick mill by horse c.1920 pine is described by the term site quality - a measure of the total volume of timber produced. Site quality is based on a series of indices related to the predominant height reached by a stand at age 20 years. Site quality classes (which range from I to VII) form the basis for calculating growth rates and the quantities of the various classes of log material that will become available for industry. Table 25 sets out the productivities of the different site qualities. The productivity values should be compared with those given for hardwood production in Table 24.

Softwood Plantations on Public Land

Softwood plantations, predominantly of radiata pine, cover approximately 8,600 ha of public land. About 7,700 ha of pines have been established on State forest (reserved forest and unreserved Crown land), 820 ha on land vested in The Ballarat Water Commissioners, and 180 ha comprising small school plantat-

Table 25

SOFTWOOD PRODUCTIVITY

Site quality	MAI (cu.m per ha per annum)	Total volume (cu.m per ha per 35-year rotation)	Area where this is the dominant site quality *
III	25	863)	Moorabool, Wilsons, Gong Gong Reservoirs
IV	22	783)	
V	19	656	Spargo Creek, Mount Lonarch
VI	15	523	Enfield, Garibaldi, Creswick
VII	6	226	Eaganstown, Scarsdale

Source: Forests Commission, Victoria
* This refers to the site quality at existing plantations. Productivity can be increased by at least one S.Q. unit by improved establishment techniques such as deep ripping.

ions. The larger areas are shown on Map 9, Vegetation.

Managed by the Forests Commission

The plantations on State forest within the study area comprise the greater part of the Ballarat Plantation Development Zone. They occur at Mount Lonarch, Scarsdale, Ballarat, Creswick, Garibaldi, Spargo Creek, and an area south of Eaganstown. Plantations of highest site quality, site quality III in this case, occur in high-rainfall areas surrounding Ballarat Water Commissioners reservoirs and works. (see Table 25).

The establishment and maintenance of softwood plantations under the *Softwood Forestry Agreements Acts* of 1967, 1972, 1976, and 1978 resulted in an expansion of the plantation program. Under this scheme, the Mount Lonarch project was commenced in 1965 and Spargo Creek in 1969. These projects, and earlier plantations, involve clearing native forests considered to have a low potential for hardwood sawlog production, heaping and burning the debris, and subsequently planting one-year-old seedlings. In recent years, farmland of marginal agricultural value has been purchased and planted with softwoods.

The Ballarat Water Commissioners plantations

Portions of the land surrounding water storages managed by The Ballarat Water Commissioners are planted to softwoods. As well as providing catchment protection, these plantations are managed for timber production. The Commissioners provide sawlogs to their own mill, which cuts timber for case manufacture, and occasionally to other contractors.

Others

Approximately 25 small school plantations, totalling about 180 ha and managed by the Education Department, are located throughout the study area. These plantations are generally established to provide an endowment for a local school and to serve as a resource for environmental teaching programs.

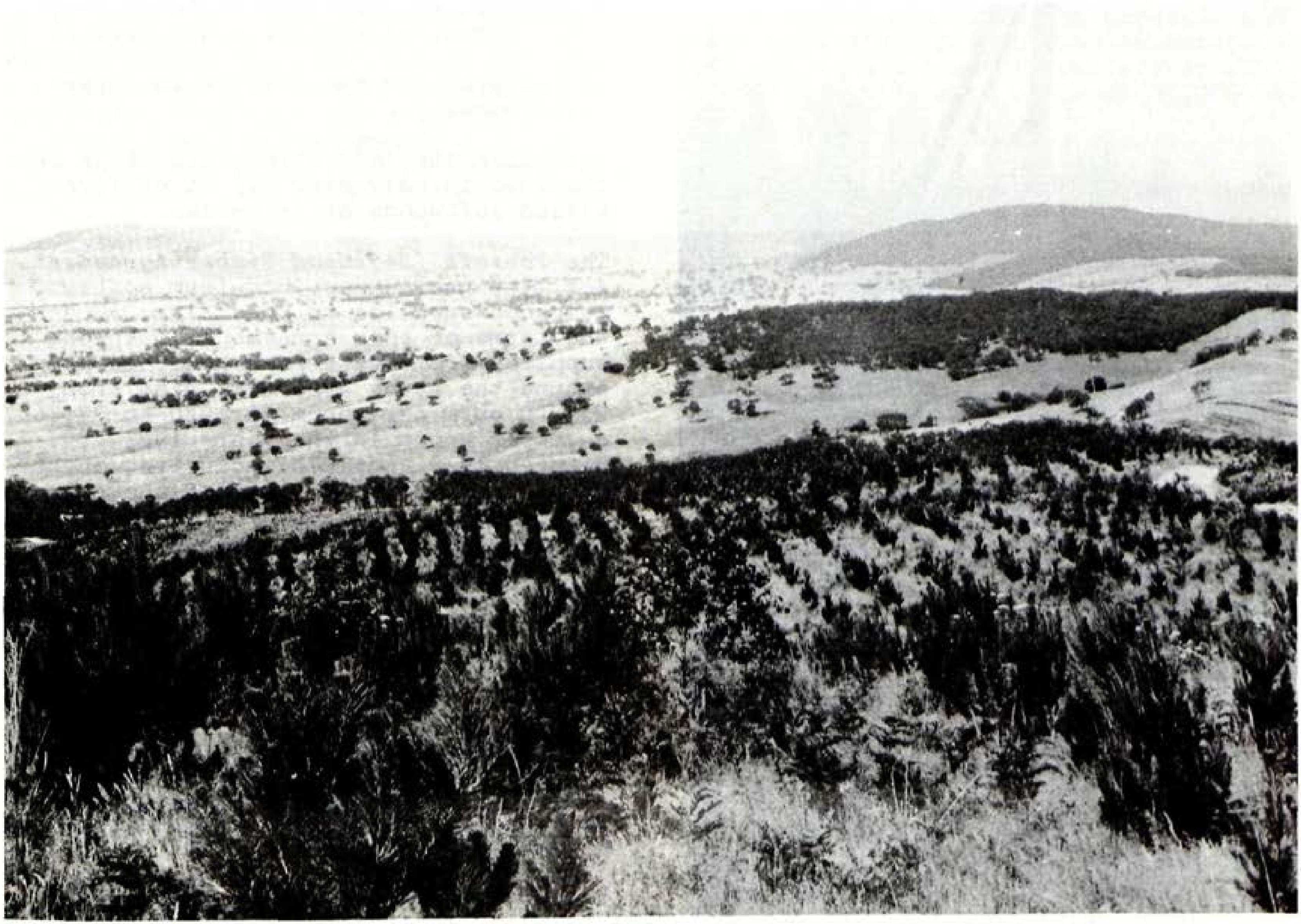
The Ballarat Sewerage Authority manages softwood plantations surrounding its works adjacent to the Yarrowee River.

Softwood Plantations on Private Land

About 800 ha of softwoods have been planted by private owners, mostly during the last 10 years. This includes about 300 ha owned by a firm that has a timber-preservation plant at Bungaree. Another 280 ha are owned by various individuals assisted under the Farm Forestry Loan Scheme administered by the State government.

Softwood Timber Supplies

Current sawlog and peeler-log allocations from State forest within the study



Young plantations of radiata pine (site quality V) overlooking the headwaters of the Avoca River near Mount Lonarch

Salvaging fire-killed radiata pine at Creswick following the fires of February 1977

area total 24,900 cu.m per annum. The allocations are supplied to three saw-mills at Ballarat, one each at Colac and Stawell, and a veneer mill in Mel-bourne.

Presently, all softwood pulpwood from State forest within the study area is supplied to A.V. Wehl Industries Limited at Ballarat for manufacture into part-icle board.

Following the 1977 fires, all mills were involved in salvaging 270 ha of fire-killed softwoods at Creswick.

The *Forests (Softwood Timber Agreement Act* 1969 guarantees long-term softwood pulpwood supplies to this firm. Under the terms of this agreement, pulpwood supplies from State forest within and around the study area will rise from 21,240 cu.m per annum in 1980 to 37,760 cu.m per annum in the years 1985--89. Between 1975 and 1978 inclusive, about 9,200 cu.m annually - 66% of the pulp-wood supplied to A.V. Wehl from State forest - came from the Ballarat study area. The remainder came from other parts of the Ballarat Softwood Plantat-ion Development Zone.

Within this zone, the availability of softwood sawlogs is expected to increase from an annual level of 37,000 cu.m a year (average between 1975 and 1979), to 60,000 cu.m a year by the end of the century. Similarly, softwood pulpwood is expected to increase from 14,000 cu.m a year to 90,000 cu.m a year.

Preservation plants at Bungaree and Beaufort also receive supplies from State-owned plantations. The current commitment is about 1,900 cu.m per year, consisting mostly of post-size timbers obtained from thinnings.

In 1978, plantations owned by The Ballarat Water Commissioners supplied about 5,000 cu.m of sawlogs, mainly to their case mill, and 1,400 cu.m of pulpwood, mainly to A.V. Wehl Industries Limited.

Employment

The three softwood sawmills located at Ballarat presently employ about 88 people. One of these mills, with 26 employees, draws its supplies entirely from private property. Another, owned by The Ballarat Water Commissioners, obtains timber from its own plantations. The A.V. Wehl particle-board mill at Ballarat employs about 160 people and is one of the city's major secondary industries. Other firms processing softwood round timbers are located at Beaufort and Bungaree and employ a further 15 people. Softwood sawmills located outside the study area, at Colac and Stawell, draw supplies from within it.

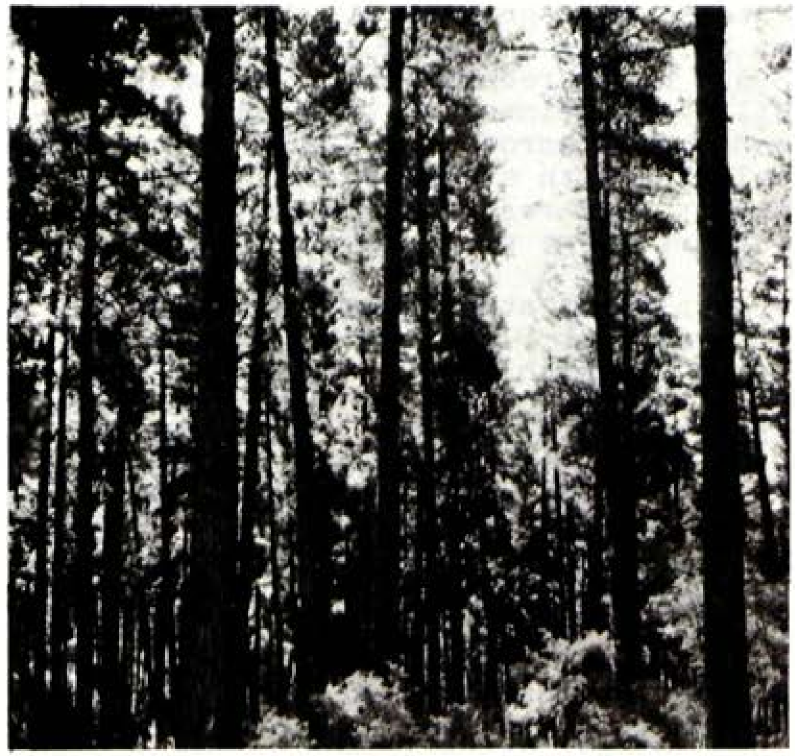
These employ a total of 66 people. A Melbourne-based firm using veneer logs from Ballarat and Creswick Forest Districts and other softwood areas of the State employs about 85 people.

General Aspects of the Softwood Industry

Federal policy laid down in the 1960s determined that Australia should aim at self-sufficiency in forest products and that this could be achieved by establishing plantations of conifers at an annual planting rate of about 30,000 ha.

Subsequently the *Softwood Forestry Agreement Acts* of 1967, 1972, 1976, and 1978 made Commonwealth funds available to the States to establish and maintain softwood production.

A number of arguments both for and against an expanding softwood planting



Mature pine plantation at Creswick

program have been raised. These include challenges to the self-sufficiency concept, environmental concern over clearing of native forests, and differing estimates of timber demand. An inquiry is currently being conducted by a Senate Standing Committee on Trade and Commerce into all Aspects of Australia's Forestry and Forests Produce Industries. This may have a bearing on future funding.

In Victoria, the Forests Commission intends to develop the plantation-extension program at the rate of 3,000 ha per annum - a reduction from about 3,500 ha in recent years. Plantations will be continued in the eight development zones across the State, which were selected with a view to providing sufficient wood resources to attract and support large permanent industries.

The Ballarat study area falls within the Ballarat Plantation Development Zone, in which the Commission intends to establish 24,000 ha of softwoods at an annual rate of 440 ha. The State softwood plantation within the Ballarat Plantation Development Zone currently totals some 11,700 ha; of this, 7,700 ha are located within the study area, and the rate of planting there is about 370 ha per annum.

Of the remaining 12,300 ha to be established in the Zone, the Commission intends that plantations will be located on sites containing native timber of low productivity and/or purchased marginal farmlands.

In recent years the Forests Commission has adopted a policy that, wherever possible, plantation extension will be carried out on purchased farmland.

Since 1966, the Commission has purchased privately owned farmland where such areas have become available at economic prices. A total of 1,665 ha has been purchased at Mount Mercer, Garibaldi, Carngham, and Raglan in recent years, and much of this has been planted.

A study commissioned by the Land Conservation Council in 1975 considered the economic evaluation of softwood alternatives in the Ballarat softwood zone. Given that the average cost of plantation finance is 7%, the study indicated that to break even with this cost, farmland of SQ II could be purchased for \$760 per ha, of SQ III for \$500 per ha, and of SQ IV for \$300 per ha. (Note that these are 1975 figures.)

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AGRICULTURE

Major agricultural enterprises in the Ballarat area produce wool, prime lambs, beef, cereals, and potatoes. Less important enterprises are apiculture, dairying, pig-farming, and oilseed cropping, with very minor production of fresh fruit, vegetables, wine grapes, and cut flowers.

About 80% of the study area supports farming. Some 2,900 holdings are at least one hectare in size, but less than 2,000 of these are commercial (that is, where farming is the main source of income to the owner or manager). The rest are sub-commercial and hobby farms. The size of commercial farms is about 250 ha but holdings are generally larger in the Shires of Ararat, Leigh, Lexton, and Ripon (average size around 350 ha), and generally smaller in the Shire of Bungaree (average size around 90 ha).

Environment and agricultural production

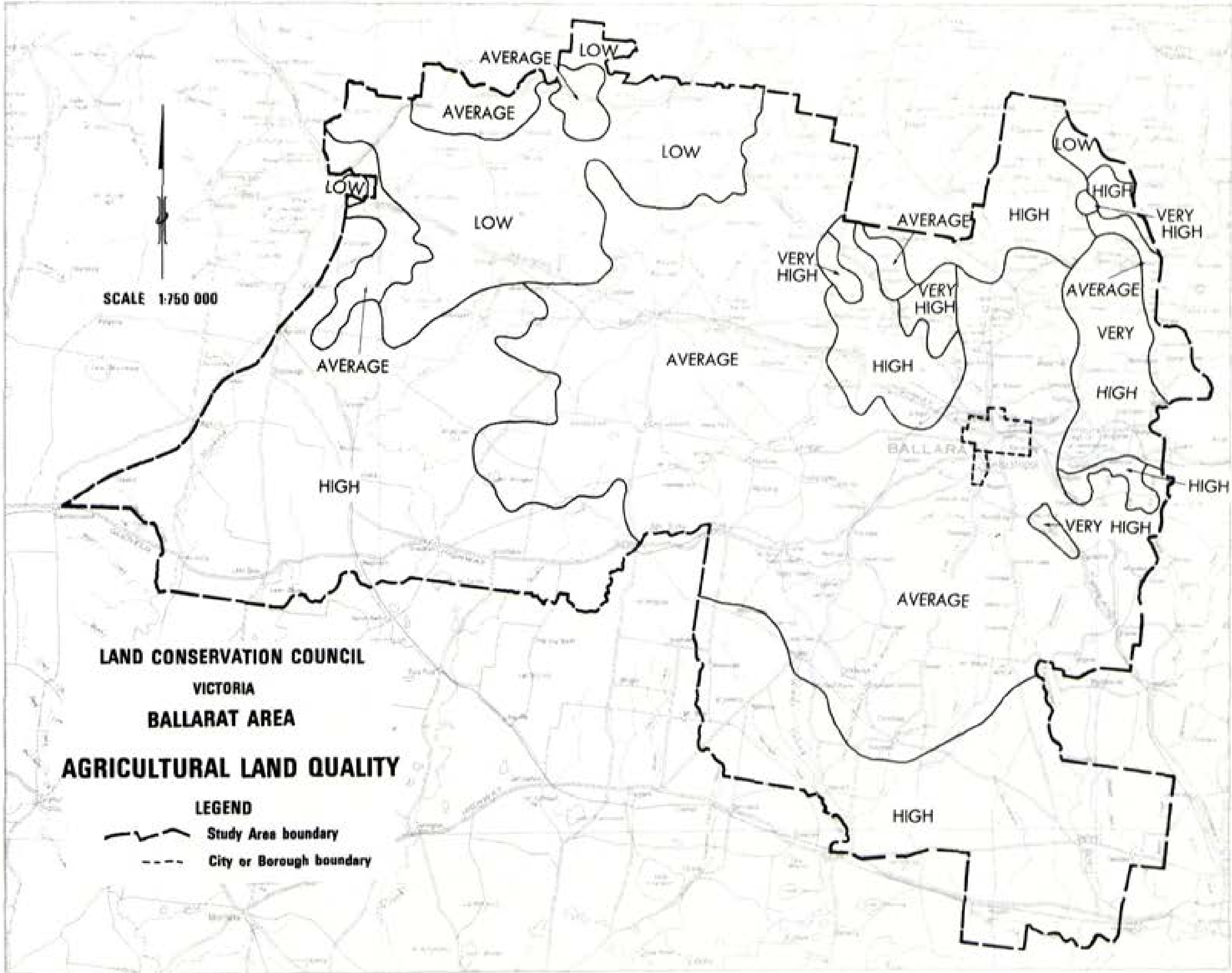
Rainfall and soil type are the main factors controlling the distribution of most of these enterprises throughout the study area.

Average annual rainfall in the agricultural region ranges from 500 mm along the southern border to 850 mm north-east of Ballarat; about half of the district receives 650 mm or more. Cereal and oilseed crops are largely confined to the drier areas, or to the better-drained soils of wetter areas, since soil waterlogging severely restricts the growth of these crops. Prime lambs, dairying, and beef cattle are largely restricted to areas where a longer growing season promotes greater pasture production. Potato-growing is largely restricted by soil type and the availability of either good-quality groundwater or sufficient surface catchment for irrigation.

Agricultural land quality

The Department of Agriculture and the Town and Country Planning Board are assessing the quality of agricultural land throughout Victoria. This land is rated according to five categories - very high, high, average, low and very low. Ratings are based on the present productivity of the land under good average management, and the present understanding of its versatility for producing a range of agricultural products.

Within the study area, private agricultural land has been classified into the


AVERAGE
LOW
AVERAGE
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LOW
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VERY
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SCALE 1:750 000
LAND CONSERVATION COUNCIL
VICTORIA
BALLARAT AREA
AGRICULTURAL LAND QUALITY
LEGEND
Study Area boundary
City or Borough boundary

first four categories, with none as very low quality (see agricultural land quality map on page 179).

In the east of the Ballarat area, some land on finely structured red gradational soils of volcanic origin receiving high rainfall, is rated very high. It has high productivity (stocking rates of 12--14 dry-sheep equivalents per hectare), and high versatility (suitable for potatoes, lucerne, cereals, oilseeds, prime lambs, vealers, and dairying).

In the north-east, south-east, and south-west, land of high agricultural quality occurs on brown gradational soils of volcanic origin in the higher-rainfall areas, and on yellow brown duplex soils of volcanic origin in the lower-rainfall areas. It has moderate productivity (8--12 dry-sheep equivalents per hectare), and moderate versatility (suitable for cereals, oilseeds, sheep, and beef cattle).

Through the centre of the study area much of the land is rated as average agricultural quality. It occurs mainly on red and yellow sodic duplex soils of non-volcanic origin, in the medium-rainfall parts. It has moderate productivity (8--12 dry-sheep equivalents per hectare), and low versatility (suitable mainly for sheep and beef cattle with very limited cropping to oats and barley). Localized areas of soil salting occur on this land at present, which pose a potential threat to productivity.

The north-west contains some low agricultural quality land, mainly on red and yellow sodic duplex soils in the lower-rainfall section. Productivity is low (5--7 dry-sheep equivalents per hectare) and also versatility (suitable for sheep, with limited cereal cropping).

The main soils of agricultural significance are:

* Red volcanic soils (the red and brown gradational soils described in the soils chapter) are found mainly to the north and east of Ballarat. They are well suited to the growing of crops, pasture, and lucerne; potato production is virtually restricted to this soil type.

* Grey basaltic soils (uniform grey clays and various duplex soils) predominate on the plains of the south and south-west. In the higher-rainfall areas these soils suffer from prolonged winter waterlogging. They are well suited to pasture, and in the drier areas grow excellent cereal and oilseed crops.

* Soils developed on Ordovician sediments (various sodic and stony duplex soils) occur throughout the study area. The topsoil is usually shallow, overlying an impermeable yellow clay. Poor fertility and structure and winter waterlogging make these soils poorly suited to cropping, but they are suited to growing pasture.

Land of high agricultural quality east of Mount Warrenheip used for potato-growing

Pastures

The growing season for pasture extends on average from early April to late November in most parts of the study area. Areas to the north-east of Ballarat have up to 2 months' longer growing season (see Table 10 in the Climate chapter). Improved pastures make up more than 80% of the total, the balance being native species with volunteer introduced species. About 5% of the total pasture area is cut for hay each year, producing around 100,000 tonnes of hay at an average yield of 3.7 to 4.0 tonnes per ha.

The main sown species in improved pastures are Victorian perennial ryegrass and subterranean clover (Mount Barker, Bacchus Marsh, and Woogenellup cultivars). There are also smaller but significant areas of phalaris, cocksfoot, lucerne, white clover, and strawberry clover. Subterranean clover is the dominant pasture legume in all but the highest-rainfall areas, where white clover is the main one.

Lucerne is grown as a specialty crop for hay and summer grazing, and is sown on a small proportion of total farm area. The crop is generally grown without irrigation and is restricted to deep well-drained soils.

Improved pastures throughout the study area respond to regular applications of superphosphate, and in many parts respond also to potassium fertiliser. The trace element molybdenum is also needed occasionally on some soils, especially those derived from Ordovician sediments.

Seed production was once an important sideline enterprise from pastures. However, regulations requiring increased standards of quality have made it a specialist industry. Perennial ryegrass is the species most frequently grown for seed and is now produced by a small number of specialist growers in the north-east of the study area.

Fodder

Fodder conservation is an integral part of farming in the Ballarat area. Spring growth of pasture is normally far in excess of requirements while, at average district stocking rates, stock require supplementary feed in winter. So a tradition of hay-making has developed, with surplus hay - especially from the Shires of Ballarat, Creswick, and Ripon - being sold out of the study area.

Lucerne is grown for hay and grazing on 1,700 ha, much of it in the Shires of Ballarat, Ararat, Creswick, and Lexton. Most lucerne is grown without irrigation and produces an average of 4.5 to 5.0 tonnes of hay per ha in two or three cuts each year.

Sheep

The Ballarat area supports approximately three million sheep, of which 45% are

Sheep grazing on undulating volcanic plains adjacent to Smeaton Hill

breeding ewes, producing about 12 million kilograms of wool annually. Median flock size lies between 1,000 and 2,000 sheep.

Sheep are run on about 65% of rural holdings, but the proportion of commercial farms running sheep is much higher than this. They are well distributed throughout the study area, with the greatest concentration in the Shires of Ripon, Lexton, Grenville, Ararat, and Leigh. The remaining Shires support fewer sheep but more cattle.

Of the properties running sheep, about 80% have breeding ewes, breeding their own replacement sheep, or prime lambs.

Others run dry sheep. In the Shires of Ararat, Lexton, Ripon, Grenville, and Leigh, sheep are run predominantly for wool and mutton, the main species being Merino, Corriedale, and Polwarth.

Prime lamb production is the major sheep enterprise in the Shires of Ballarat, Bungaree, Creswick, and Buninyong. The main breed is a second-cross lamb produced from a joining of first-cross ewes (Border Leicester X Merino) and Dorset Horn rams. Store lambs are also fattened on summer fodder crops or lucerne for sale in autumn. This enterprise fits in well with potato-growing.

Beef cattle

Of the approximately 130,000 beef cattle in the study area, about 50% are cows and heifers. They are well distributed throughout, with a higher concentration in the Shires of Ballarat, Bungaree, Buninyong, and Creswick.

Approximately 65% of rural holdings in the study area run beef cattle. Most herds on commercial farms are between 20 and 80 head. Beef cattle are also very popular on hobby farms and subcommercial farms, which commonly run less than 20 head. There are only a small number of specialist beef producers, most beef herds being run in conjunction with sheep, cereals, or potatoes.

The majority of the cattle in the study area are Hereford or Hereford crosses. Cattle are mostly sold off breeding properties as vealers or store weaners, although some may be carried on for sale at about 18 months old. On other properties it is common practice to buy weaner steers and sell them in prime condition at around 1½--2 years old. A small number of properties sell 2½- to 3-year-old bullocks. Peak sales of prime cattle take place in late spring and summer.

Dairying

Dairying is a declining industry in the area. For many years the number of dairy properties has been falling at the rate of about 10% a year. Most of these have been the small mixed farms, milking less than 20 or 30 cows, that once dominated the industry.

About 200 dairy farmers operate in the Ballarat area (mostly in the Shires of Ballarat, Buninyong, Creswick, and Bungaree), with an average herd size of 45--50 cows (mainly Friesians) - well below the average for Victoria. Total annual production is around 10 million litres of market milk and 0.5 million kg of butterfat for manufacture. About half of the dairy farmers hold contracts to supply market milk.

Because of its cold winter and dry summer, the Ballarat area is regarded as being less suited to dairying than other parts of Victoria. With the phasing out of milk contracts over the 10 years starting from 1976/77, it is expected that dairy farming will further decline in importance in this area.

Pigs

Ballarat has the largest weekly pig market in Victoria, and the area contains approximately 120 piggeries and 20,000 pigs. About 70% of the piggeries have breeding sows; the remainder buy and fatten store pigs. Most are side-lines to other farm enterprises, with only a small number of highly capitalised and intensively run piggeries.

Potatoes

Potato-growing is restricted to the red volcanic soils in the Shires of Creswick, Bungaree, Buninyong, Ballarat, and Lexton. Potatoes are planted in November--December, and are ready for harvest by late April. Harvesting proceeds from April to October, the tubers storing well through the winter in the well-drained red soil.

The area under cultivation for potatoes (approximately 3,200 ha) is mostly spray-irrigated from private dams and bores, and yields an average of 24 tonnes per ha. The bulk of the crop is sold as table potatoes or 'ware', but significant proportions are grown under contract for processing or for certified seed. About 22% of Victoria's total potato output comes from the Ballarat area, which is regarded as one of the most suitable in Australia for the production of high-quality seed potatoes.

Cereals

Usually, depending on seasonal conditions, about 45,000 ha of cereals are grown each year. A major limitation to cereal-growing is waterlogging of soils in winter and early spring. For this reason, the main cropping areas are in the lower-rainfall parts in the south and west of the study area, and on the well-drained red volcanic soils of the higher-rainfall parts.

Oats is the most important crop and about 25,000--30,000 ha are sown to it annually. Most is for grain production with only 4,000--5,000 ha being used for hay. The crop grows throughout the area and grain yield averages 1.7--2.0 tonnes per ha. Hay production is confined mostly to the north-east of the area in the Shires of Ballarat, Creswick, and Lexton.

Wheat is also an important cereal, growing mainly in the Shires of Ararat, Leigh, and Ripon. An area of between 10,000 and 12,000 ha is sown annually, with average production at about 1.7--2.0 tonnes per ha.

Approximately 5,000 ha are planted to barley annually - mostly in the Shires of Ararat and Leigh, but small areas in the north-east produce this crop in rotation with potatoes. Average yield is around 1.7--2 tonnes per ha.

Oilseeds

Rapeseed is by far the most important oilseed crop in the area. Between 500 and 1,000 ha are sown annually, with an average yield of around 0.6--1.0 tonnes per ha. Most of the production comes from the southern part of the Shire of Ararat, where the rapeseed is grown in rotation with cereals and pasture, usually immediately following the pasture phase.

Harvesting rape

Sunflowers are grown on a small scale throughout the area, the most favoured sites being the black cracking clays of uniform texture and grey clays of uniform texture. The crop grows during late spring and summer without irrigation, and yields on average around 0.6--1.0 tonne per ha.

Both rapeseed and sunflowers are generally grown for oil production, under contract to a processor.

Agriculture and grazing on public land

Land vested in The Ballarat Water Commissioners surrounds storages managed by the Commissioners. Much of it is planted with softwoods or carries native vegetation, but some is leased for grazing and potato-cropping. At Wilsons Reservoir, leases have been issued for grazing (involving 573 ha), and for potato cultivation (involving 42 ha). Last financial year - 1977/78 - this returned some $35,000. In addition, the Commissioners graze a herd of cattle on scrubby woodland at Pootilla.

Grazing on reserved forest, under licences issued by the Forests Commission, occurs in the Dunneworthy Forest (about 2,000 ha), at Mount Doran (57 ha), and on farming land at Chepstowe purchased for pine planting. The Dunneworthy and Chepstowe parcels are grazed by sheep.

Grazing on Crown land takes place under grazing licence, unused-road licence/ water frontage licence, or permit from a Committee of Management. The three types of licence are commonly issued to provide extra grazing for adjacent landowners. Conditions generally exclude cultivation.

The Department of Community Welfare Services farms some 1,000 ha of public land attached to the Langi Kal Kal Youth Training Centre near Trawalla. The farm is used as a grazing enterprise, running 500 Angus cattle and 10,000 Perendale sheep. Livestock produced are slaughtered to supply rations for the various divisions administered by the Department - such as correctional services (for example, Pentridge Prison) and welfare services. The Department also controls land surrounding the Ararat Prison within the City of Ararat), of which 4 ha is used for vegetable production and the remainder for sheep and cattle grazing. Again the produce is used within the correctional services.

Apiculture

The apiculture industry depends upon the introduced honey-bee *Apis mellifera*, a social insect that collects and stores quantities of plant nectar, the excess of which is harvested as honey. In the process of collecting nectar, which is a

Sunflowers: an oilseed crop grown in the south-west of the study area

carbohydrate food source, the bees also collect pollen on specially adapted hairs on their rear legs. Pollen is a protein food that they store, along with the nectar, for feeding. The pollination activity of honey-bees, particularly in relation to agricultural and horticultural crops, is probably more important than their commercial value as producers of honey.

Beehives situated on public land near Creswick

Commercial bee-keeping is a 'migratory' industry. Operators truck their hives to areas of high nectar yield, following the honey flow of different eucalypts. They also travel to over-wintering areas where the bees can build up their stocks of pollen. In the south-west of the study area, for example, thousands of colonies of bees are transported in to assist in the pollination of seed crops such as sunflower, mustard, rape, and lucerne. Lucerne produces high yields of nectar and pollen, and a good-quality honey. Its value to the bee-keeper, however, lies in the pollen resources - a high-quality food for the breeding colony.

In addition to 187 registered apiarists living in the study area, some 200 migratory apiarists visit the area with their hives. The increase in the number of amateur operators indicates an important recreational aspect of bee-keeping.

The bulk of Victorian honey is sold to large processors who clarify and pack it for export and for the home market. Most bee-keepers also maintain a small local trade in their own areas. About half of the annual Australian production is exported, mainly to the United Kingdom, but popular honeys such as yellow box are almost entirely consumed by the home market. In 1978 there were 492 bee-keepers in Victoria (in this instance a bee-keeper is defined as one with more than 40 hives). They produced 3,476 tonnes of honey and 61 tonnes of beeswax.

Important plant species

On agricultural and horticultural land, lucerne and seed crops and various clovers are important sources of nectar and pollen. Declared noxious weeds, such as blackberry, and thistles are also important sources. A potential disadvantage in utilizing these plants lies in the application of pesticides, which can rapidly decimate a whole apiary.

On forested lands most of the honey is produced from eucalypts, of which 20 or more species grow in the study area. The most prolific or reliable producers are considered to be yellow box, red box, grey box, red gum, blue gum, yellow gum, manna gum, red stringybark, and messmate stringybark. The apairist uses many other species, which do not produce high nectar yields, or on their own produce a poor-quality honey, for brood rearing. These include wattles, tea-trees, bottle brushes, honey-myrtles and paperbarks, banksias, sweet bursaria, and the austral grass tree.

Licensing of bee-keeping on public land

On private forested and agricultural land, siting of hives is by arrangement with the landowner. On reserved forest, the Forests Commission issues bee-farm and range licences. A licence covers an area with a 1.6-km radius, which has good access, satisfactory vegetation, and a supply of water. Records show that such areas are located beside forest access roads, generally within a few kilometres of the forest boundary. Temporary bee sites are allocated on areas that are small or have poor access, a short working season, or some other deficiency. Temporary licences may be issued in choice bee-keeping areas with the advantage that they may be closer together than the more permanent sites.

The Department of Crown Lands and Survey operates a similar system of licences on unreserved Crown land.

The Ballarat area currently contains 26 bee-farm and range licences and more than 100 temporary sites. The location of bee-farms is shown on Map 11, Current Land Use.

Bee-keeping and other land uses

Bee-keeping as a land use produces few, if any, conflicts. The competitive effect of the honey bee on the native bee population (estimated to be 3,000 species in Australia, mostly undescribed), is unknown. Silvicultural practices such as thinning may temporarily reduce the availability of a flowering crop, but rapidly result in enhanced crown development and more profuse flowering in the retained trees. Forests Commission policy is to reserve yellow box trees for apicultural purposes as far as practicable. In areas used by apiarists consideration is also given to the potential of large-crowned trees of other species for honey production.

Fuel-reduction burning programs are designed to avoid or minimize burning in areas carrying good honey-producing trees when they are heavily budded or in flower.

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MINERALS AND STONE

Gold

The Ballarat area includes gold-fields that were among the most productive in the State. The first major discoveries were exceptionally rich shallow alluvial deposits at Buninyong and Golden Point, Ballarat, in about August 1851. The deposits were followed downstream beneath layers of younger alluvium and basalt to be worked as deep leads. Gold-bearing quartz veins or reefs were discovered under the alluvial deposits, especially at Sebastopol, and in bedrock outcrops.

With the closure of alluvial mines in the early 1870s, Ballarat became predominantly a quartz mining centre until World War I. The decline of the shallow alluvial mines at Ballarat in the 1870s coincided with a massive expansion into deep alluvial (deep lead) mining elsewhere in the study area, especially on the Berry lead north of Creswick. Deep lead mining decreased rapidly after 1910, but continued to 1925 at Langi Logan, and to 1940 at Caralulup.

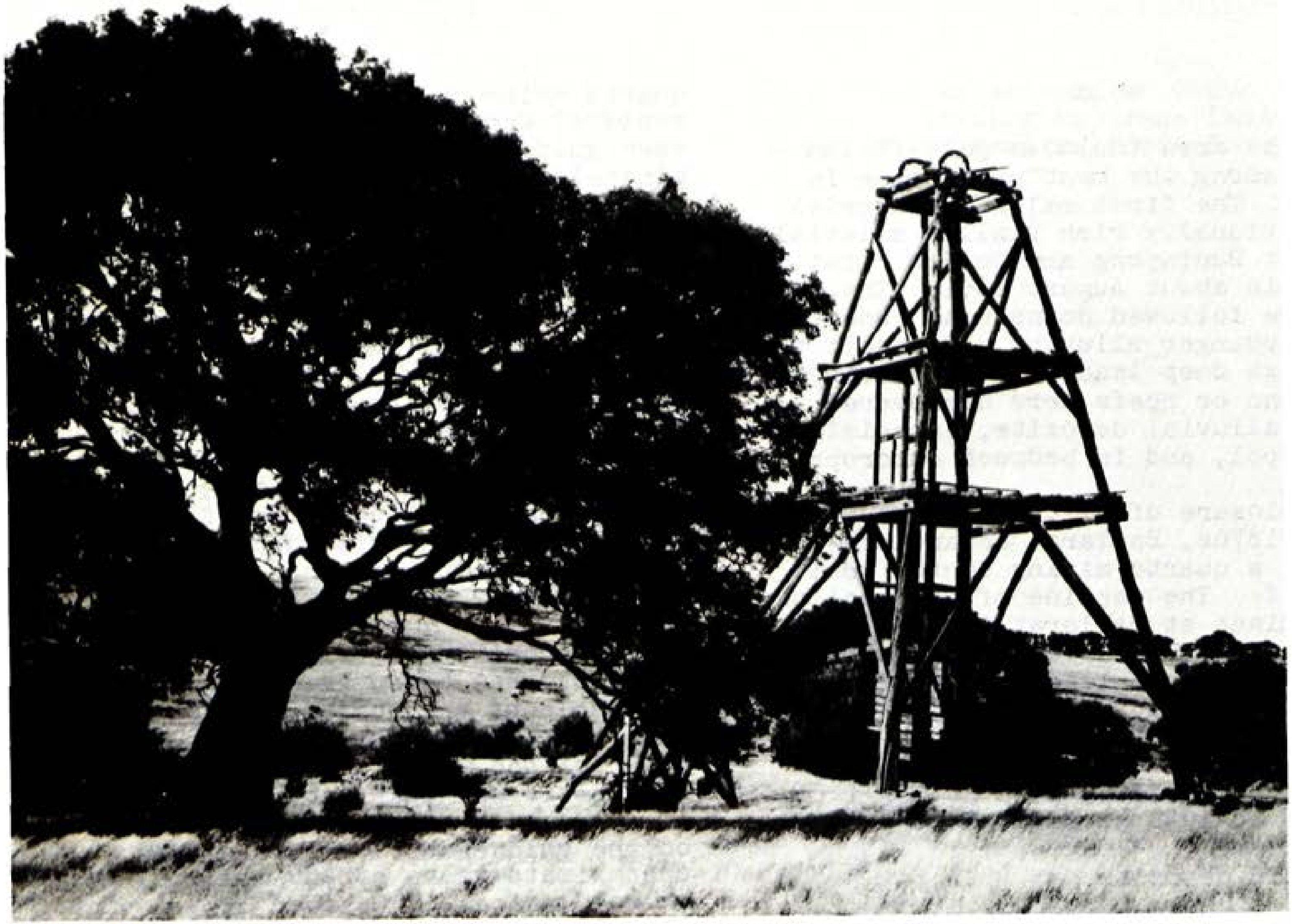
Primary gold deposits

All significant production of primary gold in the study area has come from quartz veins or reefs confined to sediments of Cambrian to Ordovician age. In each gold-field, relatively narrow mineralized zones - a few hundred metres wide and 2 km or more long - have provided the bulk of the yield. Many fields consist of one such zone, and some of two or three.

Shallow alluvial and eluvial deposits

Around Ballarat, Lower Ordovician sediments form an area of gentle topography. It was the weathered deposits of these sediments (eluvial deposits), together with the alluvial deposits of gullies into which the eluvial deposits merged, that yielded much of the gold during the early rushes.

These deposits were extremely rich and more gold was taken from them than from the whole of the subsequent deep lead and quartz mining operations. From 1851 to 1856, when working of this form of deposit was most intensive, 79,427 kg of gold was transported out of Ballarat on the gold escort. (This has an approximate value of $80 million, based on gold prices in October 1979.) The amount transported by private means will never be known. By comparison, reef mining from the late 1850s to 1918 yielded 57,900 kg of gold. More recently, between 1953 and 1956, large-scale dredging of alluvial gravels has taken place along the Wimmera River near Amphitheatre.



Poppet head of abandoned deep lead gold-mine near Illabarook

Deep leads

Deep leads are gold-bearing river channel deposits, which were laid down in the late Tertiary and later buried beneath Quaternary alluvium or basalt or both. In the heads of valleys and gullies, the leads were often relatively narrow and shallow. As the leads were traced into deeper ground and the alluvials became broader in extent, the original method of working by individuals or small parties gave way to mining by larger companies, which had sufficient finances and technical expertise.

The largest and more productive deep leads around Ballarat are those leading north into the Avoca and Loddon Valleys. The Berry--Moolort--Loddon system with all its large and rich tributaries ranks as the best gold-producing lead in Victoria. The four main southern tributaries commence near Lake Learmonth, Ballarat, Creswick, and Spring Hill and join into one course to the north near Glengower.

Within the deep leads, the gold-bearing gravel or wash was commonly up to 1 m thick and 100 m wide in a lead more than 300 m wide. Often extensive drilling was required to locate their highly sinuous courses. Gold yields were of the order of 10--20g per cu. m of wash.

The leads were extensively mined underground at Ballarat from 1855 to 1872. Elsewhere in the study area, the deep lead mines started in the 1870s or later and were worked through to World War I.

Specialized equipment and techniques were needed to cope with the weak ground and the enormous quantities of groundwater flowing through these buried river courses. Companies such as the Spring Hill and Central Leads Mine, north of Creswick, were faced with continuous pumping of up to 9 Ml of water per day. Further north, just out of the study area, the Charlotte Plains Company was forced to pump at 28 Ml per day for 6 years before mining, and then continued at 22 Ml per day during mining. (Compare this with Ballarat's average daily water consumption of 32 Ml per day and Ararat's consumption of 4.9 per day.)

The return of the natural water level after such prolonged de-watering operations takes many years. In the Hopkins Valley, within the study area, water in the New Langi Logan shaft stood at 12 m prior to de-watering. The lead was worked to 91 m and operations ceased in 1925. By 1934 the water level was still 45 m from the surface.

Other Metals

Arsenic

Arsenopyrite is widespread and occurs in small quantities in quartz reefs and veins. Arsenic has been recovered from gold ores containing arsenopyrite at Ballarat.

Chromium

Chromite is recorded in Cambrian rocks at Mount Stavely.

Copper

Native copper occurs in alluvial deposits at Ballarat and Creswick, and as films in quartz reefs at Egerton. Malachite (copper carbonate) occurs in quartz reefs at Mount Egerton.

Iron

Limited deposits of iron ore east of Lal Lal were mined between 1875 and 1902. The deposits, consisting of siliceous limonite varying in grade, were 1--2 m thick. Most of the limonite of commercial value has been removed. Initially the ore was smelted on site in the first iron-ore smelting furnace to operate in Australia. The iron produced was used in Ballarat, for ornamental fencing, gates, and mine skips, and later in the construction of railway engines.

Lead

Native lead has been recorded in the deep leads at Ballarat.

Wolfram

Quartz reefs in contact metamorphosed sediment north-east of Pittong contain wolfram and gold. The quartz reefs are up to 3 m thick with the mineralized part up to 0.6 m thick. Also associated with the reefs are small amounts of native bismuth, bismuth carbonate, bismuth sulphide, copper carbonate, copper sulphide, manganese protoxide, molybdenite, and silver.

Zinc

Sphalerite occurs in the complex lodes of many Victorian gold-fields, and is recorded as large crystals and masses at Ballarat.

Mining

There are five mining leases on public land in the study area. Their locations are shown on the mineral and stone map, and Table 26 gives further details.

Exploration

Since the introduction of the present system of exploration licences in 1965, 30 such licences have been issued that fall within the study area. At June 1979, 11 licences were current, and expenditure on exploration is estimated to exceed $300,000 in the financial year 1979/80. Licensed areas vary from 132 sq. km to 792 sq. km. All contain some public land.

Exploration has been directed particularly towards gold exploration, and has been concentrated on known gold-fields and extensions to these fields. Both reef and alluvial fields have been and

Table 26

MINING LEASES - BALLARAT AREA

Lease no.	Area (ha)	Land status	Mineral	Location	Expires
7	64.4	Crown	Gold	Berringa	15.10.88
305	52.6	"	"	"	8. 3.93
216	5.8	"	"	Barkstead	22. 9.90
9227	3.6	"	"	"	21.10.79
9253	2.4	Crown & private	"	Broomfield	13. 6.85

Source: Department of Minerals and Energy.

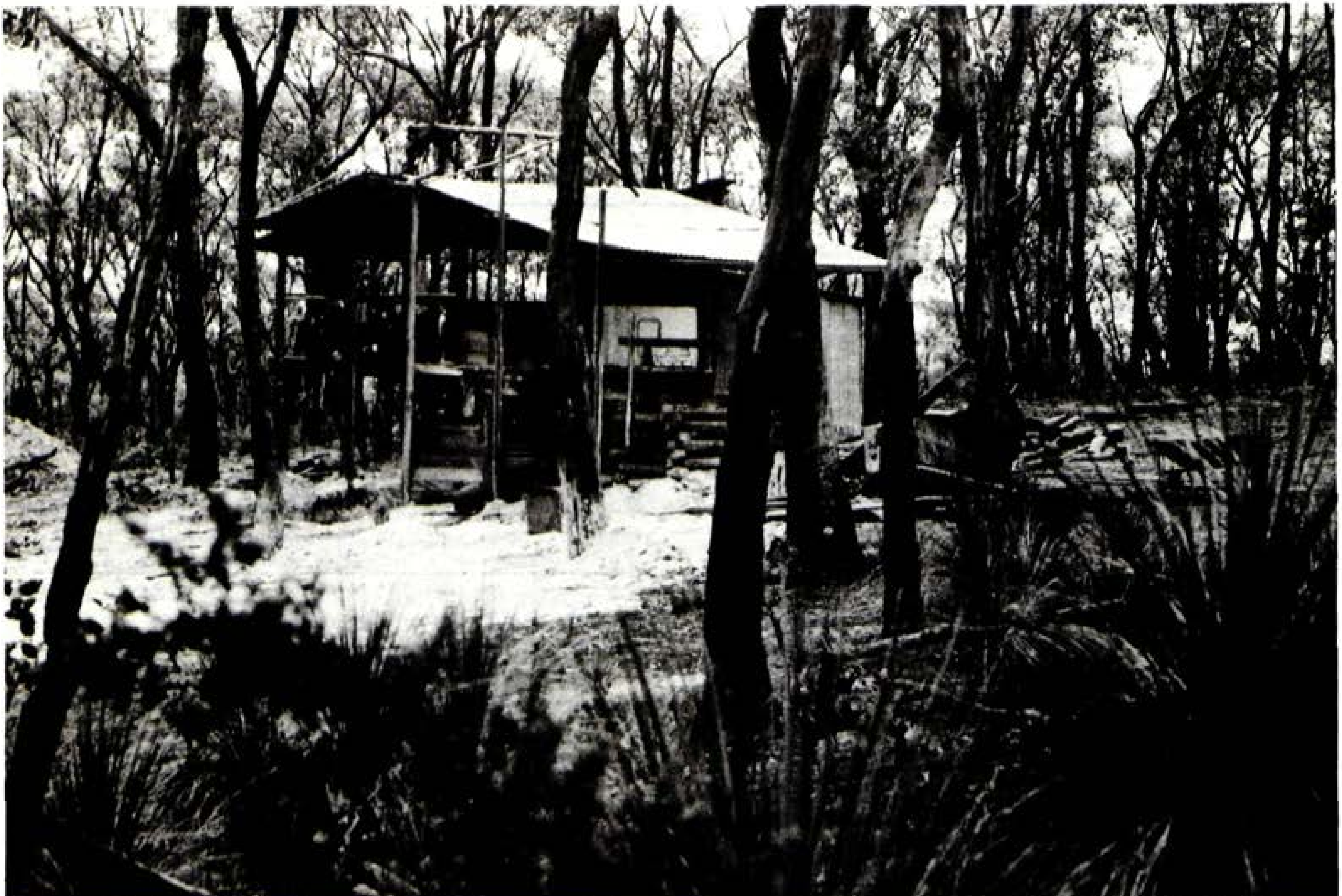
are being investigated. There has also been a general interest in the Cambrian volcanics and sediments at Mount Stavely, and the Cambrian sediments near Ararat, for base metals.

With the rising price of gold the number of applications for exploration licences in the study area is increasing. Among the few areas where little interest in mineral exploration has been shown are the granitic areas at Langi Ghiran and Mount Cole, and the Tertiary volcanic plains in the Mininera--Streatham--Lake Bolac area.

Non-metallic Minerals

Brown coal

Brown coal was first discovered at Lal Lal by miners shaft-sinking for alluvial gold about 1857. At the end of the 1850s, attempts were made to open up the coal for local use, and between 1863 and the late 1890s, 13,000 tonnes were mined from a 35-m shaft by underground methods by the Victorian Lignite Co. and sold in Geelong, Melbourne, and Ballarat. The deposits were worked intermittently between 1914 and 1922 and later unsuccess-



Kaolin mine on public land east of Lal Lal

ful attempts were made to exploit the coal in pulverized form. Mining was briefly attempted in 1940, but again was unsuccessful.

The coal deposit is present in lenses that show considerable variation both laterally and vertically, with overburden up to 20 m thick. The quality also shows considerable variation, and generally has a high ash content. In 1949 it was concluded that the percentage of overburden to the shallowest proved coal made open-cut mining uneconomic at that time.

Diatomite

A resource of diatomite (the siliceous remains of microscopic organisms called diatoms) occurs in the Parish of Clarkesdale, near Happy Valley, on private and public land. The resource, of approximately 10,000 tonnes, is uniform in colour. Production from 1943 to 1973, amounting to 2,250 tonnes, was used in Melbourne for the manufacture of insulating materials.

Kaolin

Deposits of high-quality kaolin are relatively widespread in the study area. The kaolin occurs as kaolinized granite, or kaolinized dykes. Kaolinization is a hydrothermal process that results in the production of kaolin from the decomposition of the feldspars in granite.

The material is currently being mined from kaolinized granite under mining lease on private land just south of Pittong. It is refined on site, with more than 60% being used for filler and coating in paper manufacture by paper mills at Melbourne and Brisbane. Other uses are for ceramic products, rubber, paint, and textile fibreglass. Approximately 30% is exported to New Zealand and south-east Asia.

For the year ending September 1979, 100,000 tonnes of decomposed granite were mined at Pittong, producing 27,000 tonnes of refined kaolin. Reserves of decomposed granite are large.

About 12,000 cu. m of kaolin are mined annually from decomposed granite on private land near Lal Lal by the Ballarat Clay Company. The higher-quality or 'brighter fraction' material is used at Ballarat to coat paper from Tasmania, to produce a high-quality glazed paper. About 25% of the kaolin is 'filler fraction' and is sent to Shoalhaven, N.S.W., for paper pulp filler. Reserves are adequate for 15--20 years.

Kaolin occurs in a kaolinized dyke at Egerton, which varies in thickness from 1 m to 3 m. The major part of the dyke consists of pure white kaolin (98% aluminium silicate). Costs associated with the depth of working and de-watering, combined with staining of the kaolin at depth, caused cessation of mining during 1975, after more than 70 years. Most of the kaolin, after being crushed, sized, dried, and bagged, was used in Melbourne.

A kaolinized dyke up to 1 m thick occurs on public land adjacent to Lal Lal Reservoir. The kaolin is white, very fine-grained, uniform in texture, and completely free from quartz. Chemical analysis shows it to be 98% aluminium silicate. The dyke, first mined in 1936, was worked to a depth of 32 m, but it is probable that kaolinization has taken place to much greater depths. The mine closed in 1955. Currently there is a small operation on public land a short distance north of the original mine, probably working the same dyke.

Other workings are reported at Snake Valley and on a dyke near the old Lal Lal iron mine. Prior to the removal of the tramway line to the iron mine, 760

Table 27

STONE PRODUCTION FROM BALLARAT AREA 1976--77 (TONNES)

Type	Total	Quantity from public land	Percentage of total
Crushed and broken basalt	258,173	7,745	3
Stoneware clay	25,120	6,782	27
Fireclay	2,385	0	0
Brick clay and shale	103,676	15,551	15
Sand (for concrete)	55,747	55,747	100
Sand (for other purposes)	33,743	12,822	38
Gravel (approx.)	467,400	146,558	31
Total	946,244	245,205	26

Source: Department of Minerals and Energy 1979.

Notes:

1. Shire extractions account for 425,000 tonnes (25% from public land).
2. There are a total of 22 licences and leases as follows:

   Licences: clay (9); sand and gravel (5); hardrock (4)
   Leases: sand and gravel (4)

tonnes of kaolin were mined and shipped to England from the latter dyke.

Stone and the Extractive Industries

Extractive industries are subject to the provisions of the *Extractive Industries Act* 1966 on Crown land and private land and the *Forests Act* 1958 on reserved forest.

The Department of Minerals and Energy issues permits to search for stone, defined as basalt, scoria, clay, sand, gravel, soil or other similar material under the *Extractive Industries Act*. For the purposes of commercial quarrying, the Department issues leases on Crown land and licences on private land.

Municipal bodies and the Country Roads Board make non-commercial extractions and therefore are not subject to leasing or licensing under this *Act*. They are, however, subject to licensing under the *Forests Act* if extractions take place on reserved forest. (Extractions of less than 2 m are regulated by the *Soil Conservation & Land Utilization Act* 1958 and the *Land Act* 1958.)

The quantity of stone extracted in the study area totals approximately 946,000 tonnes annually, 26% of which comes from public land. Table 27 summarizes stone extractions from public and private land. Map 12, Minerals and Stone, shows the location of current pits and quarries.

Hardrock

The major hardrock supplies come from three basalt quarries on private land at Brown Hill, Dunnstown, and Miners Rest. The rock is crushed to supply aggregate for road-making and for the construction industries in Ballarat. This large resource of basalt is located almost entirely on private land.

Gravel

Many of the areas of Tertiary gravels mined for gold last century are now worked for gravel. They are generally quarried by the shires, mostly for road-making material. The largest quarry, at Sago Hill, is owned and run by the City of Ballaarat.

These gravels are relatively widespread between Rokewood and Creswick Berringa and Mannibadar, and between Berringa and Corindhap, small parts of which lie on public land. The potential resource is shown on Map 12, Minerals and Stone. At both Illabarook and Dereel, broad areas of Tertiary sediment on public land have been shallow-stripped for gravel to a horizon consisting of a hard cemented conglomerate. Investigations of similar shallow-stripped deposits around Bendigo and St. Arnaud have shown that beneath this conglomerate lies a large gravel resource that could last for decades. Further exploration for gravel resources beneath the conglomerate should be encouraged.

Vast area of Tertiary gravel and sand near Smythesdale. This resource is sluiced (right) and washed to produce sized sand and aggregate

Table 28 gives the average annual gravel requirements of the shires represented in the Ballarat area between 1975 and 1979 and the extent to which supplies were obtained from public land. This percentage may vary greatly from year to year, depending on location of the resource in relation to roadworks.

Tertiary gravels are also a valuable resource for the construction and concrete industries in Ballarat, which include the manufacture of concrete roof tiles, pavers, and water tanks.

Two large areas of Tertiary gravel on public land on either side of the Glenelg Highway, just north of Smythesdale, are sluiced and washed to produce sized sand and aggregate. The present sluicing operation is very similar to that used last century to recover gold.

Table 28

SHIRE GRAVEL EXTRACTIONS ON PUBLIC LAND (1975--79)

Shire	Percentage obtained from public land	Average annual requirements (cu.m)
Ararat	12	93,000
Ballarat	3	17,000
Bungaree	0	27,000
Bunninyong	80	45,000
Creswick	50	18,000
Grenville	20	40,000
Leigh	30	21,000
Lexton	20	23,000
Ripon	30	34,000
		318,000

Source: Department of Minerals & Energy 1979

Indeed, at one of the sites the bulk of water for sluicing is drawn from the mining dam that was constructed for the original gold-sluicing operation. The dam is on public land a kilometre to the south of the present quarry. Small amounts of gold are recovered as a by-product of the washed sand operation.

In many areas, gravels were sluiced or dredged exhaustively, with the result that the whole of the Quaternary or Tertiary sediments in a particular drainage line were turned over. Often such areas were so despoiled that they remained public land, being of little use for any other purpose. Because of the unconsolidated nature of the gravel and limited use of these areas, they have from time to time been utilized for gravel extraction. One such area on public land is along Creswick Creek west of the town-

Removal of sand and gravel

ship, where the shire is obtaining gravel. If such areas have potential for other public uses, then planned gravel extraction is one means by which the land can be reshaped and eventually reclaimed.

Granitic sand

Several areas of granitic rocks occur within the study area. The colluvial slopes developed on granitic areas usually contain good-quality gravel, and extraction is relatively simple. Private pits utilize the gravel on slopes surrounding the granite at Mount Misery, Mount Bolton, and Mount Emu. Granitic sand has been extracted from public land at Langi Ghiran, and from several localities throughout the Mount Cole forest by the Shires of Ararat and Ripon and by the Country Roads Board. During 1978, 22,275 cu. m of granitic sand was extracted from Langi Ghiran, and 6,000 cu. m from the Manly Point Pit near Mount Cole. Granitic sand is also extracted from public land at Mount Bolton.

Clay

Large areas of the block of Cambrian to Ordovician mudstone and siltstone between Creswick and Rokewood are deeply weathered to clay. Such clay has been utilized widely in the past, supplying the local brick and earthenware industries.

Three major companies employing a total of 368 people now operate in Ballarat utilizing this clay. One of these companies, based at Ballarat and founded last century, sells bricks and pavers throughout Victoria and has successfully survived competition from Melbourne-based companies. This company obtains red and white plastic clay from private land at Enfield under an Extractive Industry licence. About 10--15,000 cu. m of white shale is obtained annually from a large quarry at Humbug Hill on public land south of Creswick under a Forests Commission licence, covering 7 ha. Supplies of red shale are obtained from private land next to the brick-works.

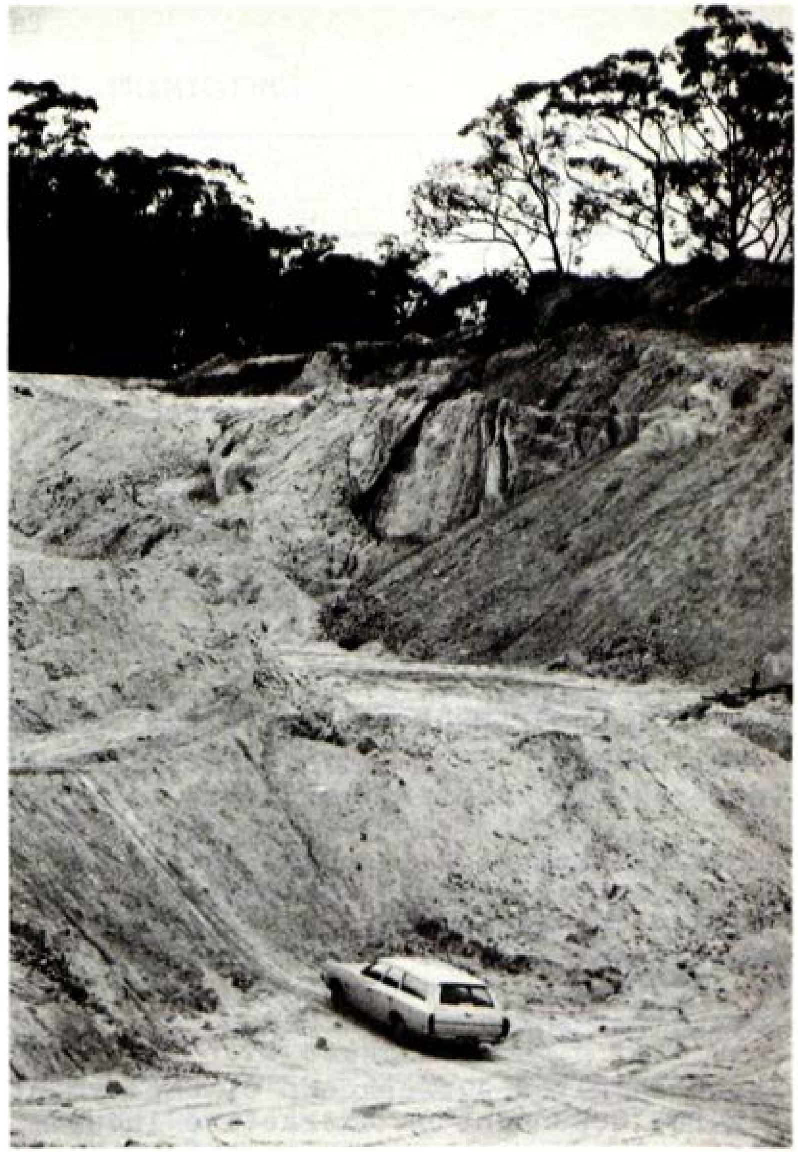
The second company makes mainly quarry tiles for paving, some roofing tiles, and minor amounts of other clay products. It sells its tiles Australia-wide, with 40% sold in Melbourne, but less than 2% of its total sales are in Ballarat and country Victoria. It has a small export market to south-east Asia. Most of its white plastic clay is obtained from private land at Enfield, under Extractive Industries licence, which has adequate supplies for 25 years. Red plastic clay is obtained from a private quarry at Ballarat East.

Another company makes earthenware pipes. It obtains all supplies of clay from private land at Enfield, Ballarat East, and Buninyong. An area of public land at Buninyong adjoining its private land quarry contains a resource of red plastic clay in excess of 110,000 cu. m.

The Ballarat East quarry has a life of 10 years, and the company would envisage eventually expanding its clay-winning operations at Buninyong. The earthenware pipe industry in the 1970s has been subjected to considerable competition from the plastics industry, which produces an alternative product.

Kaolin

Kaolin is relatively widespread in the study area, and is utilized in the manufacture of paper, and in pottery and ceramics, rubber, paint, and fibreglass. As kaolin is defined as a mineral under the *Mines Act* 1958, it is discussed under the preceding section on non-metalic minerals.



White shale, quarried from public land at Humbug Hill south of Creswick, is used in brick manufacture at Ballarat

Table 29

EMPLOYMENT IN EXTRACTIVE INDUSTRIES

Industry	Persons
Hardrock quarries	25
Clay and clay-dependent industries	386
Kaolin	116
Sand, and associated concrete and tile industries	* 80
Shires (including contractors)	*130
Country Roads Board	* 80
	817

*Estimates only

Source: Department of Minerals & Energy

Potters

About 15 potters living in and around Ballarat utilize small amounts of clay from the same sources that industry draws upon.

Employment

Table 29 gives a breakdown of employment figures dependent on extractive industries. It shows that at least 800 people are directly involved in the extraction, carting, and processing of stone in the Ballarat area. (Those employed in the kaolin industry are included because of the similarities of operations.) The shire figures vary from time to time depending on the road construction and maintenance program, and on the number of contractors required. The Country Roads Board at Ballarat employs 302 people and it is estimated that, of this figure, about 80 field staff work in the Ballarat area.

These figures for the shires and Board are estimates of the numbers directly involved in extracting, carting, and spreading stone and gravel on roads.

WATER UTILIZATION

Water resources in the Ballarat area, utilized for urban and agricultural consumption, are supplied from perennially flowing rivers and streams, artificially collected rain-water, reservoirs, and groundwater. The resources are managed by locally constituted Authorities under the *Water Act*.

The State Rivers and Water Supply Commission oversees the financial and technical activities of 14 water authorities - 11 waterworks trusts and three local governing bodies. These authorities have the responsibility of constructing, maintaining, and continuing waterworks within a defined district, usually covering a township and surrounding areas. A further independent authority, the West Moorabool Water Board, was established by a separate Act of parliament to oversee the construction and operation of the Bungal Dam, which forms the Lal Lal Reservoir, a storage designed to supply water to both Ballarat and Geelong.

Details concerning the various authorities, the resources under their control, and the areas served, are summarized in Appendix 9.

The reader is also referred to Map 7, Water Resources, Utilization and Topography.

Historical background

With the discovery of gold in the early 1850s, the relatively large populations that developed in the gold-mining districts were generally without the benefits of water supply, either for domestic use or for the treatment of mine products. There were few municipal authorities capable of dealing with such problems; in addition, most mining populations did not remain sufficiently settled to warrant investiture with the necessary powers.

Until 1860, Ballarat drew its supply from Yuilles Swamp, the site of Lake Wendouree. In 1861 the government commenced the construction of reservoirs on an *ad hoc* basis, works being undertaken by the Mining Department at a time when the Victorian Water Supply Department had no significance except as a minor branch.

A number of these storages are still in use today, including Beales Reservoir (constructed in 1863), Pincotts Reservoir (1867), and Gong Gong Reservoir (1877). The Langi Ghiran Reservoir, with its wall of immense granite blocks, was constructed in 1876. Several water supply reserves containing old mining dams are still located close to old mining townships such as Creswick, Buninyong, Scarsdale, Happy Valley, and Cape Clear.

Utilization of Surface Water Resources

Urban water supply

The most significant and important use of surface water resources is for the provision of reticulated supply to 33 townships and two cities.

The various waterworks trusts that supply water for urban usage operate on a relatively small scale. Beaufort Waterworks Trust, for example, which supplies the township, maintains headworks on Fiery Creek within Mount Cole forest and two small storage reservoirs.

At the other end of the scale, The Ballarat Water Commissioners (a local governing body), maintain seven storages to the north-east of Ballarat (Moorabool, Wilsons, Beales, Pincotts, Gong Gong, Kirks, and White Swan Reservoirs), and further augment their supplies with water pumped from the Lal Lal Reservoir. The Commissioners administer the water supply to the City of Ballarat and sell bulk supplies to five adjacent waterworks (Rokewood, Buninyong, Linton, Smythesdale--Scarsdale, and Bungaree--Wallace). Cardigan Village is a part of the Ballarat Water Commissioners' district.

The West Moorabool Water Board provides water from the Lal Lal Reservoir (on the West Moorabool River, south-east of Ballarat), to augment the supplies for Ballarat and Geelong. The Board also supplies water to the Bannockburn Waterworks Trust for distribution to the townships of Bannockburn, Lethbridge, Meredith, Inverleigh, Shelford, and Teesdale. Table 30 sets out details of major storages.

Diversions for irrigation, domestic, and stock use

The difficulty in obtaining suitable sites to enable construction of storages of large capacity limits the potential for the development of major irrigation projects.

All streams are committed to the extent of summer flows: however, if off-stream storages are provided to store excess flows in winter, further diversions could be made available. Excess winter flows are, for example diverted from Coghills Creek across the Great Dividing Range for storage in Lake Learmonth.

In 1977, 127 Ml of water for irrigation was diverted directly from channels man-

Mount Cole Reservoir

aged by The Ballarat Water Commissioners for use on adjacent properties.

Private diverters are also supplied with water from Newlyn Reservoir and Hepburns

Table 30

MAJOR WATER STORAGES IN THE BALLARAT AREA

Storage	Capacity (Ml)	Catchment area (sq.km)	Catchment description (see notes)	Authority	Remarks
Lal Lal Res.	60,000	260	1	West Moorabool Water Board	
Gong Gong Res.	1,902)		1)	The Ballarat Water Commissioners	
Kirks Res.	400)	2,553	1)		
Pincotts Res.	218		1)		
Beales Res.	415	681	1)		
Wilsons Res.	1,013	841	2)		Public land external to storage buffer, used for agriculture
White Swan Res.	14,107	117	3)		
Moorabool Res.	6,738	3,026	1)		
Newlyn Res.	3,300	67	2)	State Rivers & Water Supply Commission	
Hepburns Lagoon	3,000	760	2)		
Dean Reservoir	164	2.5	2)	Creswick Shire Council	Public land external to storage buffer, used for agriculture
Russells Res.	64	nil	)		
Cosgrave Res.	680	32	)		
Langi Ghiran Res.	70	1	3)	Ararat City Council	
Mt. Cole Res.	380	4.5	3)		

Table 30 (Continued)

MAJOR WATER STORAGES IN THE BALLARAT AREA

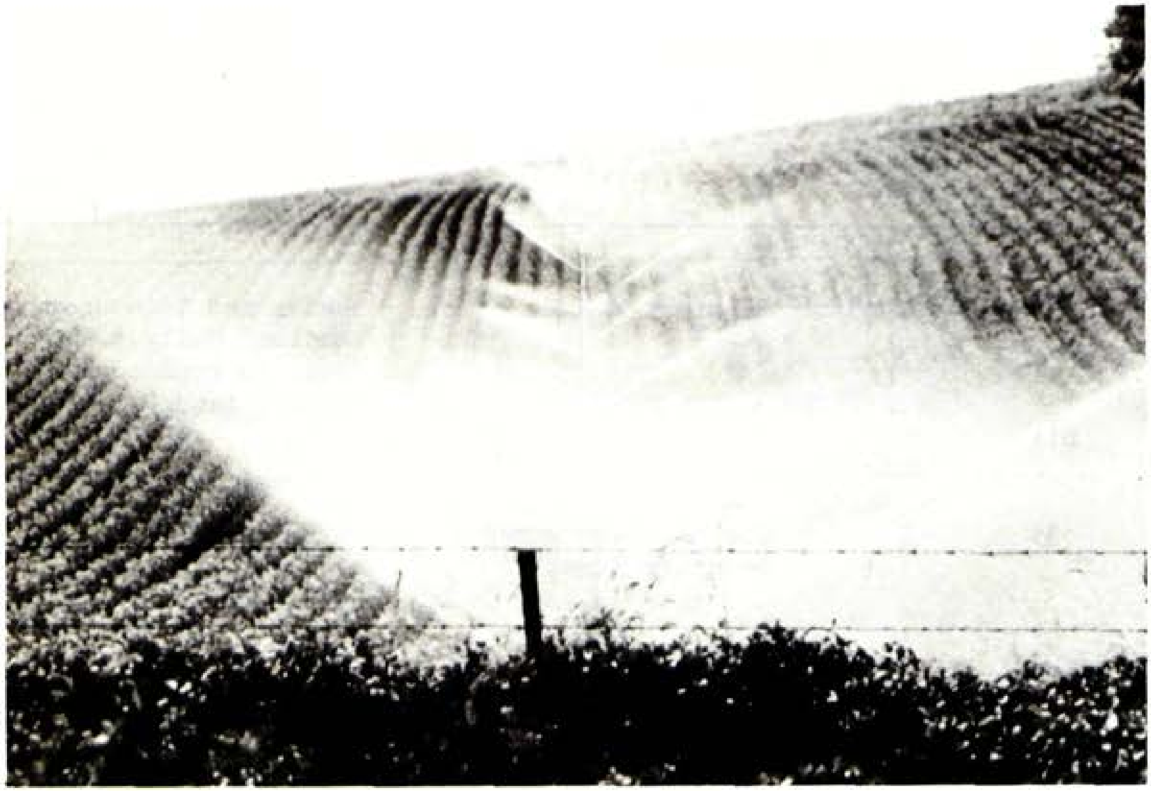
Storage	Capacity (Ml)	Catchment area (sq.km)	Catchment description (see notes)	Authority	Remarks
Fiery Creek Headworks	-	10	3)	Beaufort W.W.T.	Water fed into storages - Musical Gully & Troys Res. surrounded by forested public land
Musical Gully	230	1	)		
Troy's Res.	68	nil	)		
Korweinguboora Res.	2,100	35	3	Geelong Waterworks & Sewerage Trust	
Doctors Creek Res.	90	23	1	Lexton W.W.T.	

Notes:

1. More than half of catchment cleared and used for agriculture, and containing roads and townships. Area of forested public land adjacent to storage.

2. Cleared and used for agriculture and containing main roads and townships. Small buffer of public land adjacent to storage.

3. Entirely or almost entirely contained within forested public land.



Irrigation of potato crop near Dean

lagoon, primarily for irrigation of potato crops. Appendix 10 lists the authorized diversions from rivers and lakes in the study area.

Other uses

Water supplied from an old mining dam near Smythesdale is used for sluicing and grading Tertiary gravel beds. Water is supplied to Lake Wendouree from The Ballarat Water Commissioners supply system to maintain the level lost by evaporation. In 1976 this amounted to 770 Ml and in 1977 to 404 Ml.

Utilization of Groundwater Resources

Appendix 11 lists those parishes within the study area showing the number of licences issued and total authorized extractions from groundwater resources. Significant groundwater extractions occur in the Parishes of Ascot (1,100 Ml per annum) and Glendaruel (1,022 Ml per annum) west of Creswick, and in the

Parish of Bungaree (962 Ml per annum) to the south of Ballarat.

Of the 800 ha irrigated in these three parishes, approximately 530 ha are used mainly for potato-growing and other annual crops, with the remainder used for pastures and lucerne.

The township of Streatham obtains its domestic water supply from a 36 m deep bore, yielding 0.14 Ml a day with a T.D.S. of 1,500 mg per l. Water supply for the township of Learmonth is supplied from two bores. The proposed water supply to Waubra will be from a nearby bore. Apart from an area of high-quality groundwater north of Ballarat, the groundwater deposits in the study area are generally of poor quality, with T.D.S. content ranging between 3,000 and 7,000 mg per l.

Treatment of Water Supplies

Treatment of domestic water supplies to reduce the amount of algae, micro-organisms, colour, and turbidity to acceptable limits is more likely to be carried out in districts where water supply catchments support a number of diverse land uses. Incompatible uses, such as cropping and grazing along stream and storage buffers, may also introduce high levels of nitrates, phosphates, and pollution with faecal matter.

Because of diverse uses in the Lal Lal catchment, The Ballarat Water Commiss-

Groundwater extraction for watering stock in the parish of Glendaruel ioners chlorinate their share of water supplied from Lal Lal Reservoir. Other authorities that cholorinate their supplies are Creswick Shire Council, Lexton Waterworks Trust, Bannockburn Waterworks Trust, and Bungaree--Wallace Waterworks Trust.

Work on the construction of fluoridation plants at White Swan, Gong Gong, and Lal Lal Reservoirs has been halted pending the outcome of an independent inquiry into the fluoridation of Victorian water supplies.

Proposed Storages and Future Sources of Supply

Water resources of the region are sufficient to meet foreseeable domestic and stock demands and no firm proposals for the construction of new storages are current.

In general, there is little chance of developing major projects because of the difficulty of obtaining suitable storage sites. Possible sites have, however, been identified on the Avoca River near

Lal Lal Reservoir is operated by the West Moorabool Water Board

Amphitheatre and on the Woady Yaloak River, just north of the main Skipton--Geelong road. The lakes of the south-western section of the area cannot be seriously considered as a possible source of further supply. Catchment areas are incapable of maintaining lake levels during periods of less-than-average rainfall, and supplementary diversions from other catchments would appear to be impracticable.

Underground water in parts of the study area has potential for greater use, but detailed investigations would be essential before planned development could be considered.

Future demand

Water from Bungal Dam has been allocated to the West Moorabool Water Board and The Ballarat Water Commissioners over a demand growth period on a sliding scale, with the final allocation being on the basis of one-third to Geelong and two-thirds to Ballarat.

The demand for water from Lal Lal Reservoir at the present time is very low; of the potential regulated annual output of 23,000 Ml, it is estimated that only 3,000 Ml per annum is presently utilized. Based on predicted increases in demand in Ballarat and Geelong, however, the spare output of some 20,000 Ml per annum will be reduced until 1989, by which time the regulated output of the storage will be fully committed.

The initial stage of the Bungal Pumping Scheme is designed to meet the needs of the City of Ballaarat until about 1985 (predicted population of 80,000 at that time), when it could by arrangement increase its share of allocations from Bungal Dam to meet Ballarat's requirements up to the year 2000 (ultimate provision for a population of 140,000). Augmentation of the existing scheme would be achieved by duplicating the Rising Main in stages, progressively adding pumps as required.

It would also be technically feasible to transfer this 'spare water' from Lal Lal Reservoir, across the Divide into the Werribee River system near the township of Ballan, where it could be used to augment supplies either to those areas served by the Merrimu--Melton Reservoir system or to Pykes Creek Reservoir system.

Catchment Areas

Tenure

Catchments for some of the smaller storages - for example, those in the Mount Cole forest and Mount Langi Ghiran - are contained wholly within forested public land (reserved forest). Most of the larger storages, however, lie within catchments where the bulk of the land is cleared and held under private ownership; in these cases, the water authority generally owns or controls an area of land adjacent to the storage itself.

Aerial photograph of two storages managed by The Ballarat Water Commissioners

Uses

Land owned by The Ballarat Water Commissioners surrounding their storages at Gong Gong, Kirks, and Pincotts is used for pine plantations, and grazing and cropping is permitted at Wilsons Reservoir. At the larger storages the authorities have provided picnic facilities and ornamental plantings.

The blast furnace adjacent to the Lal Lal Reservoir has historic interest and provides the focus for a popular recreational area. Bona fide local residents are permitted to fish at certain terminal storages.

Planning controls

In order to prevent deterioration of the land and so protect water quality, whole catchments may be proclaimed under the provisions of the *Soil Conservation and Land Utilization Act* 1958 and the *Land Conservation Act* 1970. Under these *Acts*, the Soil Conservation Authority may become actively involved in controlling land use changes in the catchment. A further step in catchment control is the determination, after biophysical study and discussion with users, of the most suitable forms of land use in a water supply catchment.

In the study area, the following water supply catchments have been proclaimed: Lal Lal, Moorabool (She-oaks), Trawalla Creek, Creswick, Cairn Curran, and Wimmera. A land use determination has been prepared for part of the Lal Lal Water Supply catchment, and a proposal for proclamation of the Ballarat Water Supply Catchments has been prepared.

EEL FISHERIES

The short-finned eel *Anquilla australis*, is harvested from lakes and swamps in the Ballarat area by commercial fishermen using small boats and fyke nets. (These long, cylindrical nets are normally set at dusk and cleared at dawn the following day.)

The industry - a relatively new one, stemming from the mid 1950s - is supervised by the Fisheries and Wildlife Division. Currently, the Division has licensed about 28 commercial eel fishermen in Victoria, of whom five operate in the study area from a base at Skipton.

The greater part of the catch is frozen and exported, and the remainder is smoked and sold on the local market. Victoria is the main eel-producing State in Australia.

Life cycle of the short-finned eel

Mature eels spawn in the ocean, apparently in the deep waters of the Coral Sea. The larvae are carried by oceanic currents and, after undergoing a number of transformations, enter the estuaries of rivers along the south-eastern coast of Australia. At a later stage, the elvers migrate into the lakes and swamps and upper reaches of rivers and creeks. Following maturity, the eels migrate downstream to the sea and return to the spawning grounds.

Fishing waters

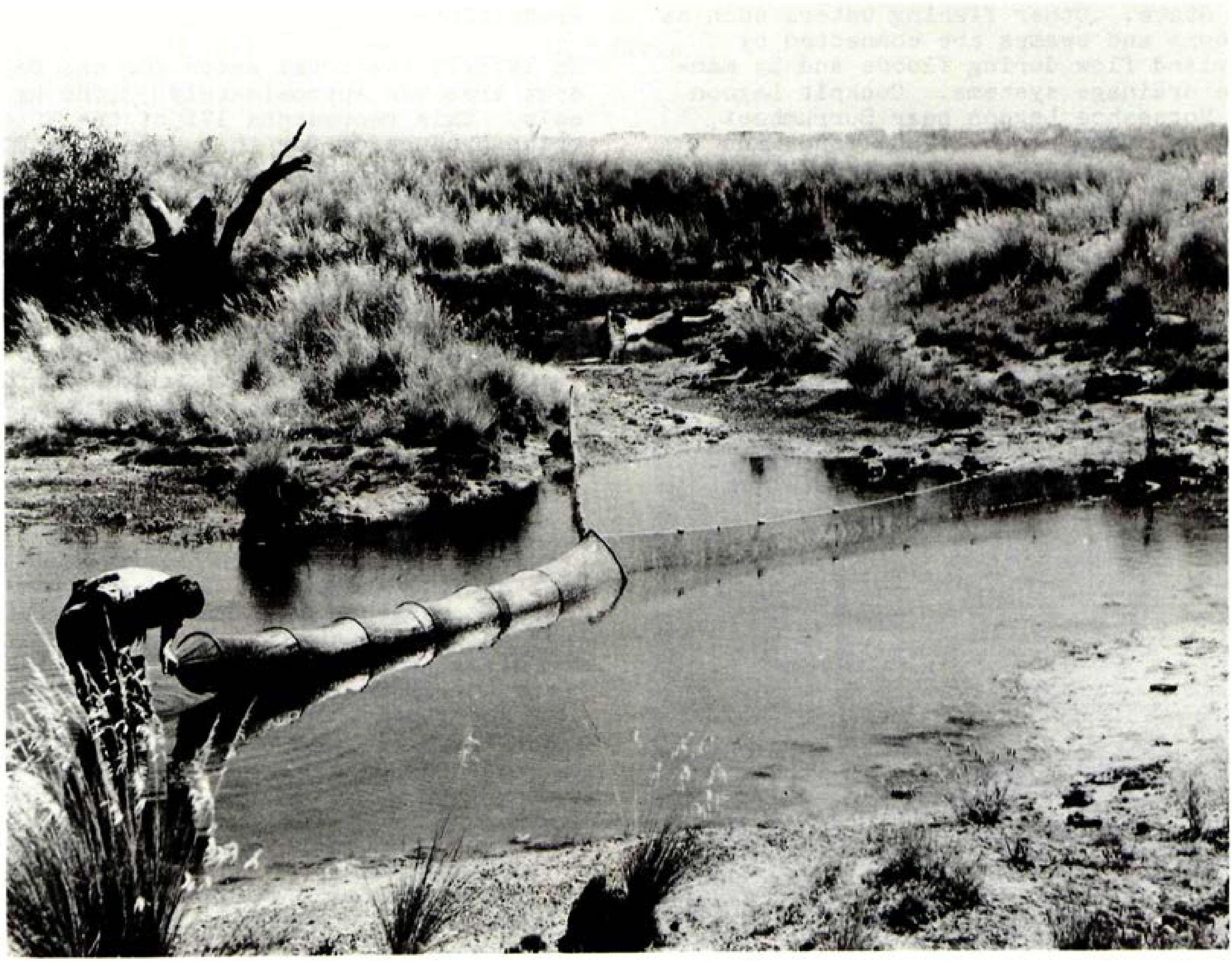
The main access routes from the sea to the watercourses and lakes of the study area are the Hopkins River and the Barwon River. The Hopkins River provides access to the major fishing waters - Lake Bolac and Lake Burrumbeet. Both are public land, and Lake Burrumbeet is the most important eel-fishing ground in

Table 31

EEL PRODUCTION IN THE STUDY AREA (kg)

	Lake Burrumbeet	Lake Bolac	Others
1976/77	14,811	2,249	7,153
1977/78	21,094	8,263	6,074
1978/79	17,445	6,566	7,012

Source: Fisheries and Wildlife Division



Fisherman setting fyke net

the State. Other fishing waters such as lagoons and swamps are connected by overland flow during floods and by man-made drainage systems. Cockpit Lagoon and Horseshoe Lagoon near Burrumbeet, Bingley swamp north of Shelford, and many other unnamed swamps and lagoons on private property are fished on a seasonal basis.

Production

In 1978/79 the total catch for the Ballarat area was approximately 33,000 kg of eels. This represents 17% of the Victorian production for that year (200,000 kg). Table 31 shows production figures in kilograms for the past 3 years for the two major lakes and other areas.

UTILITIES

Utilities and services essential to the community are often located on public land. These include water supply (discussed earlier), transport and communication systems, and the supply of energy. Public land is often utilized for waste disposal, survey markers, cemeteries, and institutional uses such as army training and correctional services. This chapter describes the current use of public land for these purposes and attempts to assess future requirements.

Waste disposal

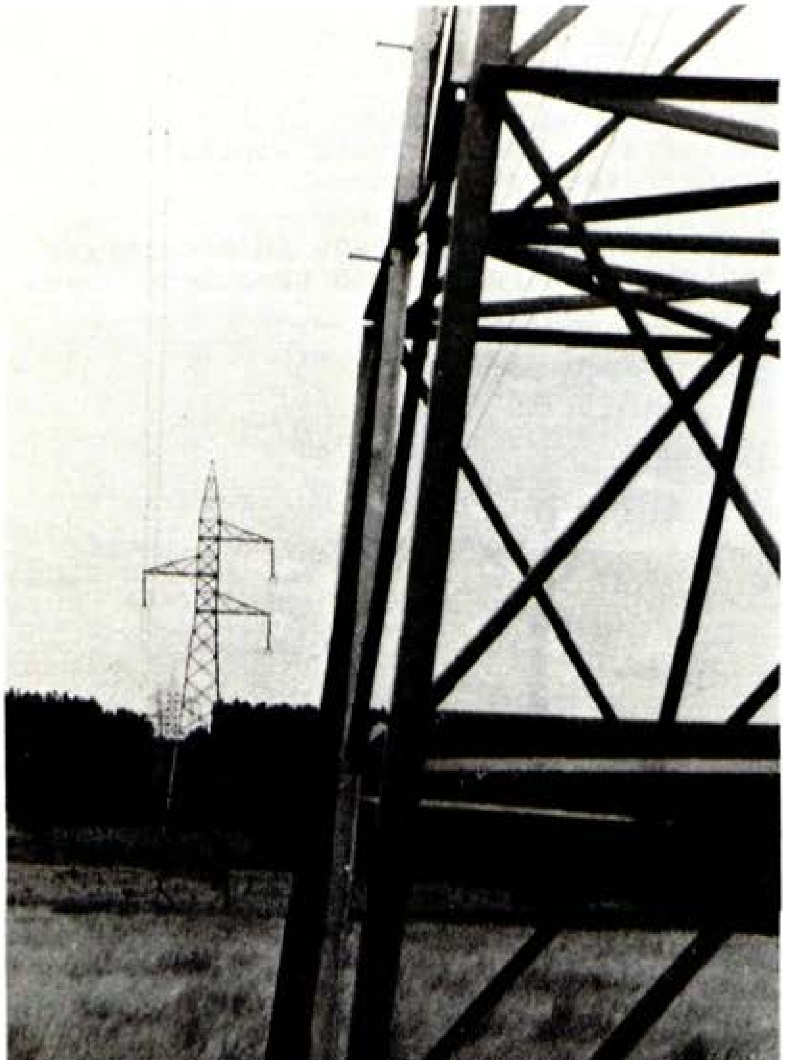
The disposal of waste produced by urban communities is an increasing problem for municipalities and land managers. Selection of new sites for rubbish tips can be difficult, as in many cases little public land remains near towns, and conflicts with recreation and landscape preservation often arise. Also, illegal dumping of rubbish occurs on public land.

Solid waste from towns in the study area is usually disposed of by the landfill method, often on public land reserved for this purpose. Certain solid wastes, for example kaolin wastes that are used in the paper industry, are dumped at Sago Hill on land owned by the City of Ballaarat. Toxic liquid wastes are transported to Melbourne.

Sewerage systems operate in the larger centres, generally, and treatment areas

Cemetery at Staffordshire Reef

are often located on Crown land reserved for this purpose (land vested in sewerage authorities is not public land according to the *Land Conservation Act*). For example, the Ballarat Sewerage Authority controls a large area of Crown land adjacent to the Yarrowee River south of Ballarat, which houses treatment works and maturation ponds. Further details on the sewerage authorities are included in Table 32.



Warrenheip--Terang 220-kV line

Water supply

This topic has been fully discussed in the chapter on water utilization. At this stage, there are no firm proposals for the future construction of water storages, although possible sites have been identified on the Avoca River near Amphitheatre and on the Woady Yaloak River just north of the Geelong--Skipton road.

Electricity supply

The *State Electricity Commission* of Victoria supplies electricity to the study area from the State high-tension grid network. Single-circuit 220-kV lines from Bendigo, Horsham, Geelong, and Terang feed into a terminal station sited on the Western Highway at Warrenheip.

Sub-transmission lines of 66 kV link up to substations adjacent to the City of Ballaarat for further distribution to urban areas.

Easements for sub-transmission lines and wood-pole distribution lines run mainly in road reserves, but some portions are

Table 32

SEWERAGE AUTHORITIES

Authority	Population served	Method of treatment	Effluent disposal
Ararat Sewerage Authority	8,000	Primary sedimentation, filtration, secondary sedimentation, sludge digestion and drying lagoons	Irrigation of pasture. Any effluent to Hopkins River
Ballarat Sewerage Authority Ballarat Nth (Trade Wastes) Ballarat South	58,600	Primary sedimentation, biological filters, humus tanks, maturation ponds, sludge digestion and drying facilities	Ballarat Sth. Effluent passes through maturation ponds to Yarrowee River. Ballarat North effluent passes through maturation ponds to Burrumbeet Creek
Beaufort Sewerage Authority	1,200	Oxidation ponds	Yam Holes Creek
Creswick Sewerage Authority	2,000	Oxidation ponds	Proposed effluent disposal infiltration bed, then to Creswick Creek
Cardigan Village	1,000	Oxidation lagoons	Irrigation of pasture
Buninyong (proposed)	900		
Mt Helen (proposed)	400		

Source: State Rivers and Water Supply Commission, Local Authorities Branch.

in their own easements. The 220-kV transmission lines pass through both public and private land along a 36.58-m easement. On the Ballarat--Terang route, the easement passes through approximately 12 km of forested public land in the Staffordshire Reef area.

To cover future requirments, the Commission is planning an additional 220-kV line for the Geelong--Ballarat route; a possible additional tower line between Ballarat and Bendigo; and a terminal station near Ararat. Future developments within the sub-transmission service have also been planned. Future transmission and sub-transmission lines would be sited adjacent to existing easements or reserves.

Supply of natural gas

The Gas and Fuel Corporation of Victoria has the responsibility for a pipeline conveying natural gas from Brooklyn to Ballarat. This pipeline traverses a 20-m easement north of the Western Highway, generally on freehold land. There are no plans for the extension of pipeline easements at this stage.

Transport

Road transport

The Country Roads Board is the authority responsible for meeting the cost of, constructing, and maintaining the State's road system. In addition, the Forests Commission and local municipalities have a certain sphere of importance.

The Western Highway, a State highway (also designated a national highway), links Melbourne and Adelaide, passing through Ballarat. Proposals to re-route the highway to the north of Ballarat have been suggested, to provide a freeway around the city. The proposed route would pass through Crown land and reserved forest north of Nerrina.

Rail transport

Ballarat is an important railhead in the Victorian Railways' network. At this point, heavy-duty track from Melbourne to Adelaide connects with lines to Geelong and Mildura. Another line connects Ballarat and Skipton. Uneconomic routes that have been terminated over the years include the Ballarat--Waubra, Creswick--Daylesford, and Ballarat--Cressy lines. Most of the land along the old rail lines has been sold, but the part of the route passing through reserved forest north of Barkstead remains intact.

Air transport

Two major aerodromes owned by the respective municipalities and licensed by the Commonwealth Department of Transport are located at Ballarat and Ararat (see Map 10). The Department also maintains a communication site on Ben Nevis and Smeaton Hill (on private land), and a navigational-aids site in reserved forest to the north-west of Little Hard Hills.

Communications

Telecom Australia operates three radio/telecommunication sites in the study area - on Mount Buninyong, Lookout Hill, and Mount Hollowback (on private land).

No other sites are required in the foreseeable future.

As part of its communication network, the Forests Commission has two remote V.H.F. radio installations - one on Camp Hill near Beaufort, and the other on Sulky Hill near Creswick.

The Commonwealth Postal and Telecommunications Department operates a facility on Lookout Hill for the national television station ABV-3 and the Ballarat commercial station. This site is under lease to the Forests Commission. No sites for the future extension of the national broadcasting service are envisaged.

Communication systems and navigational aids managed by the Department of Transport are discussed above.

Military Use

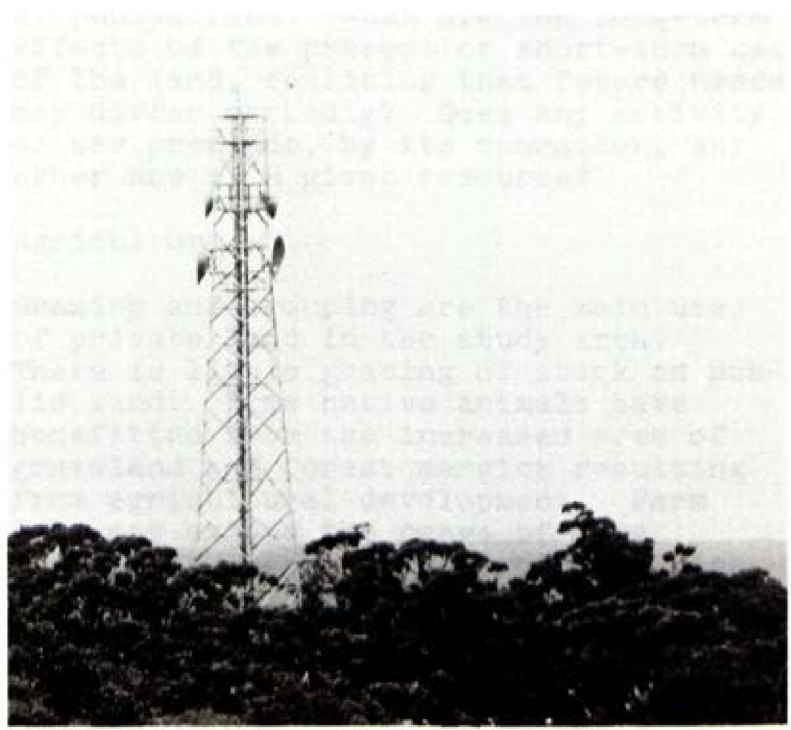
The Ballarat area contains three areas of public land proclaimed under the *Defence Act* for use as military training areas. The Mount Cole Training Area includes reserved forest broadly bounded by Mounts Lonarch and Cole and Ben Nevis. The Little Hard Hills Training Area is broadly bounded by Berringa, Smythesdale, and Little Hard Hills. Glen Park Training Area extends from Creswick to the White Swan Reservoir.

Military training exercises, up to 2 days a year, are conducted and may involve up to 180 personnel, 10 heavy vehicles, and 3 light vehicles. Firing of blank ammunition and the use of pyrotechnics may be included.

Institutional Use

The Department of Community Welfare Services administers the Ararat Prison and Langi Kal Kal Youth Training Centre.

At Langi Kal Kal, youths serving sentences for minor offences enter into



Radio/telecommunication tower on Mount Buninyong programs aimed at bringing about a more satisfactory adjustment to community living. The farm attached to the centre (see the agriculture chapter) provides one opportunity for education and training.

The Ararat Prison is the largest outside Melbourne. Its industries include manufacture of tubular steel furniture, signwriting, and silk-screen printing.

Prisoners are also employed in farming and re-forestation work.

Other Uses

Public utilities and institutions occupy public land for schools, cemeteries, trigonometrical stations, public buildings and municipal depots. Small areas of public land are continually required for these purposes.

LAND USE RELATIONS

The preceding chapters described the natural resources of the study area and discussed the existing and potential uses of public land. This chapter considers interactions between the principal land uses - agriculture, apiculture, mining, nature conservation, recreation, timber and water production, and the provision of services.

Uses are competitive when an increase in one leads to a decrease in another based on the same set of resources, supplementary when the increase in one does not change the other, and complementary when the increase in one benefits the other.

Depending on their relative intensities, a combination of types of land use may vary between being complementary, supplementary, and competitive. Generally, the most flexible are those that complement or supplement many others over a great range of intensities.

The more obvious physical or economic aspects of such interactions are only part of land use relations. There are also other direct and indirect effects, such as social or environmental consequences. All these factors collectively determine the degree of compatibility of various land uses.

These interactions (land use relations) must therefore be considered before decisions can be made regarding the uses of public land. What are the long-term effects of the present or short-term use of the land, realizing that future needs may differ markedly? Does any activity or use preclude, by its operation, any other use of a given resource?

Agriculture

Grazing and cropping are the main uses of private land in the study area. There is little grazing of stock on public land. Some native animals have benefitted from the increased area of grassland and forest margins resulting from agricultural development. Farm dams may extend the range of some amphibians, reptiles, and bird species. Nevertheless, agriculture is normally incompatible with most aspects of nature conservation because, although some species benefit, most are severely reduced in number or eliminated by the removal of their habitat and the introduction of alien plants and animals.

Agricultural activities have in many cases added visual diversity to the landscape, increasing enjoyment for those sightseeing, picnicking, or driving for pleasure. The volcanic cones north and west of Creswick provide an example of a scenic agricultural landscape.

In most cases, agriculture affects water production; conversion from forest to grassland can alter the volume and timing of run-off, sometimes causing erosion and so affecting water quality. Pollution may also result from excessive or injudicious use of fertilizers and pesticides, or from the concentration of stock near watercourses.

The use of additional forested public land for agriculture would compete, in particular, with timber production and most aspects of nature conservation, and to varying degrees with most other forms of land use. Forest grazing may aid fire protection by reducing the accumulation of fine fuels in forested areas. However, cattle may selectively graze native herbs and grasses and so reduce the conservation value of an area.

One conflict with existing agricultural use in the study area arises from the increasing pressures of urbanization, tourism, and recreation. The demand for small-acre subdivisions may cause land prices and rates to rise well in excess of economic rural values. Farmers on viable properties may therefore be placed under increasing pressure to subdivide their land for 'rural retreats' or hobby farms for people from Melbourne and local towns.

Apiculture

Apiculture may complement agriculture where the bees serve the useful function of cross-pollination. Being based largely on the maintenance of native flora, apiculture is supplementary to timber production, recreation, water production, and some aspects of nature conservation.

Bees do compete with native fauna for nectar and pollen, but the significance of this competition and its ecological effects remain unknown.

Mining and quarrying

Mining and extractive industries are scattered throughout the study area. These can be competitive with most forms of land use through site disturbance, roading, and pollution. Competition is usually localized, however, and its degree depends on the type and scale of operation.

Underground mining does not usually involve as much site disturbance as open-cut mining or surface stripping, but dumping of waste material such as mine tailings may still conflict with other uses. Other aspects that must be closely controlled are roading, drainage, and most importantly, rehabilitation of the site when operations have ended.

Most forms of mining and quarrying are incompatible with timber production,

The timbered volcanic cone of Mount Warrenheip and cleared cones around Dean are parts of a diverse agricultural landscape apiculture, agriculture, and nature conservation.

Nature conservation

Nature conservation is generally compatible with a wide range of uses, such as water production, apiculture, and low-intensity recreation and hardwood production. It tends to compete with any activity that radically changes the natural vegetation, such as mining, agriculture, urban development, or intensive forestry.

Over-use by recreationists may be a problem in areas dedicated to nature conservation, because members of the public often see these areas primarily as recreational resources. Other aims of parks and reserves - such as biological conservation, landscape preservation, and scientific research - are therefore threatened.

Areas set aside specifically for scientific reference must be managed to exclude activities other than limited scientific study. This use is complementary with nature conservation and water production only.

Recreation

Outdoor recreation encompasses a wide range of activities, and interactions with other land uses vary according to the type of recreation and its intensity.

Some activities - such as golf-courses and rifle ranges - require areas with specialized recreational facilities. Also, certain informal types of recreation need natural undisturbed sites, and these compete with all other land uses except perhaps nature conservation and water production.

A single land use in a particular area may conflict with one type of recreation and yet simultaneously complement another. For example, an abandoned quarry may mar a panoramic view for sightseeing yet provide an ideal site for gem fossicking or for use by trail bikes. Similarly, forestry roads may reduce the value of an area for nature study, but make it more accessible for picnicking and pleasure driving.

Most recreational activities are relatively flexible, however, and can be accommodated in areas managed primarily for other uses. Nevertheless, some pastimes (such as fishing or the use of off-road vehicles) can become exclusive, especially at high usage rates.

Softwood timber production

Softwood timber production in plantations is an inflexible land use. It is competitive with hardwood timber production, agriculture, nature conservation, and some types of recreation activity. Softwood production is a complementary use in catchments surrounding many of The Ballarat Water Commissioners storages. Pines provide essential cladding for a catchment once cleared for agriculture as well as a source of income when harvested.

Plantations can also add visual diversity to an area. Because of the relatively open understorey in mature plantations, they provide good opportunities for picnicking and other recreational activities such as orienteering, trail-bike riding, and camping.

Hardwood timber production

Production of timber - a renewable resource - may be considered a relatively flexible land use when carried out at low intensity. It is compatible with forest grazing, honey production, and all but the strictest forms of nature conservation. It can benefit some forms of outdoor recreation by providing access tracks for walking and pleasure driving.

Harvesting operations have an immediate effect on values such as vegetation, fauna, and landscape. The effects become more noticeable as the size of the area being harvested increases and when most or all of the trees in a stand are felled. In mountainous terrain, its visual impact may adversely affect certain recreational values at points some distance from the actual operation.

Increasing the levels of hardwood production decreases its compatibility with other uses, such as nature conservation and many forms of recreation. Intensive practices may favour certain commercially valuable species of eucalypt, remove trees containing sites for nesting animals, greatly reduce the size to which trees are allowed to grow, intensify harvesting activities, and require the increased use of fire.

Water production

Production of water is an important use of public land. To some extent it is competitive with agriculture, hardwood timber production, mining, and recreation, depending on the intensity of these uses, the management techniques employed, and the intended use for the water.

Activities such as logging, road-making, quarrying, clearing, and grazing can cause soil disturbance and reduce absorption by the soil, leading to increases in surface run-off, stream turbidity, peak flows, and siltation. In catchment areas, however, co-operation between the authorities concerned ensures that these hazards are minimized.

Inundation by water in storages has various effects on nature conservation. It destroys the original habitats, and this may be important if the area contains endemic or notable species. The water body, however, creates a new aquatic habitat that has value for some fish and waterfowl. Variations in level, as it is utilized, can reduce its value for nature conservation. Storages alter flow regimes and may also affect water temperature and oxygen content downstream. Thus they can affect wildlife habitat away from the actual storage site.

Water storages also increase the opportunities for some forms of recreation. Picnicking in landscaped gardens at White Swan and Kirks Reservoirs is a popular activity, both for residents of Ballarat and for day-trippers from Melbourne.

Public utilities and transport

Generally the provision of these services requires the allocation of small areas of land, but in most cases this represents an inflexible use.

Due to growing recreational pressures and more interest at a local level in nature conservation, there are increasing problems with waste disposal. Most disposal sites are generally regarded as unsightly, sometimes produce offensive odours, and, if not carefully managed, may have detrimental effects on other uses such as water production.

Cleared easements for transmission lines or gas or water pipes are competitive with conservation of flora and fauna, and may be visually unattractive from surrounding areas.

Similarly, telecommunications facilities on peaks or ridges conflict with scenic values, especially when constructed in attractive or remote landscapes.

Since these services, and most others, are considered essential, compatibility with other land uses is achieved by careful siting, location, and design to minimize the conflicts.

PART IV

BLOCK DESCRIPTIONS

BLOCK DESCRIPTIONS

In this part of the report, the study area has been divided into four blocks that have similar climate, soils, topography and vegetation within broad limits.

For each block, the location and land tenure, the nature of the land, present uses, capabilities for various uses, present condition of the land, and likely land use hazards are described.

A consistent format of headings and subheadings has been used to help compare specific information for various blocks. Some sections deal only with the public land. These include vegetation, recreation, and wood production.

A key diagram at the beginning of each description gives the approximate location of that block in the study area. Greater detail for all blocks is shown on Map 5.

Capability

This term refers to the value of the land for the particular use to which it may be put. Present levels of use are described, where possible, to give some indication of capability. The potential productivity of land is important, particularly in the long term. For some uses such as nature conservation it is based primarily on the inherent characteristics of the land. For others it also depends on inputs (such as fertilizer applications) that raise productivity.

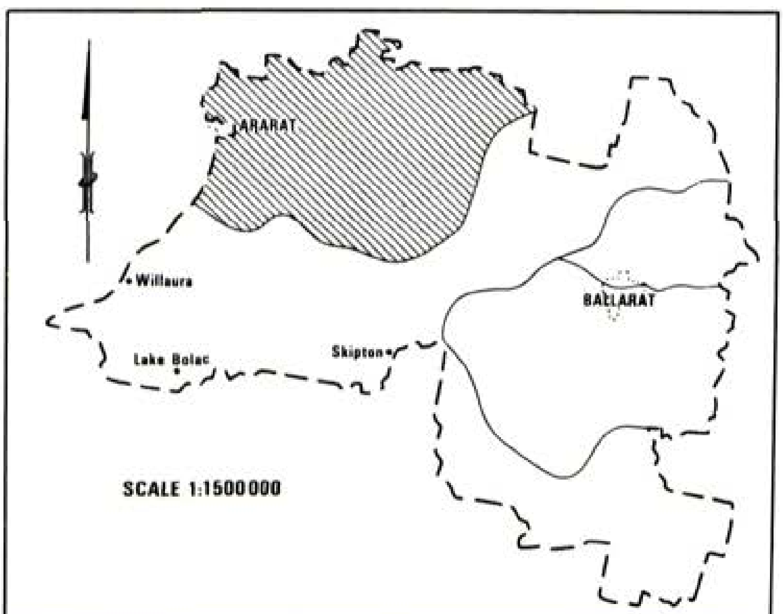
Capabilities are given in general terms only, because the amount of information available has varied from block to block, and because some of the values have been difficult to quantify. In assessing capability, comparisons have been made with other blocks and with other parts of the State.

1. LANGI GHIRAN--BEN MAJOR

A. General

1. Tenure and location

In this block, large parcels of forested public land, which are mostly reserved forest managed by the Forests Commission, occur as fairly discrete sub-blocks: Dunneworthy, north of Ararat; Langi Ghiran; Ben Nevis--Ben Major; and Waterloo-Beaufort. A further area,



1. LANGI GHIRAN—BEN MAJOR

Langi Kal Kal, which is reserved for penal purposes and used for farming, is managed by the Department of Community Welfare Services. Public land in the block totals approximately 28,500 ha.

Langi Ghiran and Ben Nevis--Ben Major sub-blocks fall on the Great Dividing Range and drape the headwaters of the Avoca and Wimmera Rivers, and Fiery, Middle and Trawalla Creeks. The Hopkins River and Mount Emu, Mount Cole and Glenlogie Creeks rise in agricultural land.

The City of Ararat and the townships of Beaufort, Lexton, Amphitheatre, Elmhurst and Raglan fall within this block.

B. Nature of the Land

1. Climate

North-westerly and south-westerly air-streams produce high rainfalls as they rise about the ranges. Falls in excess of 700 mm per annum can be expected along the Great Dividing Range (there are no long term stations in the mount-ains), diminishing to 600 mm in the foothills and to 550 mm on the western edge of the Dunneworthy forest.

2. Geology and geomorphology

The area contains basement material of sediments formed in the Cambrian period. Later, in the Devonian, these sediments were intruded by molten rock that solidified (as granite) before reaching the surface. Erosion, taking place over many hundreds of millions of years, then exposed the granites that now form the peak of Mount Langi Ghiran, the plateau containing Mounts Buangor, Cole and Ben Nevis, and the isolated Granite Hill. The Dunneworthy and Ben Major--Mount Lonarch sub-blocks are made up of the earlier Palaeozoic sediments. There are ridges of metamorphosed rocks that are highly resistant to erosion at the junction of granite and sediments. A good example is the basin-like phenomenon near the Mount Lonarch district, which is surrounded by the resistant ridges and mountain peaks of Mount Lonarch, Ben Major and Ben More.

Volcanic activity in the Tertiary period resulted in lava flowing along the valleys of Fiery Creek and the Hopkins River. The North-Western Highway bisects these watercourses close to the point where the flow came to a halt. The lava flowed around the eastern side near Langi Kal Kal, and at this point Mount Emu Creek follows the junction of the sediments and the lava plain.

Alluvium and gravel from material washed out during the Tertiary and Quarternary periods now form plains and terraces along the valleys of major rivers and creeks.

In geomorphic terms, this block is referred to as the "midlands" and the plains (of both sediments and basalt) as "midland plains". These features are illustrated in Maps 3, 6 and 8.

3. Soils

Granite parent material mainly produce yellow duplex soils, but there are areas of coarse sand soils of uniform texture in the block, which are used for the extraction of granite sand. Yellow duplex soils occur on the gently sloping Palaeozoic sediments around Dunneworthy. Stony gradational soils may occur on the steeper and metamorphosed sediments and there are limited areas of soils formed on basalt.

4. Vegetation

A great range of vegetation types can be found on public land in this block (see Map 9, Sheet 1). The granite peaks of Mount Buangor, Lookout Hill and Dawson Rocks support communities of snow gum, whereas other peaks such as Ben Major, Ben Nevis and Langi Ghiran have red stringybark and long-leaf box.

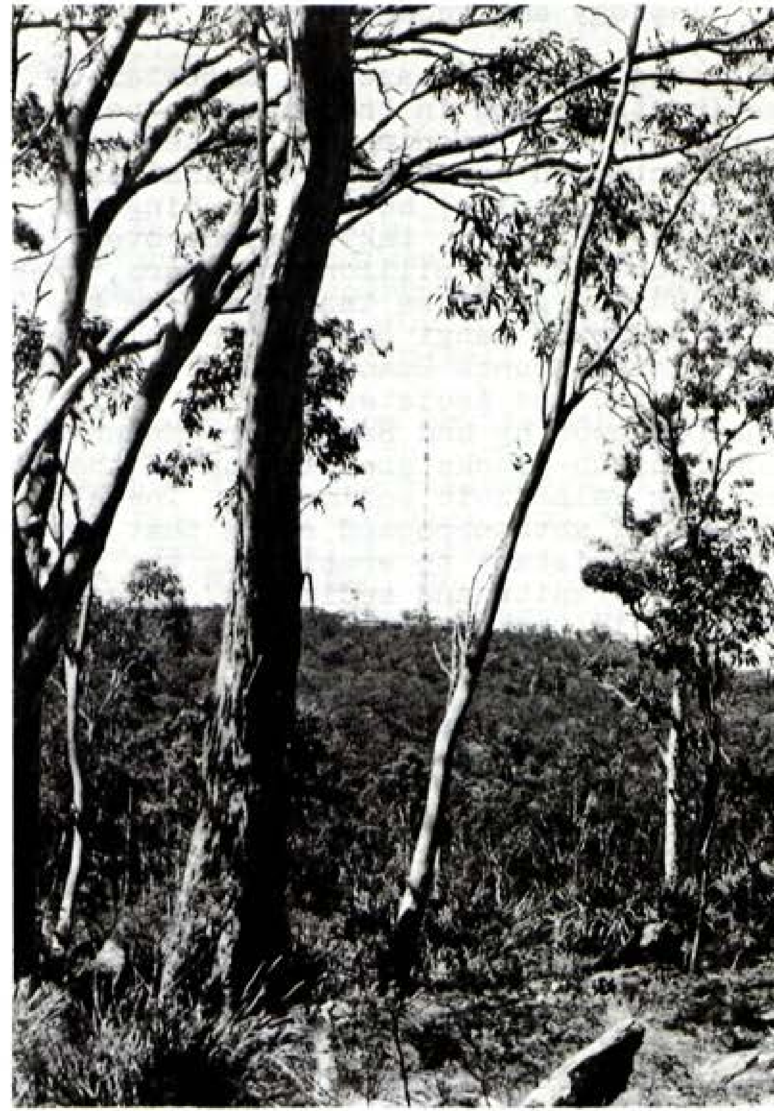
Open forest III and IV of messmate stringybark associated with blue gum, brown stringybark and manna gum cover the axis of the Mount Cole/Ben Nevis plateau. The northerly and westerly foothills of the plateau support red stringybark (open forest II) with varying amounts of blue gum and long-leaf box. The southerly and easterly slopes exhibit candlebark, blue gum and narrow-leaf peppermint.

The Ben Major and Waterloo--Beaufort sub-blocks consist of undulating sediments. On northerly slopes there are forests of red stringybark and long-leaf box (open forest II); messmate stringybark (open forest II) occurs on the southerly slopes, with candlebark, scent-bark, swamp gum and peppermint in the broader gullies and flats.

The western side of the Langi Ghiran sub-block supports a woodland of yellow box and river red gum. At Dunneworthy, yellow gum woodland occurs on the flats with red stringybark (low open forest and woodland) on the low ridges.

River red gum occurs on frontages to the Hopkins River near Dobie and the Wimmera River downstream from Elmhurst. A stand of red gum woodland occupies part of the Langi Kal Kal Youth Training Centre.

Two undescribed species of grevillea are abundant locally. One occurs only on the eastern slopes of the Mount Cole plateau and the other only in forests south of Ben Major. Shining tea-tree and veined beard-heath are found at Langi Ghiran, but the only other occurrence of these two species is in the Grampians.



Snow gum community at Dawson Rock. Lookout Hill television tower and radio telecommunications tower in the background

5. Fauna

Major habitats that occur on public land are general forests, pine plantations and small areas of wetland including permanent streams and the Bittern lagoon. The species common in these habitats are discussed in Chapter 11 and listed in Appendices 6, 7 and 8.

It is interesting that the wombat, bush rat and greater glider are absent from the wet open forests of the Ben Nevis--Ben Major sub-block. (This area is separated from the nearest similar habitat, at Barkstead, by the expanse of the basalt plains.) The swamp rat is distributed throughout the damp ferny habitats typical of the wet open forests and the yellow-footed antechinus is restricted to dry open forests near Mount Langi Ghiran and Mount Cole. The red-necked wallaby and the introduced red and sambar deers are found in the Ben Nevis--Ben Major sub-block. There is indirect evidence that the yellow-bellied glider is present in this area.

6. Land systems

The following groupings of land systems (which are differentiated by geological and topographic differences), predominate on public land: Granite hills II, Palaeozoic sediments I, II and III. On private land, land system groupings are Granite hills I, Palaeozoic sediments I and II, Metamorphics, Alluvial plains, Tertiary, and Basalt plains I and IV.

The reservoir at Mount Langi Ghiran

C. Present Use and Capabilities

1. Conservation

The Langi Ghiran sub-block has a high capability for nature conservation. Few roads penetrate the rugged granite area and there is no significant history of timber extraction. Langi Ghiran contains an aboriginal cave - the 'cave of the serpent' - and a lagoon in the saddle between Mount Langi Ghiran and Mount Gorrin is believed to have been frequented by the Aborigines. The area shows an affinity to the vegetation of the Grampians, having in common two plant species that are not found elsewhere.

Parts of the Ben Nevis--Ben Major sub-block also have a high capability for nature conservation. There are two endemic grevilleas (Mount Cole grevillea and Ben Major grevillea), and the swamp gum *Eucalyptus yarraensis*. The forests in the Mount Cole/Ben Nevis plateau contain blue gum at the westerly limit of its range and tall stands of regenerated messmate stringybark, which have been retained as an example of the former forests. Attractive stands of snow gum occur on Mount Buangor - the highest mountain in the study area (989 m) - and on Dawson Rocks.

Geological features worthy of conservation include the area of contact between granite and sediments that is exposed in the railway cutting near Langi Ghiran; the amphitheatre of metamorphosed ridges near Mount Lonarch; and the road cutting through Palaeozoic sediments on the Western Highway near Beaufort.

Items of historic interest include the gold-mining relics associated with the Fiery Creek diggings, in particular the mullock dumps along the former Main lead and Waterloo lead.

The water supply systems at Langi Ghiran include storages and water races constructed late last century using locally quarried stone.

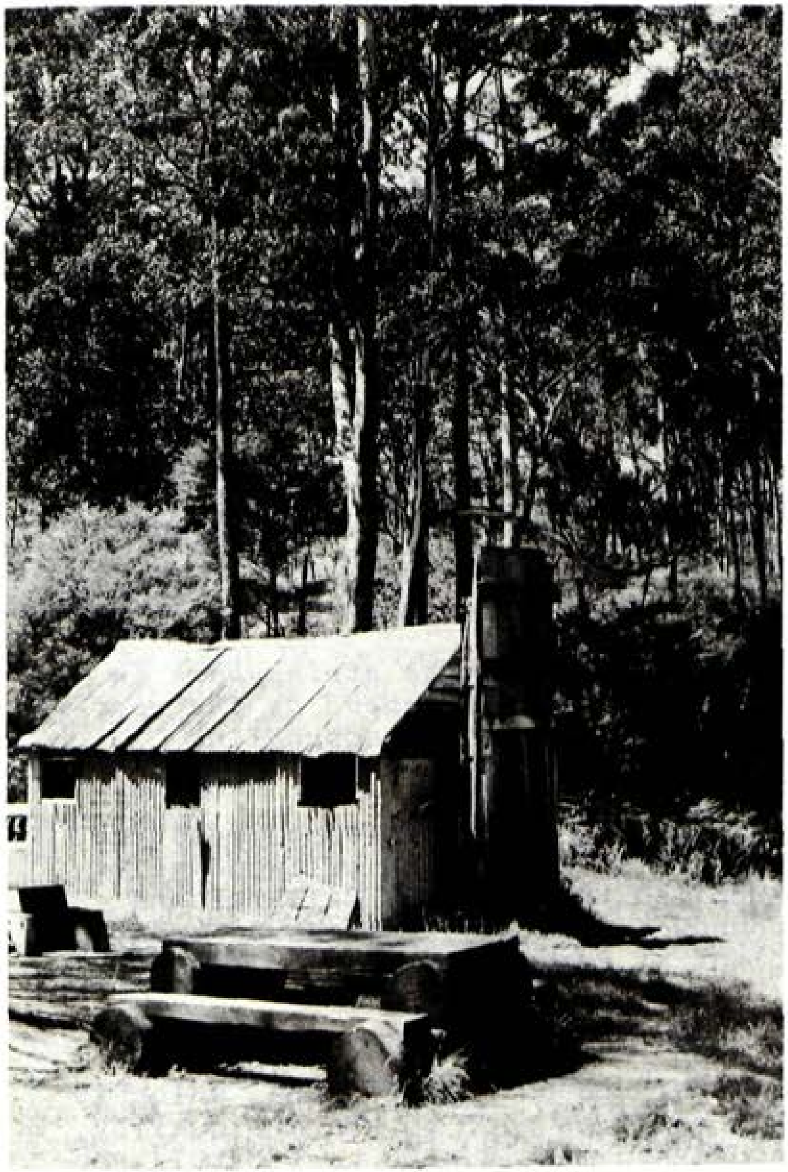
The lagoon and associated red gum woodland at Langi Kal Kal is typical of many areas on the basalt plains. Its presence on public land, as well as its use by water birds including the brolga, greatly enhance its conservation value.

2. Recreation

The major recreation resources of this block are the forested mountains and foothills which comprise the bulk of the public land. The areas are discussed in Chapter 15 and shown on Map 10.

Recreational development has been concentrated on the Mount Cole State forest, which includes reserved forest along the Ben Nevis--Mount Cole--Mount Lonarch divide. Fourteen picnic and camping areas are maintained by the Forests Commission, which has also designated (under the *Forests Act*), the Buangor Forest Park, Ferntree Waterfalls Scenic Reserve, the Glut Roadside Reserve and the Victoria Mill Scenic Reserve.

Popular activities in this forest include bushwalking, camping, picnicking, pleasure driving, and to a lesser extent rock climbing, horse riding and car rallies. The camp sites at Middle Creek and Ditchfields are popular with school



Mugwump picnic ground is situated in the Mount Cole Forest

groups and scouts; impressive views can be obtained from the prominent peaks of Ben Nevis, Mount Buangor, Lookout Hill, Ben Major and Mount Lonarch. The Forte picnic area has recently been established within the pine plantation south of Mount Lonarch.

Most of the Langi Ghiran sub-block is designated as a forest park, the main aim for which has been minimal recreational development. Its attractions include a walking track to Mount Gorrin, Aboriginal cave art, varied flora, rocky outcrops and the old reservoir. Archery tournaments are occasionally held on a site adjacent to the small picnic ground.

A highway relaxation area has been established beside the Hopkins River at Dobie. Rest facilities have been provided on the river frontage for the benefit of long-distance travellers.

Areas of public land adjacent to large townships, are frequently used by local residents. For example, the forested areas south and north of Beaufort are used for nature study, picnicking, yabbying and horse riding.

3. Hardwood

Certain areas in this block have stands producing hardwood timber at between 3 and 8 cu.m per ha per year. These areas are classed as highly and moderately productive and are labelled 2b and 2c on

Map 9. The stands, mainly of messmate stringybark, blue gum and manna gum, occur along the Great Dividing Range, on the Mount Cole plateau and at Mount Lonarch. They supply sawlogs to two mills at Beaufort and one at both Ararat and Chute.

Harvesting and regeneration is concentrated in areas of *Armillaria* dieback as part of a technique to control the fungus.

The remaining forested areas in the block are classified as stands of low productivity (see Table 24). However, they do have the capability to supply minor forest produce such as farm posts and firewood.

4. Softwoods

Radiata pine was first planted in 1965 in an area south of Mount Lonarch and now covers an area of about 1280 ha extending east along the Great Dividing Range from the Raglan-Elmhurst road. In past years, the Forests Commission has purchased farmland mostly on the south side of the Divide for softwood planting. Most of this farmland is estimated to be about site quality V. Future purchases of such land would be dependent on its availability at a suitable price. The Commission also plans to continue the plantation eastwards into forested public land of estimated site quality V. The planting rate is presently 80 ha per year.

Die-back in messmate stringybark in the Mount Cole forest caused by the root-rot fungus Armillaria luteobubalina

Utilization of the softwood resource started in 1978, with pulpwood being supplied to a mill at Ballarat and roundwood posts to a pressure treatment plant at Beaufort.

5. Agriculture

Agriculture on private land, which is all rated as poor to average quality, is concerned mainly with beef cattle and sheep for wool. In general terms, the vegetated public land has a low capability for agriculture.

At Langi Kal Kal Youth Training Centre, the Department of Family Welfare Services runs a farming enterprise to provide beef, lamb and mutton for its various department's. Youths under detention at the training centre work as farm labourers.

Sheep are grazed under an annual licence system on reserved forest at Dunneworthy, on Crown land at Warrak, and on various water frontages.

There are 19 bee farm licences and numerous temporary licences on public land. All available sites in the vicinity of yellow box stands are being utilized.

6. Minerals

Granite sand is extracted from shallow pits on public land near Mount Cole by the Shires and the Country Roads Board, and from a privately owned pit northwest of Mount Langi Ghiran. Former pits near Langi Ghiran have been re-vegetated. In the past, Tertiary gravels have been taken under tailings licence from former deep lead-mining dumps along the Waterloo lead and from gravels along the Wimmera River.

The capability for the supply of sand from granite colluvium is high on the outwash slopes surrounding granite areas and low for the supply of Tertiary gravels. There is potential for the discovery of gold and other minerals around the Palaeozoic sediments adjacent to and beneath the basalt. Exploration licences indicate an interest in all of the block except the granite areas.

7. Water

Major river catchments on public land include those of the Wimmera and Avoca Rivers. Approximately 2% of the Wimmera River catchment (proclaimed) and 1% of the Avoca River catchment lie within the block. Trawalla Creek is also within a proclaimed catchment. Forested public land on both sides of the Divide encompass water supply catchments for Ararat, Beaufort, Waterloo and Elmhurst.

The township of Ararat receives its water supply from a storage at Mount Langi Ghiran and a further storage, connected by underground pipeline, at Mount Cole. Elmhurst is supplied from the headwaters of the Wimmera River.

South of the Divide, Beaufort and Raglan are supplied via pipeline and storages (Musical Gully and Troys Reservoir) from the headwaters of Fiery Creek. Waterloo receives its water from a small storage located on public land adjacent to the townshipm and Lexton is supplied from a weir on Doctors Creek.

8. Utilities

Communications sites have been established on many of the higher points along and adjacent to the Great Dividing Range. On Lookout Hill there are towers for national and commercial television; on Ben Nevis, an air-transport communications site and a fire tower; Mount Lonarch has a fire tower. Camp Hill near Beaufort has a station to aid the Forest Commission's V.H.F. communication system.

The Australian Army uses the Mount Cole and Mount Lonarch forests for field training exercises up to 6 days per year.

The Ballarat to Horsham 220 kV transmission line passes to the north of the Great Dividing Range, but occupies little public land.

9. Hazards

The incidence of wildfire on forested public land is low. During the period 1974/75 - 1978/79 the Forests Commission attended 12 fires in State forest and 14 fires on private land within 1 km of the forest boundary.

The honey fungus *Armillaria luteobubalina* is potentially very hazardous to wood productivity. The fungus is associated with the dieback disease which now affects eucalypts and some understorey species in 1200 ha of native forest located to the south of the Victoria Mill Scenic Reserve. Techniques of control, which involve timber harvesting, are currently under investigation in the area.

Blackberry presents a minor problem at Ferntree waterfalls, the Glut, Middle Creek and Ben Major. Browsing of plant-eucalypts by wallabies is a problem in the Mount Cole area.

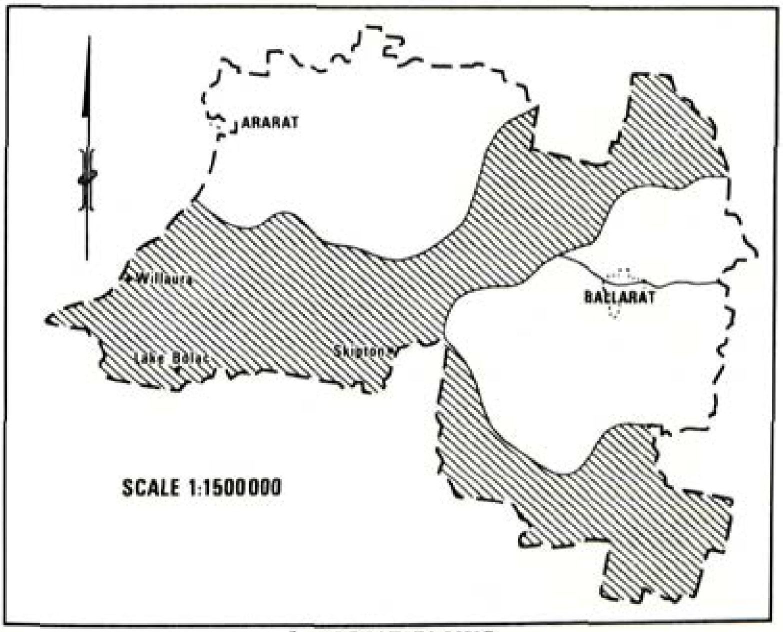
The incidence of soil erosion is low on public land, but it is a potential hazard should the use of the land be intensified. Mismanagement of the forests may also produce salinization of water supplies within and beyond the block, as discussed in the Hazards chapter.

2. BASALT PLAINS

A. General

1. Tenure and location

Most of the Basalt Plains block is freehold land used for agriculture. The largest areas of public land are lakes, which are reserved for public purposes and water supply. They are Lake Burrumbeet (2,400 ha), Black Lake (75 ha), Lake Wongan (230 ha), Lake Bolac (1340 ha), Lake Learmonth (500 ha) and Lake Goldsmith (696 ha). The Forests Commission have also purchased farmland at Carngham for planting of softwoods. Public land in the block is approximately 8,250 ha.



2. BASALT PLAINS

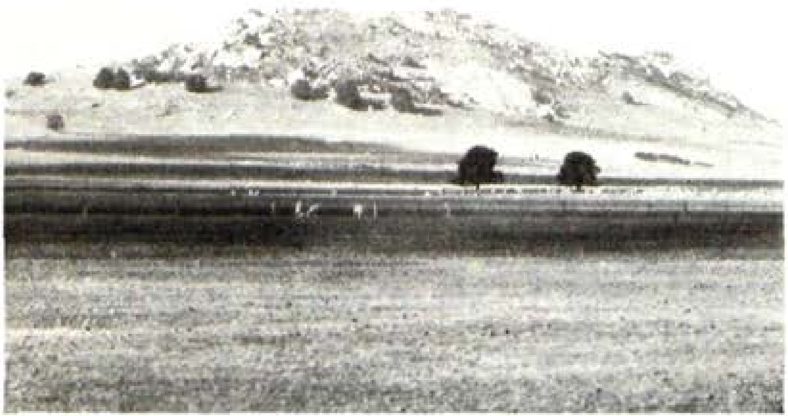
Major watercourses crossing the basalt plains are the Hopkins, Woady Yaloak and Yarrowee Rivers, and Fiery, Mount Emu, Creswick, Birch and Middle Creeks; the last three are tributaries of the Loddon River.

Townships representative of those in the block are Lake Bolac, Skipton, Willaura, Shelford, Smeaton and Learmonth.

B. Nature of the Land

1. Climate

A predominantly south-westerly airstream passes over the plains, resulting in low rainfall in the flatter southern areas, for example 524 mm at Lake Bolac, and increases to approximately 700 mm in the vicinity of the Great Dividing Range, for example 675 mm at Learmonth. Rainfall is 585 mm at Clunes, on the northern side of the Divide. Stations at Lismore and Clunes, south and north



Mount Emu, a granite monadnock, rises abruptly from the basalt plains west of Chepstowe

of the study area, record temperatures and show that Clunes has slightly higher summer maxima and slightly lower winter minima than Lismore.

2. Geology and geomorphology

The block consists of broad, flat, volcanic plains north and south of the Great Dividing Range and low altitude, undulating volcanic plains that straddle the Divide. The lava flows that formed the present day plains originated from volcanic activity in the Tertiary period. Where the lava plain extends across the Great Dividing Range, there is a marked concentration of extinct lava volcanoes, such as Mounts Callender, Blowhard, Hollowback and Saddleback Hill, Brown Hill and Ladymount.

Lava from volcanoes and other vents flowed over the pre-existing plains, filling river valleys and altering drainage patterns. Many of the buried valleys contained gold-bearing gravels or deep leads. Lakes were formed by lava blocking the flow of a watercourse (Lake Burrumbeet), and later, when water accumulated in eruption craters (Black Lake) and depressions on the lava plain. Former lakes and swamps, those that developed outlets or have been drained in modern times, now contain broad areas of alluvium. Entrenched and meandering watercourses have formed across the flat basalt plains, for example, Hopkins River and Fiery Creek.

The granitic Mounts Emu, Misery and Bolton, remnants of a land surface older than the lava flows, protrude through the plains. Another remnant land surface, associated with an incursion of the sea during the Tertiary, is exposed along the Yarrowee River valley in the vicinity of Shelford. Rocks associated with the Grampians, and acid lavas deposited during the Silurian, outcrop between Wilkliffe and Willaura.

3. Soils

The predominant soils of the basalt plains are as follows.

* Coarsely structured, yellow-brown, sodic, duplex soils occur over vast areas of the plains. Grazing and cropping, particularly of oilseeds, are the main forms of land use, but seasonal waterlogging restricts productivity.

* Finely structured, red, gradational soils are found in the higher rainfall areas near the Great Dividing Range. Land use in this area, extending from Waubra through Learmonth to Tourello and Smeaton, is cropping and in some instances dairying and potato growing.

* Shallow, red-brown, stony soils can be seen on the rising country north-west of Skipton and south-east of Rokewood. The surface rock restricts land use to grazing.

* Black, cracking clays on alluvium derived from basalt were laid down along drainage lines and creek flats throughout the block. Since they are prone to waterlogging they tend to be used for grazing rather than cropping.

* Grey clays occur in low-lying situations and on terraces formed from river alluvium. They are also prone to waterlogging.

4. Vegetation

The plains originally supported tussock grassland with red gum woodland edging the watercourses and fresh-water lakes.

Black Lake in the crater of the maar at Stockyard Hill

The plains have been profoundly altered by 140 years of cropping and grazing. Remnants of the original native grassland are restricted to areas of public land along roadsides, railways and stream frontages. The vegetation on these areas, however, has been altered by weed species, grazing and fire.

Stands of red gum border sections of the public water frontages on the Hopkins River, Fiery Creek, their tributaries, and Lakes Bolac and Burrumbeet. Parts of roadside reserves contain kangaroo grass *Themeda australis*, wallaby grass *Danthonia* spp., common everlasting *Helichrysum apiculatum*, blue devil *Eryngium rostratum* and featherheads *Ptilotus macrocephalus*.

Saline lakes, for example Wongan, Cockajemmy and Turangmoroke, are bordered by zones of salt-tolerant plants such as beaded grasswort *Salicornia quinqueflora*, and grey grasswort *Arthrocnemum halocnedoides*. The freshwater lakes are usually fringed by tall spike-rush *Eleocharis sphacelata* and common reed *Phragmites communis*. The tree violet *Hymenanthera dentata* and white elderberry *Sambucus gaudichaudiana* typically occur among basalt escarpments, for example those bordering Black Lake.

The area of land known as the Inverleigh Common supports an unusual and important woodland of red gum and rough-barked manna gum. Plantations of sugar gum *Eucalyptus cladocalyx*, and acacia have been established on the western border. The common is contiguous with public land in the Melbourne Study Area, and the Final Recommendations for that area advised that it become a flora and fauna reserve.

Rare plants in the block include the Australian anchor plant, which is found in a few locations including the basalt cliffs bordering Creswick Creek, north-west of Creswick. This once widespread species has been reduced by agriculture and grazing.

5. Fauna

Two major fauna habitats are represented - aquatic and grassland. The larger

A small colony of the Australian anchor plant persisting on basaltic cliffs adjacent to Creswick Creek

lakes and the watercourses are public land, but the grassland habitat consists mainly of freehold agricultural land.

Lake Goldsmith, a brackish lake, attracts many waterbirds, and has been managed for this purpose for some time. Waders such as wood sandpiper, greenshank and red-necked stint migrate

Basaltic cliffs along Creswick Creek. The rounded lower rocks show where flood water has eroded the surface

annually from the northern hemisphere and can be observed on the shallow mudflats and saltmarshs surrounding Goldsmith and many of the other lakes. Waterfowl that are frequently observed belong to the families Anatidae (ducks and geese), Plataleidae (ibis and spoonbills) and Rallaidae (coots, moorhens, rails and swamphens). The brolga, which is not common, has been recorded nesting at Lake Goldsmith, Lake Wongan and various swamps on private property.

Certain species, once considered to be characteristic of grassland habitats, are now rarely recorded from this portion of the basalt plains. The list includes the bustard, plains wanderer, bush thick-knee, little button quail and Gunn's bandicoot.

6. Land systems

Ten of the 12 groupings of land systems differentiated by geology and topography are represented in this block. The Basalt plains systems predominate, consisting of flat plains, undulating plains with volcanic cones, and stony rises. Portions of the Granite hills I, Palaeozoic sediments I and Metamorphics groupings occur as monodnocks or relic areas that are, however, well represented in other blocks. Alluvial plains surround many of these relics.

C. Present Use and Capabilities

1. Conservation

Lake Goldsmith, south of Beaufort, is the only area of public land set aside for nature conservation. The lake is an important feeding and nesting area for a wide range of water birds, including migratory birds from the northern hemisphere. Throughout the basalt plains there are many swamps and lakes with a high capability for the conservation of waterfowl. These include the salt lakes to the east of Lake Bolac, which are publicly owned and many privately owned bodies of water. Portions of the larger lakes, such as Lakes Bolac, Learmonth and Burrumbeet - these have a variety of uses - are presently zoned to ensure that conservation values are protected.

The capability for flora and fauna conservation is low, as most of the grassland habitat is privately owned and used for agriculture. Small areas of public land on the basalt plains have moderate to low nature conservation values. The same areas have a high capability for landscape conservation - particularly the treed frontages to Fiery Creek and the Hopkins River - because they provide visual diversity on the otherwise flat plains.

A large number of geological features, especially those associated with the Newer Volcanics, have high conservation values. Those occurring on public land are the maar lakes at Stockyard Hill and Callender Bay (Lake Burrumbeet). Privately owned features include the scoria cones at Monmot Hill, Smeaton Hill, Bald Hill and Mount Mercer, and the lava disc at Lawaluk. Mount Emu is a spectacular granite monadnock that protrudes abruptly through the basalt plains.

Examples of sediments deposited at the margin of the Tertiary sea can be seen in the valley of the Yarrowee River near Shelford.

Aboriginal relics that have been recently investigated in the south-western portion of this block include fish trap complexes at Lake Bolac and along the Hopkins River, burial sites at Lake Bolac and a stone arrangement at Lake Wongan.

Historically important homesteads and properties associated with pastoral development occur on private land at Ercidoun, Carngham and Caranballuc.

2. Recreation

The large lakes of Burrumbeet, Bolac and Learmonth are the major recreation resources of the basalt plains, and they are used extensively for boating, fishing, duck-shooting, picnicking, camping and nature study. Lake Bolac township is promoted as "the oasis of the Western District", having water-based as well as indoor and outdoor sporting facilities. Lake Goldsmith, managed for its water fowl, is shot over during the duck season, but there is little other recreational activity for the remainder of the year.

Smaller water bodies, for example Hepburn Lagoon and the Hopkins River, are fished for trout, redfin, tench and carp and receive light recreational use.

The more formal types of recreation are catered for by racecourses at Lake Burrumbeet and Ararat, golf courses at Willaura (Cockajemmy Lakes) and Lake Bolac, and the public recreation reserves located in each township.

Quail hunting occurs mostly on freehold land during the declared season from early May to the end of June.

The volcanic cones and granite mountains located around the Great Dividing Range are especially scenic. Landscapes incorporating agricultural land use and remnants of previous mining activities are major attractions for the pleasure driver.

3. Softwoods

Until recently, there has been no large-scale development of softwood forestry on the basalt plains. The Forests Commission, in line with its policy of establishing softwoods on purchased farmland, has commenced planting a newly acquired 1,100 ha property at Carngham. Further plantations on basalt country depend on the availability of suitable farmlands and funding.

A number of schools have established small softwood plantations.

4. Agriculture

Most of the land is freehold and is generally used for sheep, beef cattle and cereal cropping. The capability of the land has been rated according to its present productivity and versatility. Land rated as high quality, in the south-west, is used for cereals and oil seeds. Smaller areas of very high quality land occur on volcanic soils around the Divide and support potato cropping, lucerne, prime lambs, vealers and dairying. Average quality land, around the stony rises for example, is used mainly for grazing with some cropping.

Quail shoot on farming country near Ballarat

Apiculture plays an important role in pollination of crops such as sunflower and lucerne.

5. Minerals

Granitic sand and gravel is extracted from the colluvial slopes surrounding Mounts Emu, Misery and Bolton. Most pits are privately owned and the resources are extensive. Sand is dug from wind-blown deposits surrounding Whitestone swamp near Ercildoun and at times from deposits surrounding various other swamps.

Undulating volcanic country west of Creswick provides scenic diversity for pleasure driving

Scoria has been quarried in the past from Monmot Hill and is still extracted from Smeaton Hill. Large reserves of basalt occur almost entirely on privately owned land, throughout the plains. Outcropping Wickliffe rhyolites, mostly on private land south of Willaura, are quarried and crushed for road surfacing.

Gold is likely to be found in leads beneath the basalt plains. Early miners lost the trace of many deep leads, in particular the southerly extension of the Langi Logan lead and others in the vicinity of Burrumbeet, Learmonth and Creswick. Exploration licences issued by the Department of Minerals and Energy cover large portions of the basalt plains.

6. Water utilization

Adjacent to, and south of, the Great Dividing Range, water for stock and domestic use comes from the groundwater resource. Many townships, - Learmonth, Waubra, Wickliffe, Streatham, Willaura and Lake Bolac - obtain their water from bores, but Skipton is supplied from a spring. Townships north of Creswick, for example Smeaton (Smeaton Water Supply District) and Kingston and Allendale (Springhill Water Supply District), obtain water from Newlyn Reservoir. Teesdale and Lethbridge in the south-east obtain their supplies via releases from the Lal Lal reservoir, situated further up the West Moorabool River.

A number of diversions for stock and irrigation are authorized from the Hopkins and Yarrowee Rivers, Bullarook Creek, Lakes Bolac, Burrumbeet and Learmonth, and Newlyn Reservoir.

7. Eel fisheries

Commercial harvesting of eels occurs at Lake Burrumbeet (the most important eel-fishing water in the State), Lake Bolac and many other privately owned swamps and lagoons south of the Great Dividing Range. Lake Learmonth, which is apparently suitable, is not used for commercial fishing due to conflicts with recreational uses.

Eel production in 1978/79 represented 17% of the production in Victoria.

8. Utilities

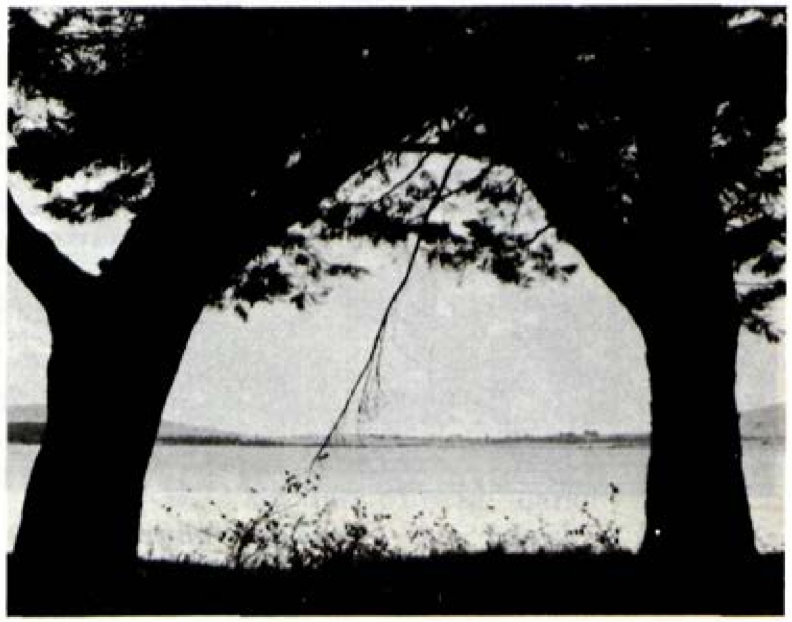
Two 220 kV transmission lines cross this block; Ballarat--Terang via Mount Kinross and Ballarat--Horsham via Learmonth. In both cases the easement width is 37 m. Routes for the proposed 500 kV transmission line from Melbourne to Portland pass through freehold property to the south of the block.

9. Hazards

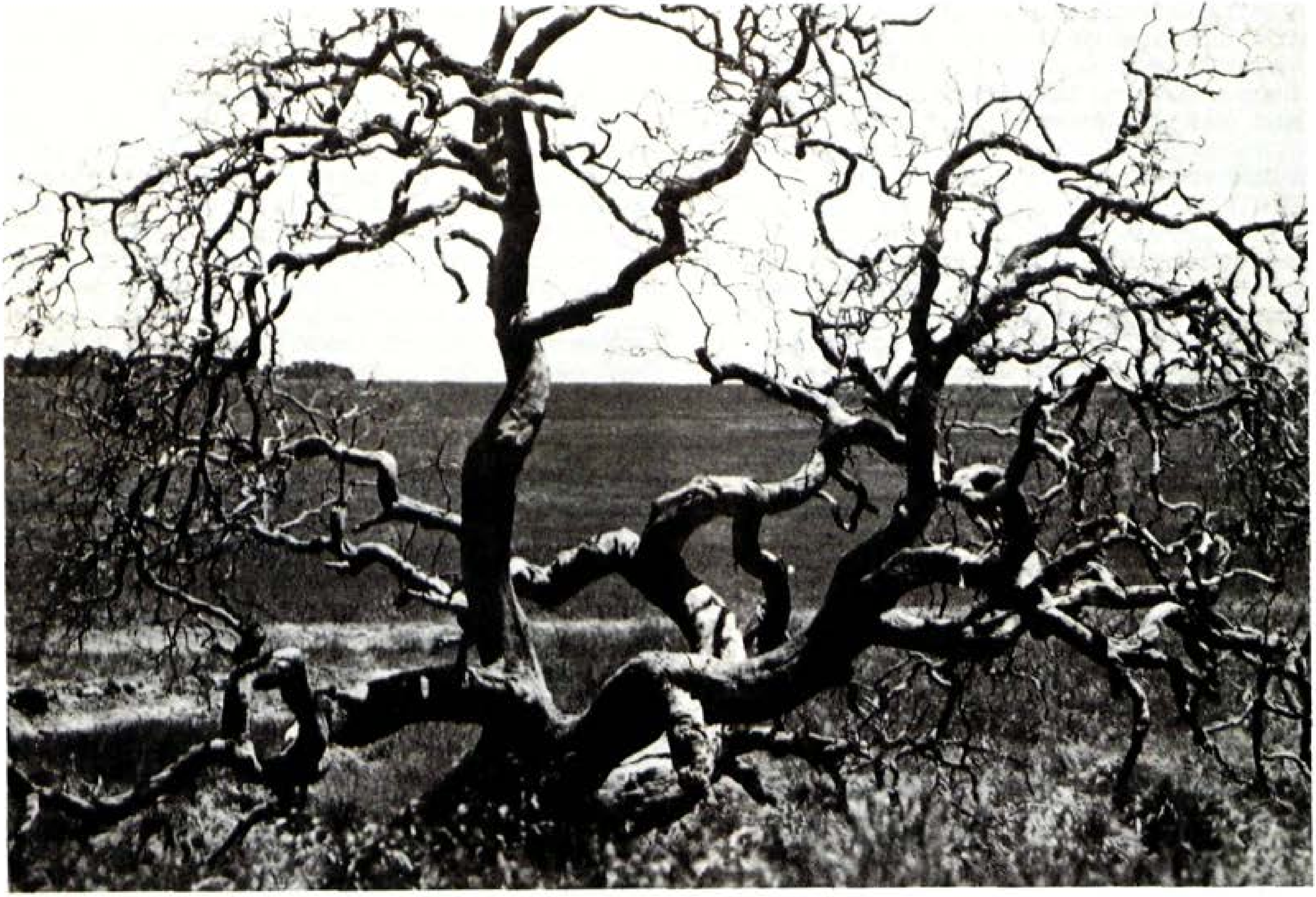
The predominant gentle slopes and moderately fertile soils derived from basalt are hardly susceptible to erosion, even though sheet-flow flooding may occur after heavy rainfall because of the lack of defined stream pattern over much of the plains. Scarps and hills with less fertile soils suffer from sheet and gully erosion when poorly managed.

Grass fires are a major hazard, and in February 1977 wildfires occurred in the Tatyoon--Streatham, Wallinduc--Werneth and Waubra districts causing major damage to property, livestock and settlement.

Eutrophication of Lake Burrumbeet has been caused by nutrients derived from human activities in the lake catchment.



Lake Learmonth is thought to be suitable for commercial eel-fishing



Gnarled old red gum provides sharp relief to the flat basalt plains

Algal blooms, and the subsequent death of livestock and decrease in recreation appeal, have required the development of a water quality management policy for the Lake Burrumbeet catchment.

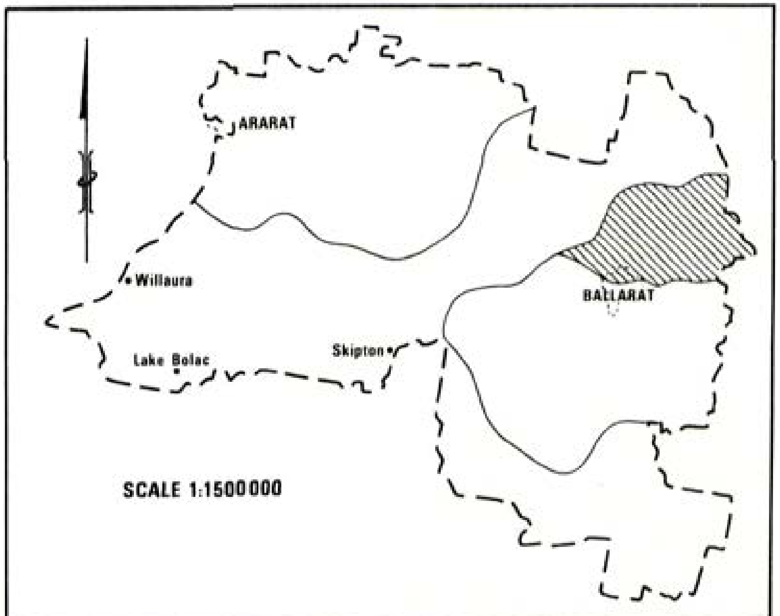
Pest animals of the agricultural land include, rabbits, mice and foxes.

3. CRESWICK

A. General

1. Tenure and location

Three large areas of public land can be identified in this block. The Creswick sub-block is mostly reserved forest, but includes unoccupied Crown land and some Crown reserves set aside to supply water. The Barkstead sub-block contains reserved forest and land surrounding the Moorabool Reservoir. The latter area is controlled by The Ballarat Water Commissioners, who also control water catchments on public land surrounding the reservoirs at Wilsons, Beals, Gong Gong, Kirks and Pincotts. The Ballarat common, a large area of unreserved Crown land adjacent to the City of Ballaarat, has been partly developed as an industrial estate. The total area of public land is approximately 13,750 ha.



3. CRESWICK

Townships include Creswick, Bungaree, Dean, Newlyn, Miners Rest and Barkstead. The Great Dividing Range passes through the block. The headwaters of the West Moorabool River, Yarrowee River and Burrumbeet Creek flow south of the Divide. Tributaries of the Loddon River - for example Birch Creek and Creswick Creek - have their headwaters in public land north of the Great Dividing Range.

B. Nature of the Land

1. Climate

Rainfall recordings from Moorabool Reservoir indicate a mean annual rainfall of 941 mm. Rainfall recorded at other

Ballarat water storages is about 25% higher than rainfall recorded at Ballarat and Creswick. The probability of receiving effective rainfall is slightly greater at Ballarat than at Creswick for most months of the year.

At Creswick the mean maximum temperature is 27°C in January and 10.2°C in July. Snow falls occasionally in the midlands, most frequently in August and September.

2. Geology and geomorphology

Parts of the lava plain produced during volcanic activity in the late Tertiary abut the higher sedimentary areas in this block. Prominent volcanoes include Clarkes Hill, Wombat Hill and Mount Pisgah. Portions of the undulating volcanic areas are public land within water supply catchments, but most are privately owned.

3. Soils

The major areas of public land occur on soils derived from Palaeozoic sediments, and some alluvial and colluvial material. Shallow, stony, gradational soils occur on crests and steeper areas. On the slopes and swales there are mottled yellow and red gradational soils or red duplex soils.

The undulating plains and volcanic cones have two main soil types. Red gradational soils occur on cones and rises. They are fertile and well structured, and are used for potato cropping. Towards the crests of cones, these soils tend to be shallow and stony. Grey, sodic, duplex soils, which are found in the lower parts of the landscape, are subject to waterlogging and so are used for grazing rather than cropping.

4. Vegetation

In Barkstead sub-block the vegetation is messmate stringybark open forest III with associated manna gum, candlebark and narrow-leaf peppermint. Messmate-dominated vegetation in the Creswick sub-block is open forest II, containing species characteristic of drier sites and poorer soils such as scent-bark, broad-leafed peppermint and red stringybark.

Vegetation dominated by scent-bark and broad-leafed peppermint occurs around Slaty Creek and Nerrina. Low open forest and woodlands of manna gum and blackwood occur along drainage lines flowing into Wilsons, Beales and Kirks Reservoirs.

Extensive plantations of radiata pine are to be found in the Creswick and Barkstead sub-blocks and surrounding the water supply storages managed by The Ballarat Water Commissioners.

5. Fauna

The general forest habitats on public land include wet open forests, particularly in the Barkstead sub-block, and dry open forests in the Creswick sub-block. Other habitats are pine plantations and wetlands, including Hepburn lagoon and Winter Swamp, and various permanent streams and storages. Lake Wendouree, in the City of Ballaarat, is an important waterbird habitat. Introduced birds and mammals are found in the urban centres of Creswick and Ballarat.

The fauna can be generally predicted from the nature of these habitats, and for details the reader is referred to Chapter 11 and Appendices 6, 7 and 8.

6. Land systems

The forested areas of public land in the Creswick and Barkstead sub-blocks can be grouped into the land system of Palaeozoic sediments II. The Ballarat common and much of the land owned by The Ballarat Water Commissioners occurs on the Basalt plains I land system.

C. Present Use and Capabilities

1. Conservation

The block has few specific nature conservation values. The Australian anchor plant, which occurs in a few locations on basalt cliffs along Creswick Creek, is not common in Victoria. Examples of *Grevillea repens, Pultenaea weindorferi* and *P. muelleri* var. *reflexifolia* are found in the Barkstead sub-block, which is part of the Wombat forest.

Capping of basalt overlying Tertiary sediments at O'Keef's mining pit, near Creswick

Also in the Wombat forest, the following mammals reach the westerly limit of their range: wombat, bush rat, greater glider, yellow-bellied glider. Koalas occur throughout the block, and their presence in a specially fenced reserve at Creswick is a very popular tourist attraction.

Important geomorphological features include the lava volcanoes of the midlands, which occur entirely on privately owned land. Creswick Creek follows the junction of Ordovician sediments and the basalt plain for some distance to the north-west of Creswick, leaving a basalt escarpment in certain places. The sides of O'Keefs pit, a former open cut mine near Creswick, illustrate the capping of basalt over gold-bearing Tertiary gravels. Similarly, workings at Black Hill near Ballarat show the weathered Ordovician structure.

The area has many sites important for historical conservation. South of Creswick there are the Australasian Mine water race, the Nuggety dam and associated water races, sluiced sediments along Mopoke gully, and remnants of Chinese market gardens. The Old Eureka lead was discovered in the southern end of this block near Nerrina. The main Eureka Lead lies further to the south and the Eureka Stockade is in the City of Ballaarat. The former government battery at Creswick and the bluestone flour mill at Smeaton, have historical significance. Some of the Ballarat water storages have been continuously in operation since the 1860s.

Small blocks of public land north of Creswick contain the cemetery and the mullock dumps of former deep lead mines.

2. Recreation

The native forest extending from Creswick to Nerrina is a major recreation resource used extensively by the local population, with activities centred around the developed picnic areas and points of interest such as St. Georges Lake, Slaty Creek and Koala Park. Historic gold-mining sites are also visited. The roads are used for trail-bike riding, horse riding and pleasure driving, and the open understorey forest is used by orienteering groups. The clay pit south of Creswick is occasionally visited by four-wheel drive clubs.

Storages and adjacent facilities controlled by The Ballarat Water Commissioners are another resource used by the local population. White Swan, Moorabool and Kirks Reservoirs have facilities for picnicking and permits to fish certain reservoirs may be issued by the Commissioners to people living locally.

In the Barkstead sub-block there is a mineral spring north of Korweinguboora Reservoir. There are also remnants of the defunct railway line from Creswick to Daylesford and the timber tramway which carried logs from Bullarto to Dean. Horseback riders from a riding school near Creswick follow forest roads and tracks.

Camps run by the Education Department, and other youth groups, are located at Creswick and adjacent areas. These are listed in Table 22.

Landscapes in this block range from undulating volcanic plains used for agriculture to forested hills and ridges. The varied scenery, coupled with picturesque towns (for example Barkstead situated within the forest), and good forest roads make this area attractive to pleasure drivers.

Picnickers adjacent to Koala Park, Creswick

3. Hardwood

In the Barkstead sub-block, messmate stringybark forests (labelled 2c on Map 9) are rated as having moderate productivity. The stands, which are harvested on a partial cut system, supply sawlogs to three mills at Ballarat, with one at Daylesford and one at Korweinguboora.

Pulpwood is cut during the drier months and stockpiled as logs for transport to the mill at Bacchus Marsh during the winter.

The messmate stringybark forests in the Creswick sub-block are rated as low to moderately productive (labelled 2e and 2c on Map 9). They are managed on a

Young plantation of Pinus radiata

sustained yield basis supplying 2,550 cu. m per year of sawlogs to three mills at Ballarat. Minor forest produce is obtained from all areas.

4. Softwood

Softwood plantations of about 4,000 ha include public land managed by the Forests Commission in the Creswick and Barkstead sub-blocks and areas surrounding the water storages managed by The Ballarat Water Commissioners. Small school plantations occur near Nerrina and Creswick.

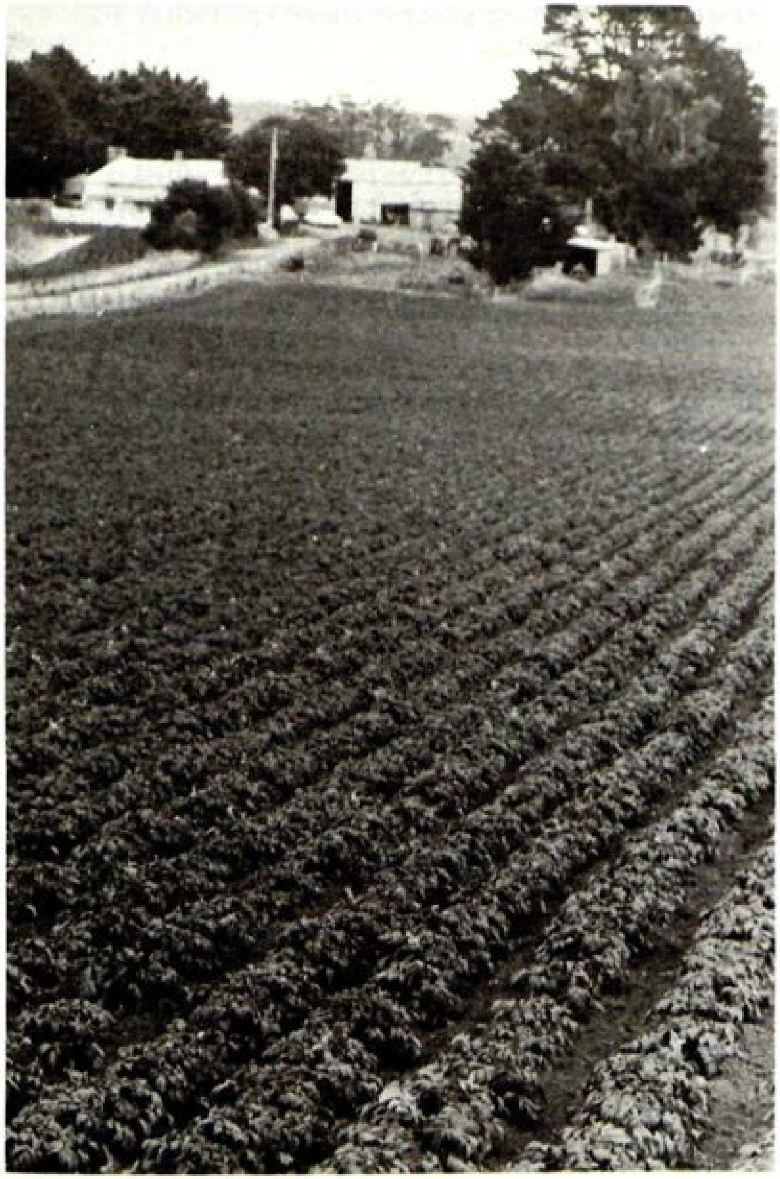
Sawlogs from Forests Commission plantations supply three mills at Ballarat and a veneer mill in Melbourne. Post-sized timbers obtained from the thinnings are treated at a preservation plant at Bungaree. Plantations surrounding the water storages provide sawlogs to a case mill, and pulpwood to a particle-board mill at Ballarat.

Public land surrounding Wilsons Reservoir, which is presently only grazed or cultivated, has a high capability for softwood production.

5. Agriculture

Land around the township of Dean is rated as very high agricultural quality. On the deep red gradational soils, potatoes are intensively cropped and sold for the table, for processing and for certified seed. The grey, sodic, duplex soils on basalt support prime lamb and beef cattle enterprises and some cereal cropping.

Approximately 615 ha of land around Wilsons Reservoir - also rated as very high quality - is leased by The Ballarat Water Commissioners to farmers for grazing and cropping. Land surrounding Dean Reservoir is similarly leased by the Creswick Shire Council.



Potato cropping is carried out on friable red volcanic soils around Dean

Most of the forested public land, which occurs on ridges and slopes of Ordovician origin, has a low capability for agricultural use.

6. Minerals

Small areas of Tertiary gravels occur on public land, two of which are utilized by the Creswick Shire Council; the Portuguese pit adjacent to Blue Waters, and another pit adjacent to Creswick Creek. The latter area has a capability for recreational or softwood redevelopment after the exhaustion of the resource. The white shale derived from weathered Ordovician sediments is extracted from a quarry at Humbug Hill which lies within the forest south of Creswick. The shale is used for brick manufacture at Ballarat. A basalt quarry operates on private land at Miners Rest.

There is potential for the discovery of gold and other minerals throughout this block, and for clay and gravels in certain areas as are shown on Map 12. Exploration licences encompass the entire block.

7. Water utilization

Creswick township is supplied with water from the Cosgrave, Dean and Russells Reservoirs, which are situated within the Loddon River Catchment. South of the divide there are seven reservoirs managed by The Ballarat Water Commissioners, supplying water to Ballarat,

Messmate stringybark open forest III near Barkstead

Cardigan Village and five waterworks trusts. Stream diversions in this block are used mainly for the irrigation of potato crops.

Two mineral springs are located on the boundary of the study area; on Deep Creek just north of Eaganstown, and north of the Korweinguboora Reservoir on the East Moorabool River.

8. Utilities

A gas pipeline from Melbourne to Ballarat passes along an easement through private land just north of the Western Highway. State Electricity Commission 220 kV transmission lines run between Ballarat and Horsham and Ballarat and Bendigo.

A number of easements pass through public land to the north of Nerrina, including S.E.C. transmission lines and a water pipeline between White Swan Reservoir and Wendouree. The Country Roads Board has plans to re-route the Western Highway to the north of Ballarat through public land at Nerrina.

Ballarat airport lies adjacent to the Ballarat common to the west of the City.

Forest areas south of Creswick are used by the Australian Army for military training exercises up to 2 days per year.

9. Hazards

In the past 5 years (1974 to 1979), the Forests Commission has attended 28 fires on public land. Two of these fires have posed a serious threat to the township of Creswick, the most recent being in February 1977.

The incidence of soil erosion is low on forested public land. There is a potential hazard for soil erosion in the areas that are favoured for the development of small-acre farmlets, many of them hobby farms.

Many of the catchments supplying water to Ballarat are partially or wholly situated within agricultural land. A potential hazard is associated with run off that may introduce pathogens from stock and domestic sources, agricultural chemicals and sediments. Increased run off, brought about by the subdivision of agricultural land also presents a potential hazard.

There is an existing hazard associated with run off from the Western Highway entering Kirks Reservoir and from the Daylesford Road entering Gong Gong Reservoir.

In previous years, outbreaks of certain insect pests have affected radiata pine plantations and the stringybark--peppermint forests near Creswick.

4. BALLARAT

A. General

1. Tenure and location

Public land areas south of Ballarat include large discrete sub-blocks close to the townships of Linton, Enfield and Lal Lal. Within these sub-blocks there is mixed land tenure: reserved forest, unoccupied Crown land and Crown reserves. A large number of other, smaller blocks of public land include the former commons at Illabarook and Cape Clear, water supply reserves at Mount Helen, Hillcrest and Happy Valley, and public land at Canadian and Mount Pleasant adjacent to the City of Ballaarat. The total area of public land is approximately 22,500 ha.

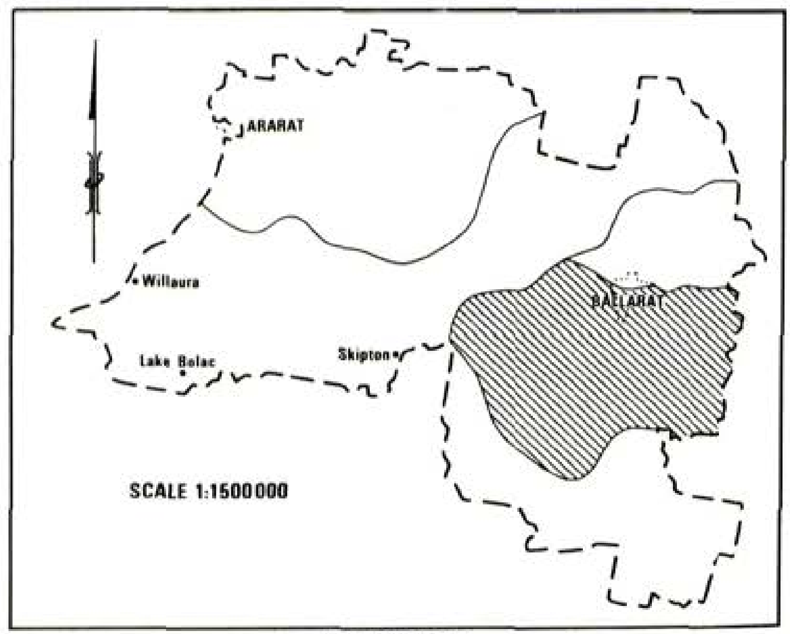
Many small townships lie adjacent to the public land including Buninyong, Durham Lead, Little Hard Hills, Berringa, Illabarook, Cape Clear, Scarsdale, Smythesdale, Snake Valley and Linton.

Watercourses forming part of the closed Corangamite catchment include the Woady Yaloak River and its tributaries. Smythes Creek, Misery Creek, Ferrers Creek, Kuruc-A-Ruc Creek and Narringhil Creek all rise in this block. The Yarrowee River (Barwon catchment) and West Moorabool River (Moorabool catchment) pass through the block.

B. Nature of the Land

1. Climate

Rainfall in this block is influenced by south-westerly and north-westerly air-



4. BALLARAT

streams, which produce high rainfalls in the more elevated areas of the Palaeozoic midlands. For example, Ballarat receives 700 mm per annum and Scotsburn 800 mm, whereas Rokewood on the lower southern slopes of the midlands receives 550 mm. The probability of receiving effective rainfall is correspondingly lower for stations situated at the foot of the midlands. Mean maximum daily temperatures at Ballarat are 25.5°C for January and 9.9°C for July.

2. Geology and geomorphology

The oldest rocks in this block are the Palaeozoic sediments of Cambrian and Ordovician origin, which now form the extensive undulating hills south of Ballarat, described as the Palaeozoic midlands. The sediments were intruded by molten rocks in the Devonian and subsequently exposed following millions of years of erosion. The Devonian rocks now form the granite outcrops at Mount Egerton, Fisken Hill, Mount Bute and Chepstowe. At Pittong and Lal Lal the highly weathered granite underlying the sediments is mined as kaolin.

Extensive erosion in Tertiary times deposited sands and gravels that often back-filled river valleys. Many of these deposits occur as relics lying on top of the older sediments and are found particularly around Dereel, Illabarook--Cape Clear, Smythesdale, and Sago Hill. Other sand and gravel deposits were covered by lava flows later in the Tertiary to form deep leads. Large areas of these sands and gravels have been mined for gold by open cut or deep shaft techniques.

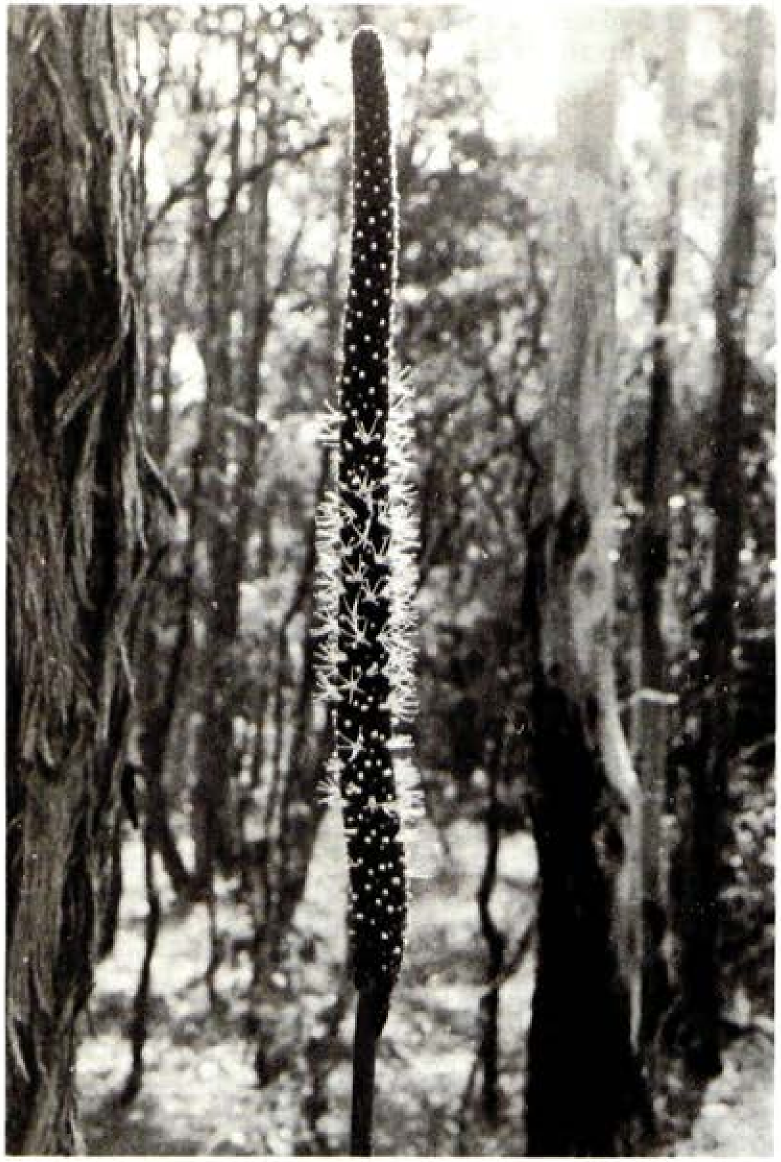
Lava flowed along the valleys of the Woady Yaloak and Yarrowee Rivers and small valleys surrounding the Palaeozoic midlands. Two prominent points of eruption, Mount Buninyong and Mount Warrenheip, and numerous smaller volcanoes on private agricultural land dominate the landscape in the north of this block.

3. Soils

The major areas of public land occur on Palaeozoic sediments and have shallow, stony, gradational soils on crests and ridges, and yellow duplex on the more gently undulating ridges. Smaller areas of public land at Dereel, Illabarook and Cape Clear have yellow sodic, yellow sodic duplex and occasionally deep sand soils. Some of these soils have been shallow-stripped for gravels, and sand has been extracted near Dereel and Lal Lal.

4. Vegetation

Low open forests of messmate stringybark predominate with mixtures of brown stringybark, narrow-leaf peppermint, candlebark and scent-bark. Wet gullies and flatter areas, particularly in the Enfield sub-block, support swamp gum - both *Eucalyptus ovata and E. yarraensis.* Stony slopes in areas of low rainfall



Small grass-tree flowering in red stringybark forest near Berringa

near Berringa and Mount Erip contain low open forests of red stringybark and broad-leafed peppermint.

At Mount Erip red ironbark and yellow box also occur. To the south, a strip of vegetation along the Woady Yaloak River frontage contains river red gum and blackwood. An area of rough-barked manna gum occurs on sandy soils that surround Dereel lagoon.

Several softwood plantations have been established, on public land at Canadian and Mount Clear, near Garibaldi and Smythesdale, and on purchased farmland near Mount Mercer.

Mount Buninyong and Mount Warrenheip support forests of messmate stringybark and manna gum with an understorey consisting mainly of austral bracken and tussock grass.

5. Fauna

General forest habitats, particularly dry open forests and woodlands, predominate on public land in this block. The under-storey habitats consist mostly of low and sparsely distributed shrubs and tussock grass, but there are exceptions. Dense bracken occurs in some better drained areas, and around Dereel dense heaths make up the understorey.

Wetland habitats consist mainly of small dams (many are former mining dams) and freshwater marshes. Other habitats include pine plantations and grassed former commons. Most privately owned land consists of grassland, but some forested areas remain. (The larger areas of forest in private ownership are shown on Map 11.)

The fauna can be generally predicted from the nature of these habitats. For details, the reader is referred to Chapter 11. Of interest are the red deer, progeny of stock released in the 1900s, which are occasionally observed in the Linton and Enfield sub-blocks. The mouse dunnart, widespread but not often seen, was recorded during a recent survey at Mount Erip and near Buninyong.

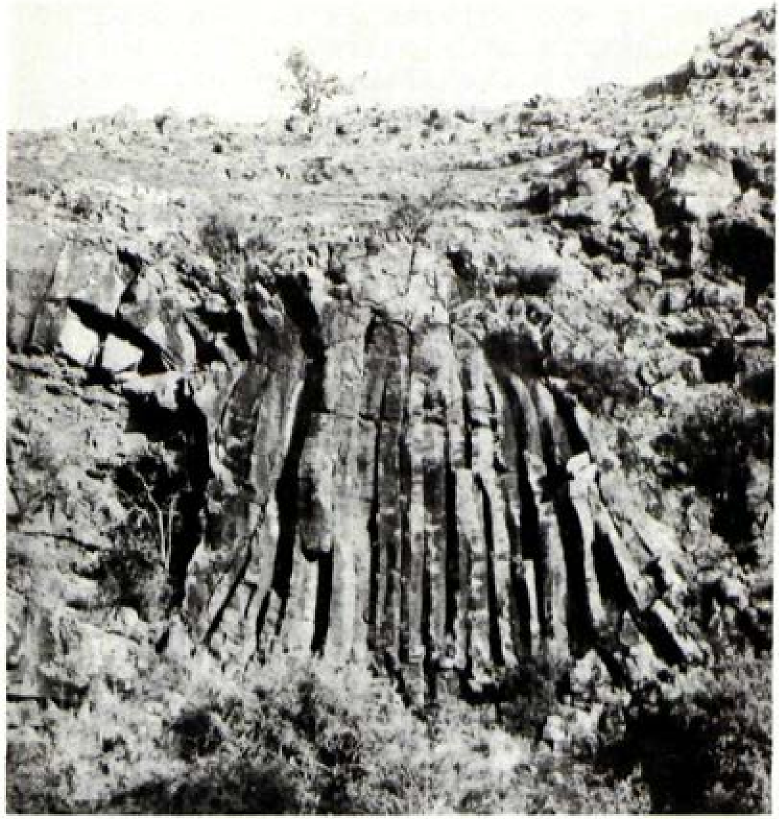
6. Land systems

Map 8 shows the distribution of land system groupings in relation to public land. Palaeozoic sediments 11 is the major grouping.

C. Present Use and Capabilities

1. Conservation

Areas important for nature conservation include Dereel swamp, which is a shallow freshwater marsh fringed by rough-barked manna gum. The southern end of the midlands around Berringa contains a diversity of wildflowers, particularly orchids, as well as the Enfield grevillea, an endemic species that is as yet undescribed. This area is known as the Enfield Forest Park.



Columnar jointing in a lava flow at 'Devils Kitchen'

Swamp gum *E. yarraensis*, and its close relative *E. ovata*, occur in flat gullies with impeded drainage in the Enfield sub-block. The former species was thought to be restricted to the Upper Yarra, but its distribution has been extended following recent surveys.

The Ballarat block contains some interesting geomorphological features, both on public and private land. An area of basalt cliffs at Piggoreet ("Devils Kitchen") was caused by Smythes Creek cutting down through the basalt capping to the underlying Cambrian-Ordovician sediments. The cliffs show evidence of at least two separate lava flows and excellent examples of columnar jointing.

Lal Lal Falls tumble over the edge of the lava plain and have eroded back into the basalt landsurface. Columnar jointing and successive lava flows are evident in the cliff face. Specimens of the uncommon Australian anchor plant grow just upstream of the Lal Lal Falls.

South of Mount Erip, the Woady Yaloak River has cut through layers of basalt and Tertiary sediments, exposing the underlying Ordovician sediments, to form a gorge that is vegetated along the frontage with river red gum.

Mounts Warrenheip and Bunninyong, are significant geomorphological features held as public land, while others, for example the tuff ring at Hardies Hill, are privately owned.

The Ballarat block is important historically, encompassing the sites of many rich gold discoveries and remnants of early settlement and industry. Within the Enfield sub-block there are gold-mining relics such as dams, water races, machinery foundations, ruins of the mullock dumps, open cuts and shafts. The Lal Lal blast furnace still stands

Mullock dump - a remnant of deep lead mining in the Staffordshire Reef area

more than a century after iron mining commenced. The furnace used brown coal from the Lal Lal lignite mine. Small townships that once had large mining populations occur around the perimeter of the Linton and Enfield sub-blocks, many with old buildings mentioned in the National Trust register.

Historic public utilities include the railway network and its bluestone stationhouses and bridges. The railway which ran from Ballarat to Colac via Cressy was closed south of Newtown in the early 1950s, but a number of wooden trestle bridges remain. Road bridges of interest include one of bluestone construction on the Mount Egerton--Yendon Road and a timber trestle bridge over the Springdallan Creek near Piggoreet.

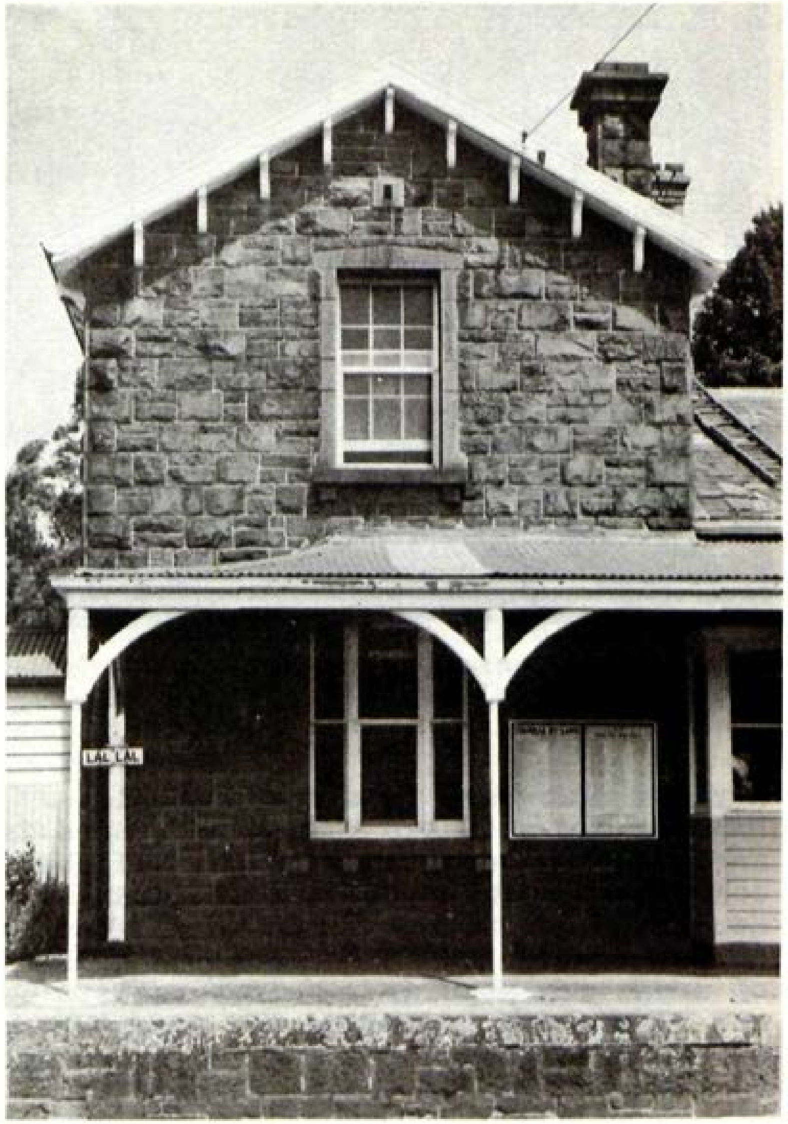
2. Recreation

Two important recreational resources close to the city are the areas known as Canadian forest and Yarrowee plantation. The areas form the forested skyline of Ballarat and part lies within the city itself. Canadian forest has a rifle range and is used for horse-riding, orienteering and nature study. The Yarrowee plantation, established on a former gold-mining locality between Mount Pleasant and Mount Clear, has jogging and motor-bike tracks and picnicking facilities.

Enfield Forest Park has picnicking facilities and walking tracks that provide access to historic gold-mining sites. Few other areas in the Linton or Enfield sub-blocks are developed for recreation, but occasional trials are conducted by motor-bike and four-wheel-drive vehicle clubs. Deer are hunted here during the month-long season.

Public land east of Lal Lal contains the Lal Lal Falls, the blast furnace and the reservoir. Picnic tables and toilets provided at these areas.

Lookouts are found at Mount Bute, a granite outcrop on the southern edge of the midlands, and at Mount Buninyong. A clay pigeon range has recently been established on public land at Haddon.



Lal Lal railway station - constructed from bluestone in 1863 - is classified by the National Trust

Foundations of mining machinery near Berringa

A youth club camp is situated beside Dawsons Dam at Snake Valley and there is an Education Department camp at Illabarook. The Ballarat College of Advanced Education conducts environmental studies on public land at Union Jack. A number of areas are popular with naturalists and fishermen, including the forests surrounding Mount Erip and the crossing to the south on the Woady Yaloak River.

3. Hardwood

Messmate stringybark forests (2e and 2d on Map 9) in this block are rated as hardwood stands of low productivity. One mill at Enfield obtains sawlogs from the Enfield sub-block; the other sub-blocks are used only for the supply of minor forest produce.

The potential exists for pulpwood harvesting, but there is at present no market for this wood product. Large areas of red stringybark and scent-bark forests have the capability to supply only minor forest produce.

4. Softwood

Forests Commission softwood plantations, of approximately 3000 ha, are situated south of Mount Pleasant, at Canadian, Garibaldi and west of Scarsdale. In recent years the Commission has purchased farmland near Mount Mercer which is currently being planted with radiata pine.

Sawlogs are supplied to mills at Ballarat and Colac, and a veneer mill in Melbourne. Pulpwood is supplied to the particle-board mill at Ballarat and round timbers to the preservation plant at Bungaree.

Plantation extension in the short term will be concentrated on the Mount Mercer property and on another property at Carngham (see Basalt Plains chapter). To meet future commitments, further plantation areas may come from public land adjacent to existing plantations or from purchased marginal farmland.

Public land near Illabarook, Rokewood Junction and Cape Clear, which is currently cleared and used for grazing, cropping and gravel extraction, has a moderate capability for softwood production.

5. Agriculture

Agricultural land in an area stretching from Buninyong and Yendon to the Western Highway is rated high to very high quality. Within this area, potatoes are cultivated at Warrenheip and Bungaree. This use overlaps with dairying and cropping, mainly of oats for grain production

The remainder of the block is of average agricultural quality and supports prime lamb, wool and beef cattle enterprises. Agricultural versatility declines as the southerly slopes of the midlands are reached.

Agricultural public land at Cape Clear, Happy Valley, Illabarook and Mount Mercer is grazed under licence or agistment, and some forest grazing occurs at Mount Doran. Most of the forested public land, which occurs on ridges and slopes of Ordovician origin, has a low capability for agricultural use.

6. Minerals

Gravels are mined from Tertiary deposits throughout this block. At Sago Hill, a large deposit of gravel is owned and utilized by the City of Ballaarat. Two companies mine gravels from former open cut gold-mines on public land near the Smythesdale township. Shires extract gravel at Dereel and Illabarook. The gravels are shallow stripped down to a cemented horizon, which may form a capping to extensive resources below this level.

High quality kaolin is mined on private land at Lal Lal and Pittong. Kaolin reserves are also found on public land at Lal Lal and Mount Egerton.

Minor amounts of sand have been quarried from public land at Dereel and diatomite from private land near Happy Valley.

Clay derived from decomposed Ordovician--Cambrian mudstone is quarried from private land at Enfield, Ballarat East and Buninyong.

Map 12 indicates areas with the potential for discovery of clay, kaolin, sand, gravel and minerals. An area near Lal Lal, mined last century, may have the potential for the recovery of brown coal. A number of mining leases occur on public land in the block and exploration licences encompass the entire block.

7. Water utilization

The Ballarat Water Commissioners supply water to the following Waterworks Trusts: Bungaree -- Wallace, Linton,

Remains of a puddling pit in red-ironbark forest, Mount Erip

Rokewood, Buninyong and Smythesdale -- Scarsdale. The West Moorabool Water Board oversees the operation of the Lal Lal Reservoir, which supplies water to Ballarat, Geelong and Bannockburn Waterworks Trust.

At present there are no firm proposals to construct new water storages. However, a possible site has been identified on the Woady Yaloak River, just north of the Skipton--Geelong Road.

8. Utilities

Transmission lines linking Ballarat -- Geelong and Ballarat -- Terang are constructed along a 37 m wide easement that mainly traverses private land. The easement for the Terang line passes through 12 km of public land in the Enfield sub-block.

The Department of Transport operates a navigation aids site for aircraft with-

Spraying of furze.
This noxious weed is often a problem in former mining areas

in reserved forest in the Enfield sub-block. Telecom has a radio-transmission facility on Mount Buninyong.

Fire lookouts operated by the Forests Commission are situated at Cherry Tree Hill and Mount Doran. A fire lookout at Mount Buninyong is operated in conjunction with the Shire.

The Australian Army make use of the Enfield sub-block up to 2 days per year for military training exercises.

9. Hazards

In the past five years (1974-79) there have been 21 fires on public land in this block, which have required the attendance of the Forests Commission. Statistics show that the Enfield sub-block is more fire-prone than others.

Large grass fires occurred near Rokewood Junction and Linton during the month of February 1980.

The incidence of soil erosion is low on forested public land, but has been a problem at the Illabarook common. Salting of agricultural land is evident in the south of this block. Management of forested land is relevant to the salinization of agricultural land and water supplies as discussed in Chapter 13.

Noxious weeds, particularly blackberry and furze, present a problem in former mining areas.

The main potential hazards to the water supply, particularly in the Lal Lal Reservoir catchment, are pollutants derived from agricultural run-off and fouling of watercourses by stock.

PART V

APPENDICES

APPENDIX 1

MEAN MONTHLY DISCHARGES OF STREAMS FLOWING SOUTH OF THE GREAT DIVIDE (Ml)

Gauging station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*Leigh River at Mount Mercer (233 215) 13 water years	2,011	629	814	1,332	3,466	3,071	9,041	11,434	10,448	7,857	1,826	913
Woady Yaloak R. at Pitfield (234 200) 13 water years	604	99	86	370	1,159	715	3,036	2,812	3,935	2,294	493	173
*Woady Yaloak R. at Cressy (234 201) 15 water years	1,443	456	284	1,098	4,107	3,922	13,075	16,541	11,669	7,635	1,406	728
*Hopkins River at Wickliffe (236 202) 38 water years	333	419	777	469	1,172	2,220	5,760	9,683	5,514	3,281	1,739	308
*Mount Emu Creek at Skipton (236 203) 32 water years	913	678	900	1,369	2,233	3,528	8,610	20,278	14,432	9,819	3,256	802
Fiery Creek at Streatham (236 204) 38 water years	641	900	863	950	1,431	2,788	7,401	10,300	6,303	4,342	2,911	740

APPENDIX 2

MEAN MONTHLY DISCHARGES OF STREAMS FLOWING NORTH OF THE GREAT DIVIDE (Ml)

Gauging station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*Wimmera River at Eversley (415 207) 30 water years	382	765	1,011	444	913	3,725	8,215	9,276	10,707	3,898	1,567	888
Avoca River at Ampitheatre (408 202) 3 water years	37	12	37	111	382	308	740	1,122	555	222	62	49
*Bullarook Creek at Clunes Weir (407 207) 24 water years	210	271	308	308	518	1,653	3,367	4,515	3,750	2,134	1,493	1,024
*Creswick Creek at Clunes (407 214) 26 water years	222	308	543	185	1,159	2,701	5,477	7,709	6,241	3,565	2,183	432
*Tullaroop Creek at Clunes (407 222) 14 water years	765	691	444	444	2,590	5,341	11,188	15,653	12,211	7,882	1,690	617
Joyces Creek at Strathlea (407 210) 6 water years	49	12	25	74	197	703	1,838	2,874	2,381	1,381	136	74

APPENDIX 3

STREAM GAUGING DATA

Gauging station	Recording period	Drainage area (sq.km) above gauging station	Annual discharge (Ml)			Mean annual discharge per drainage area (Ml per sq.km)	Salinity (mg per litre)		
			Maximum	Minimum	Mean		Maximum	Minimum	Mean
Bullarook Creek at Clunes Weir (407 207)	May 1930--Apr 1953 May 1953--Apr 1955 24 water years (finished)	158	50,640	890	19,550	124	-	-	-
Creswick Creek at Clunes (407 214)	Jan 1944--Apr 1970 26 water years (current)	308	91,370	1,060	30,710	100	1,950 at 2.4 Ml/day	210 at 565 Ml/ day	792
Tullaroop Creek at Clunes (407 222)	Sep 1955--Apr 1970 14 water years (current)	632	171,940	3,090	59,490	94	1,800 at 7.3 Ml/day	100 at 5,198 Ml/day	680
Joyces Creek at Strathlea (407 210)	Jun 1963--Apr 1970 6 water years (current)	80	17,520	330	9,740	70	1,150 at 2.4 Ml/day	105 at 256 Ml/ day	604
Adekate Creek upstream Creswick Junction (407 238)	May 1969--Aug 1977 (finished)	11.7	2,940	790	2,010	167	420	79	
Middle Creek at Rodborough (407 239)	Feb 1970--Dec 1976 (current)	129	5,550	2,680	4,110	32	1,770	87	
Avoca River at Amphitheatre (408 202)	Dec 1966--Apr 1970 (current) 3 water years	85	6,870	760	3,400	40	4,104 at 0.4 Ml/day	110 at 14.7 Ml/day	1,624
Glenlogie Creek at Amphitheatre (408 204)	May 1966--Dec 1976 (current)	52	8,050	320	2,990	58	5,633	148	
Wimmera River at Eversley (415 207)	Jan 1903--Dec 1933 (finished) 30 water years	303	90,530	6,170	41,770	138	2,500 at 0.2 Ml/day	114 at 1,883 Ml/day	727

APPENDIX 3 (continued)

Gauging station	Recording period	Drainage area (sq.km) above gauging station	Annual discharge (Ml)			Mean annual discharge per drainage area (Ml per sq.km)	Salinity (mg per litre)		
			Maximum	Minimum	Mean		Maximum	Minimum	Mean
Leigh River at Mount Mercer (233 215)	Jan 1957--Apr 1970 (current) 13 water years	593	151,200	8,680	53,820	90	1,350 at 26.9 Ml/day	200 at 2,311.4 Ml/day	829
Warambine Creek at Warrambine Station (233 223)	May 1970--Dec 1976	62.2	2,840	210	1,650	27	1,833	233	
Woady Yaloak R. at Pitfield (234 200)	Jan 1918--Dec 1933 15 water years	324	74,330	2,370	25,690	53			
	May 1957--Apr 1970 (current) 13 water years	324	65,260	3,045	16,710	52	3,275 at 26.9 Ml/day	170 at 1,139.8 Ml/day	1,420
Woady Yaloak R. at Cressy (234 201)	May 1955--Apr 1970 (current) 15 water years	1,158	183,630	6,840	62,340	54	5,050 at 22.0 Ml/day	320 at 9,050 Ml/day	2,560
Hopkins River at Wickliffe (236 202)	Jan 1921--Dec 1933 Jan 1944--Apr 1970 (current) 38 water years	1,347	126,760	860	31,660	24	9,396 at 22 Ml/day	430 at 1,057 Ml/day	3,713
Mount Emu Creek at Skipton (236 203)	Jan 1921--Apr 1933 Jan 1944--Apr 1949 Jan 1955--Apr 1970 (current) 32 water years	1,250	233,950	1,470	66,792	53	4,300 at 26.9 Ml/day	230 at 640.8 Ml/day	1,833
Fiery Creek at Streatham (236 204)	Jan 1921--Dec 1933 Jan 1944--Apr 1970 (current) 38 water years	956	137,160	600	39,550	40	2,914 at 14.7 Ml/day	250 at 1,046 Ml/day	1,587
Mount Emu Creek at Mena Park (236 213)	Dec 1966--Dec 1976 (current)	290	28,840	5,340	15,780	53	4,133	48	

APPENDIX 4

CATCHMENT BASIN CHARACTERISTICS

Study area drainage basin	Area of drainage basin within study area (sq.km)	Major streams; gauging station	Area of catchment above gauging station (sq.km)	Estimated mean annual discharge		Reliability (% of annual discharge)	
				Approximate total (Ml)	Approximate rate (Ml per sq.km)	6 months Dec--May	3 months Jan--Mar
Wimmera--Avon	402	Wimmera R. at Eversley (415 207)	303	41,770	138	10.6	5.2
Avoca	166	Avoca R. at Amphitheatre (408 202)	85	3,400	40	12.1	2.6
		Glenlogie Ck at Amphitheatre (408 204)	52	2,990	58	-	-
Loddon	1,050	Bullarook Ck at Clunes Weir (407 207)	158	19,550	124	13.2	4.0
		Creswick Ck at Clunes (407 214)	308	30,710	100	9.3	3.5
		Tullaroop Ck at Clunes (407 222)	632	59,490	94	9.3	3.2
		Joyces Ck at Strathlea (407 230)	140	9,740	70	4.5	0.9
		Adekate Ck upstream Creswick Jn. (407 238)	12	2,010	167	-	-
		Middle Ck at Rodborough (407 239)	129	4,110	32	-	-

APPENDIX 4 (continued)

Study area drainage basin	Area of drainage basin within study area (sq.km)	Major streams; gauging station	Area of catchment above gauging station (sq.km)	Estimated mean annual discharge		Reliability (% of annual discharge)	
				Approximate total (Ml)	Approximate rate (Ml) per sq.km)	6 months Dec--May	3 months Jan--Mar
Moorabool	355	West Moorabool at Morrisons (232 204)	583	69,480	120	-	-
Barwon	1,310	Leigh River at Mount Mercer (233 215)	593	52,820	90	17.8	6.7
		Warrambine Ck at Warrambine station (233 223)	62	1,650	27	-	-
Corangamite	1,200	Woady Yaloak at Cressy (234 201)	1,157	62,340	54	13.5	3.6
Hopkins	3,747	Hopkins R. at Wickliffe (236 202)	1,347	31,660	24	10.9	4.8
		Fiery Creek at Streatham (236 202)	956	39,550	40	14.0	6.1
		Mt. Emu Ck at Skipton (236 203)	1,250	66,792	53	10.3	3.4

APPENDIX 5

PLANT SPECIES OF THE TREE AND SHRUB LAYER - DISTRIBUTION AND ABUNDANCE

(from field work carried out by A.C. Beauglehole)

Scientific name	Common name	Abundance* of species in the following floristic units																							
		2a	2b	2c	2c	2c	2d	2d	2d	2d	4b	4a	3a	3a	5a	5b	5b	5f	5i	5g	5g	6d	6a	6f	6b
Eucalyptus baxteri	Brown stringybark	2	4				4	2	4	4															
E. globulus	Blue gum	4	4								4														
Leptospermum juniperinum	Prickly tea-tree	1	4		2	2	2	4	4	2	2														
Monotoca scoparia	Prickly broom-heath	1				1		1	1	2		2													
Indigofera australis	Austral indigo	1			1		4					1													
Daviesia ulicifolia	Gorse bitter-pea	2	4			4							2	4											
Epacris impressa	Common heath		4	2	4	2		4	2	2		4	4	2											
Eucalyptus obliqua	Messmate stringy-bark	2	4	4	4	4	4	4	4	4	4	4	4	4											
E. radiata	Narrow-leaf peppermint	2	4		4	4	4		4			4	2		4										
Acacia melanoxylon	Blackwood	1	2	4	2	4	1	2	1	2	4	2	4	2	2								+		
Cassinia aculeata	Common cassinia		4	4	2	4	2				4	4	4	2	1										1
Eucalyptus rubida	Candlebark		2		4	4						4	2	1	2										
Acacia dealbata	Silver wattle	4	4	4	4	2	1				4	4	4		1										
A. verticillata	Prickly moses	2	4		2	2	4				4					1									
A. myrtifolia	Myrtle wattle		2				4	1	1							2									
Pteridium esculentum	Austral bracken	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4									
Eucalyptus viminalis	Manna gum	2	4	4	2	4		2	4		4				2	2	2								
E. ovata	Swamp gum			1	1	2	4	1	1						2										1
E. dives	Broad-leaved peppermint			4		4		4	4	4		4		4	4		4		4						
E. macrorhyncha	Red Stringybark	2						2				4	4	1	4	4	4	4	4	4	4	4	1		4
E. aromaphloia	Scent-bark							4	2	2		2	2	4	2	2	2					4	2	2	
E. goniocalyx	Long-leaf box	2										4						4		4	4	1	1	4	4
E. melliodora	Yellow box											2		1		1	2	4			4	2	4	4	2
Acacia pycnantha	Golden wattle													1		4	4	2	4			4	4	4	
A. acinacea	Gold-dust wattle														4	2	4		4						4
Eucalyptus leucoxylon	Yellow gum																	2				4	4		4
E. polyanthemos	Red box											1								4					4
E. sideroxylon	Red ironbark															2	4		4						
Dillwynia hispida	Red parrot-pea															+				1			+	1	
Eucalyptus camaldulensis	Red gum																					4	2	2	
Exocarpos cupressiformis	Cherry ballart		+	1	+		+	2	1	1		1	1	1	+		+	+	+		+			1	+
Acacia armata	Hedge wattle	2	4	1			2	1				+	2	2	2	1	+		1	4		1	1	4	4
A. mearnsii	Black wattle		1				1			2		1		2		+	1	+	+	2	2	1	4		
Daviesia virgata	Narrow-leaf bitter-pea		2		2	4	2	4	4	4		4	4	4	4		+	1		4					
Platylobium obtusangulum	Common flat-pea		4				4	1	2	1		2			2	+		1				1	1	4	
Xanthorrhoea minor	Small grass-tree			4			4	2	4	4	4				4		4							4	
Correa reflexa	Common correa		1				1							1	+			+						+	
Pultenaea gunnii	Golden bush-pea			2		4	4	4	2	4				2	4		4		4						
Leptospermum myrsinoides	Silky tea-tree							1	2	2				1				2				1	+	4	1
Helichrysum obcordatum	Grey everlasting	1	2						1	1		4	4					2		2				2	4
Bursaria spinosa	Sweet bursaria						+			1	2		1				+	2		2		1		4	2
Dillwynia cinerascens	Grey parrot-pea				4	2		1	1	1		4		2						1		+			2
Acacia stricta	Hop wattle				1		4		4	1				1	1		+								
Pultenaea humilis	Bush pea			1					4					1										1	

APPENDIX 5 (continued)

Scientific name	Common name	Abundance* of species in the following floristic units																							
		2a	2b	2c	2c	2c	2d	2d	2d	2d	4b	4a	3a	3a	5a	5b	5b	5f	5i	5g	5g	6d	6a	6f	6b
Pultenaea daphnoides	Large-leaf bush-pea		4		2					1		1					2								
Gahnia radula	Thatch saw-sedge						2		2						2	1									
Leptospermum lanigerum	Woolly tea-tree		2		1						1														
Acacia implexa	Lightwood																				1			+	
Casuarina stricta	Drooping she-oak																				+				
C. littoralis	Black she-oak															+									
Banksia marginata	Silver banksia						2																	4	
Dodonea cuneata	Wedge-leaf hop-bush	2	4																						
Viminaria juncea	Golden spray																							+	
Hedycarya augustifolia	Austral mulberry										4														
Hakea sericea	Bushy needlewood													+											
Helichrysum dendroideum	Tree everlasting			+	2																				
Acacia mucronata	Narrow-leaf wattle				4	4																			
Dillwynia sericea	Showy parrot-pea											2			+							2			
Acacia oxycedrus	Spike wattle	2	4																						
Leucopogon virgatus	Common beard-heath											2												1	
Grevillea alpina	Mountain grevillea	1																						2	
Eucalyptus microcarpa	Grey box																								1
Polyscias sambucifolius	Elderberry panax					1																			
Dicksonia antarctica	Soft tree-fern						+				4														
Cyathea australis	Rough tree-fern						+																		
Grevillea sp.	Grevillea						2		+						2										
Dianella revoluta	Black-anther flax-lily														2										
Poa labillardieri	Tussock grass														4	4									
Pultenaea pedunculata	Matted bush-pea														2										
Lissanthe strigosa	Peach heath															4	4								
Eriostemon verrucosus	Fairy wax-flower																	+							
Astroloma conostephioides	Flame heath																								4
Leptospermum nitidum	Shining tea-tree	2																							
Kunzea parvifolia	Violet kunzea	1																							
Calytrix alpestris	Snow myrtle	1																							
Micromyrtus ciliata	Heath-myrtle	1																							
Coprosma hirtella	Rough coprosma		2		+																				
Pimelea axiflora	Bootlace bush		2																						
Daviesia mimosoides	Bitter-pea		+																						
Gahnia sieberiana	Red-fruit saw-sedge		4																						
Acacia genistifolia	Spreading wattle													4											
Tetratheca ciliata	Pink bells		1																	+					
Acacia aculeatissima	Thin-leaf wattle											2													
Grevillea sp.	Grevillea											2													
Cassinia arcuata	Drooping cassinia				+							+													
Xanthorrhoea australis	Austral grass-tree			+								2													
Leptospermum scoparium	Manuka												+												

APPENDIX 5 (continued)

Scientific name	Common name	Abundance* of species in the following floristic units																							
		2a	2b	2c	2c	2c	2d	2d	2d	2d	4b	4a	3a	3a	5a	5b	5b	5f	5i	5g	5g	6d	6a	6f	6b
Daviesia genistifolia	Broom bitter-pea																			2					
Cassinia uncata	Sticky cassinia					1																			
Olearia glandulosa	Swamp daisy bush										4														
Bossiaea cordigera	Wiry bossiaea					1					+														
Sambucus gaudichaudiana	White elderberry										2														
Comesperma ericinum	Heath milk-wort																								
Dillwynia ramosissima	Dillwynia									4															
Acacia aspera	Rough wattle																								
Dillwynia retorta	Small-leaf parrot-pea													+											
Acacia verniciflua	Varnish wattle		4								2									2					
Grevillea lanigera	Woolly grevillea							2		+															
Acacia lanigera	Woolly wattle								1																
Daviesia latifolia	Hop bitter-pea			2																					
Grevillea repens	Creeping grevillea				1																				
Coprosma quadrifida	Prickly current-bush				1																				
Pultenaea muelleri	Mueller's bush-pea				4	2																			
Helichrysum rosmarinifolium	Rosemary ever-lasting					1																			
Pultenaea scabra	Rough bush-pea		2																						
Dillwynia glaberrima	Smooth parrot-pea									4															
Oxylobium procumbens	Trailing oxylobium									1															
Gynatrix pulchella	Hemp bush														+										
Acacia retinodes	Wirilda															+									
Hibbertia stricta	Erect guinea-flower																								2
Calytrix tetragona	Fringe-myrtle																		4						

*abundance: + <5%
1 5--20%
2 20--50%
4 >50%

Common names in accordance with Willis (1970, 1972)

APPENDIX 6

BIRDS

Species	Habitat: aquatic	grass-land	wood-land	open forest	tall open forest	Distribution: Abundance
Emu						Survival doubtful
Great crested grebe b	X					W:U
Hoary-headed grebe b	X					W:C
Australasian grebe b	X					W:C
Australian pelican	X					R:U
Darter	X					R:R
Great cormorant	X					W:C
Pied cormorant	X					W:R
Little black cormorant	X					W:U
Little pied cormorant	X					W:C
Pacific heron b	X	X				W:U
White-faced heron b	X	X				W:C
Cattle egret	X	X				W:U
Great egret	X	X				W:U
Intermediate egret	X					W:R
Rufous night heron	X					W:U
Little bittern	X					R:R
Australasian bittern b	X					W:R

Species	Habitat					Distribution: Abundance
	aquatic	grass-land	wood-land	open forest	tall open forest	
Glossy ibis	X	X				W:R
Sacred ibis b	X	X				W:U
Straw-necked ibis b	X	X				W:C
Royal spoonbill	X					W:R
Yellow-billed spoonbill b	X					W:U
Plumed whistling duck	X					R:R
Black swan b	X	X				W:C
Freckled duck	X					W:R
Cape Barren goose	X	X				W:R
Australian shelduck b	X	X				W:C
Pacific black duck b	X	X				W:C
Mallard *	occasional farm escape recorded					
Grey teal b	X	X				W:C
Chestnut teal b	X					W:U
Australasian shoveler b	X	X				W:U
Pink-eared duck	X					W:U
Hardhead b	X					W:U
Maned duck	X	X				W:U
Blue-billed duck b	X					W:C
Musk duck b	X					W:C
Black-shouldered kite b		X	X			W:U
Letter-winged kite		X				R:R
Black kite		X				W:R
Whistling kite b		X	X			W:C
Brown goshawk b		X	X	X.P	X	W:C
Collared sparrowhawk b			X	X.P		W:R
Grey goshawk		X	X	X	X	W:R
Wedge-tailed eagle b		X	X	X	X	W:C

Species	Habitat					Distribution: Abundance
	aquatic	grass-land	wood-land	open forest	tall open forest	
Little eagle		X				W:U
Spotted harrier		X				R:R
Marsh harrier b	X	X				W:C
Black falcon		X				R:R
Peregrine falcon b	X	X	X	X.P		W:U
Australian hobby b		X.S	X	X.P		W:U
Brown falcon b		X	X	X		W:C
Australian kestrel		X				W:U
Stubble quail		X				W:C
Brown quail	X	X				R:R
Painted button-quail b			X	X.P		W:U
Little button-quail b		X				R:R
Plains-wanderer		X				R:R
Buff-banded rail b	X	X				W:U
Lewin's rail b	X					R:R
Baillon's crake b	X					W:U
Australian crake b	X					W:U Nomadic
Spotless crake b	X					W:U
Black-tailed native-hen	X	X				R:C Nomadic
Dusky moorhen b	X					W:C
Purple swamphen b	X	X				W:C
Eurasian coot b	X					W:C
Brolga b	X	X				W:U

Species	Habitat					Distribution: Abundance
	aquatic	grass-land	wood-land	open forest	tall open forest	
Australian bustard		X				R:R
Bush thick-knee b			X	X		W:R
Painted snipe	X					W:R
Masked lapwing b	X	X				W:C
Banded lapwing b		X				W:U
Red-kneed dotterel	X					W:U
Double-banded plover	X					W:U
Red-capped plover b	X					W:C
Black-fronted plover b	X					W:C
Black-winged stilt b	X					W:U
Banded stilt	X					R:R
Red-necked avocet b	X					W:U
Wood sandpiper	X					R:R Migrant
Common sandpiper	X					R:R Migrant
Greenshank	X					R:R Migrant
Latham's snipe	X	X				W:U Migrant
Sharp-tailed sandpiper	X					W:C Migrant
Red-necked stint	X					R:C Migrant
Curlew sandpiper	X					R:R Migrant
Silver gull b	X	X				W:C
Whiskered tern b	X					W:U

Species	Habitat: aquatic	grass-land	wood-land	open forest	tall open forest	Distribution: Abundance
Gull-billed tern b	X					R:U
Caspian tern	X					R:R
Feral pigeon b *		X.S				W:C
Spotted turtle-dove b *		X.S				W:C
Peaceful dove		X	X			R:R
Common bronzewing b			X	X.P	X	W:U
Brush bronzewing b				X	X	W:R
Yellow-tailed black-cockatoo				X.P	X	W:U
Gang-gang cockatoo				X	X	R:R
Galah b		X	X			W:U
Long-billed corella		X	X			R:U
Sulphur-crested cockatoo b		X	X	X	X	W:C
Rainbow lorikeet		S		X		R:R
Musk lorikeet		X.S	X	X	X	W:U Nomadic
Purple-crowned lorikeet			X	X		W:U Nomadic
Little lorikeet		X.S	X	X		W:U Nomadic
Cockatiel		X.S	X	X		R:R Nomadic
Budgerigar		X	X			W:R
Swift parrot		X.S	X	X		W:R Migrant
Crimson rosella b		X.S	X	X.P	X	W:C
Eastern rosella b		X	X	X		W:C
Red-rumped parrot b		X	X			W:C
Blue-winged parrot		X	X	X		W:R
Elegant parrot		X				W:R

Species	Habitat					Distribution: Abundance
	aquatic	grass-land	wood-land	open forest	tall open forest	
Pallid cuckoo b		X	X	X.P		W:C Migrant
Brush cuckoo				X	X	W:R Migrant
Fan-tailed cuckoo b		X.S	X	X.P	X	W:C Migrant
Black-eared cuckoo b			X	X		W:R Migrant
Horsfield's bronze-cuckoo b		X	X	X.P		W:C Migrant
Shining bronze-cuckoo		X	X	X.P	X	W:C Migrant
Powerful owl b				X	X	W:C
Southern boobook b		X	X	X.P	X	W:C
Barking owl		X	X			R:R
Barn owl b		X				W:C
Tawny frogmouth b		X	X	X		W:U
Australian owlet-nightjar b			X	X		W:U
White-throated needletail	aerial species - all habitats					W:C Migrant
Fork tailed swift	aerial species - all habitats					W:R Migrant
Azure kingfisher	X					R:R
Laughing kookaburra b		X.S	X	X.P	X	W:C
Sacred kingfisher b	X	X	X	X		W:C
Rainbow bee-eater b		X	X	X		W:U

Species	Habitat					Distribution: Abundance
	aquatic	grass-land	wood-land	open forest	tall open forest	
Singing bushlark		X				R:R
Skylark b *		X				W:C
Welcome swallow b	X	X	X	X.P		W:C
Tree martin b	X	X	X			W:C
Fairy martin b	X	X	X			W:C
Richard's pipit b		X				W:C
Black-faced cuckoo-shrike b		X	X	X	X	W:C
White-bellied cuckoo-shrike b			X	X		W:U
White-winged triller b		X	X	X		W:U
White's thrush b				X.P	X	W:U
Common blackbird b *		X.S		X.P	X	W:C
Song thrush *		S				R:R
Rose robin		S		X	X	W:R
Pink robin b				X.P	X	W:U
Flame robin b		X.S	X	X	X	W:C
Scarlet robin b		X.S	X	X.P		W:C
Red-capped robin		X.S	X	X.P		R:R
Hooded robin b		X	X			W:U
Eastern yellow robin b			X	X.P	X	W:C
Jacky winter b		X	X	X		W:C
Crested shrike-tit b		X	X	X.P	X	W:C
Olive whistler					X	R:R
Golden whistler b		X.S	X	X.P	X	W:C
Rufous whistler b		X.S	X	X.P	X	W:C
Grey shrike-thrush b		X.S	X	X.P	X	W:C

Species	Habitat: aquatic	Habitat: grass-land	Habitat: wood-land	Habitat: open forest	Habitat: tall open forest	Distribution: Abundance
Leaden flycatcher			X	X		R:R Migrant
Satin flycatcher b			X	X	X	W:U Migrant
Restless flycatcher b		X	X	X.P		W:C
Rufous fantail b					X	R:U Migrant
Grey fantail b		X.S	X	X.P	X	W:C
Willy wagtail b		X.S	X			W:C
Spotted quail-thrush b				X.P		R:U
White-browed babbler b			X	X		R:U
Clamorous reed-warbler b	X					W:C Migrant
Little grassbird b	X	X				W:C
Golden-headed cisticola b	X	X				W:U
Rufous songlark		X	X	X		R:U Migrant
Brown songlark b		X				W:C Migrant
Superb fairy-wren b		X.S	X	X.P	X	W:C
White browed scrubwren b		X.S	X	X.P	X	W:C
Calamanthus b		X				W:U
Speckled warbler b			X	X.P		W:C
Weebill			X	X		W:U
White-throated gerygone				X		R:R
Brown thornbill		X.S	X	X.P	X	W:C
Chestnut-rumped thornbill b			X	X		W:R
Buff-rumped thornbill			X	X.P		W:C
Yellow-rumped thornbill b		X	X			W:C

Species	Habitat					Distribution: Abundance
	aquatic	grass-land	wood-land	open forest	tall open forest	
Yellow thornbill		X		X		W:U
Striated thornbill b		X.S	X	X.P	X	W:C
Southern whiteface		X				W:U
Varied sittella b		X	X	X	X	W:C
White-throated tree-creeper b				X.P	X	W:C
Red-browed treecreeper					X	R:U
Brown treecreeper b			X	X		W:C
Red wattlebird b		X.S	X	X.P	X	W:C
Spiny-cheeked honeyeater		S		X		R:R
Regent honeyeater			X	X		R:R
Noisy miner b		X	X			W:C
Yellow-faced honeyeater b		X.S	X	X.P	X	W:C
Singing honeyeater		X.S				R:R
White-eared honeyeater b		X.S	X	X.P	X	W:C
Yellow-tufted honeyeater			X	X		W:U
Fuscous honeyeater b			X	X		W:C
White-plumed honeyeater		X.S	X			W:C
Black-chinned honeyeater			X	X		R:U
Brown-headed honeyeater		X.S	X	X	X	W:C
White-naped honeyeater b		X.S	X	X	X	W:C
Painted honeyeater b		X	X	X		R:U
Crescent honeyeater b		S		X	X	R:U
New holland honeyeater b		S	X	X		W:U
Tawny-crowned honeyeater b		S				R:R
Eastern spinebill b		X.S	X	X.P	X	W:C

Species	Habitat: aquatic	grass-land	wood-land	open forest	tall open forest	Distribution: Abundance
White-fronted chat b		X				W:C
Mistletoe bird b			X	X		W:U
Spotted pardalote b		X.S	X	X	X	W:C
Striated pardalote b		X.S	X	X	X	W:C
Silvereye b		X.S	X	X.P	X	W:C
European goldfinch b *		X		P		W:C
European greenfinch b *		X.S		P		W:U
House sparrow b *		X.S				W:C
Tree sparrow		S				R:R
Red-browed firetail b		X	X	X.P	X	W:C
Diamond firetail b		X	X			W:U
Common starling b *		X.S				W:C
Common myna		S				R:R
Olive-backed oriole b			X	X		W:C Migrant
White-winged chough b		X	X.P	X		W:C

Species	Habitat: aquatic	grass-land	wood-land	open forest	tall open forest	Distribution: Abundance
Australian magpie-lark b		X	X			W:C
White-browed woodswallow b		X	X			W:U Nomadic
Dusky woodswallow b		X	X	X		W:C
Grey butcherbird b		S	X	X		W:U
Australian magpie b		X.S	X	X.P		W:C
Pied currawong b		X		X	X	R:U
Grey currawong b		X	X	X.P	X	W:C
Australian raven b		X	X	X.P		W:C
Little raven b		X	X			W:C

b recorded breeding in the study area

* introduced species

Distribution : Abundance

W - widespread
R - restricted

R - rare
U - uncommon
C - common

Habitat

X - found in this habitat
P - found in pine plantations
S - found in suburban areas

APPENDIX 7

MAMMALS

Species	Habitat: aquatic	Habitat: grass-land	Habitat: wood-land	Habitat: open forest	Habitat: tall open forest	Distribution: Abundance
Echidna			X	X		W:C
Platypus	X					W:C
Tiger cat				X		R:R
Quoll		X	X			Extinct
Tuan		X	X			W:U
Yellow-footed antechinus				X		R:U
Brown antechinus				X	X	W:C
Swainson's antechinus					X	R:C
Mouse dunnart				X		R:R
Fat-tailed dunnart		X				W:U
Gunn's bandicoot		X	X			Extinct
Wombat				X	X	R:R
Koala			X	X	X	W:C
Brush-tailed possum		S	X	X	X	W:C

Species	Habitat: aquatic	grass-land	wood-land	open forest	tall open forest	Distribution: Abundance
Ring-tailed possum			X	X	X	W:C
Sugar glider				X	X	W:C
Yellow-bellied glider					X	*Unconfirmed*
Greater glider					X	R:R
Feather-tailed glider			X	X	X	W:U
Eastern pigmy possum				X		W:U
Eastern grey kangaroo			X	X	X	W:C
Red-necked wallaby				X	X	R:U
Black-tailed wallaby				X	X	W:C
Tasmanian pipistrelle				X	X	W:U
Little bat				X	X	W:C
Gould's wattled bat				X	X	W:C
Bent-winged bat				caves and tunnels		R:R
Lesser long-eared bat				X		W:C
White-striped bat			X	X		R:U
Hare *		X	X			W:U
Rabbit *		X	X	X		W:C
Bush rat				X	X	R:C
Black rat *	X	S		X	X	W:C
Swamp rat				X	X	R:C
House mouse *		X	X			W:C
Eastern water rat	X					W:U

Species	Habitat					Distribution: Abundance
	aquatic	grass-land	wood-land	open forest	tall open forest	
Grey squirrel		Ballarat gardens				Extinct
Fox *		X	X	X	X	W:C
Cat *		X	X	X	X	W:C
Sambar deer *					X	R:U
Red deer *				X		R:U

* Introduced Species

Distribution : Abundance

W - widespread
R - restricted

R - rare
U - uncommon
C - common

Habitat

X - found in this habitat
P - found in pine plantations
S - found in suburban areas

APPENDIX 8

REPTILES

Species	Habitat: aquatic	grass-land	wood-land	open forest	tall open forest	Distribution: Abundance
Long-necked tortoise	X					R:R
Marbled gecko			X	X		R:C
Thick-tailed gecko			X	X		R:C
Spinifex lizard		X				W:U
Jacky lizard			X	X		W:C
Large striped skink			X	X		R:U
Cunningham's skink		X				R:R
Black rock skink				X		R:U
White's skink		X		X		W:C
Three-toed skink				X		R:C
Garden skink				X	X	W:C
Coventry's skink				X	X	R:U
Grass skink		X	X	X	X	W:C
Three-lined skink		X	X			W:U
Bougainville's skink			X	X		W:U
Spencer's skink				X		R:R
Southern water skink				X	X	R:C
Blotched blue-tongued lizard				X		W:C
Eastern blue-tongued lizard		X				W:U
Shingle-back			X	X		R:U

Species	Habitat					Distribution: Abundance
	aquatic	grass-land	wood-land	open forest	tall open forest	
Copperhead			X	X		W:U
White-lipped snake				X		R:U
Eastern tiger snake				X		W:C
Red-bellied black snake				X		W:R
Eastern brown snake		X	X	X		W:C
Little whip snake		X	X	X		W:U

Distribution : Abundance

W - widespread
R - restricted

R - rare
U - uncommon
C - common

APPENDIX 9

WATER AUTHORITIES OPERATING IN THE BALLARAT AREA

Authority	Source of supply	Population served	Annual Consumption (Ml)	Remarks
Ararat City Council	Storages at Mt. Cole, Mt. Langi Ghiran, and Lake Fyans	8,800 in the City of Ararat	1,800	
Shire of Ararat Waterworks Trust (Elmhurst Urban District)	Weir on Hickmans Ck (tributary of Wimmera River)	190	34	
Shire of Ararat WWT (Moyston Urban District)	Reservoir supplies from Stoney and Masons Ck. (Hopkins R. and bores)	130	28	supplies from Mt Pleasant Res. to Moyston, Willaura and Wickliffe
Shire of Ararat WWT (Streatham Urban District)	bore	80	6	
Shire of Ararat WWT (Lake Bolac Urban District)	tributaries of Hopkins River and bores	400	72	same scheme supplies Moyston, Willaura and Wickliffe
Shire of Ararat WWT (Wickliffe Urban District)	as above	80	15	as above
Shire of Ararat WWT (Willaura Urban District)	as above	850	196	as above
The Ballarat Water Commissioners (Cardigan Village Estate)	The Ballarat Water Commissioners	1,000		trunk mains from B.W.C. works

APPENDIX 9 (Continued)

WATER AUTHORITIES OPERATING IN THE BALLARAT AREA

Authority	Source of supply	Population served	Annual Consumption (Ml)	Remarks
The Ballarat Water Commissioners	White Swan Res. Gong Gong Res. Pincotts Res. Kirks Res. Beales Res. Wilsons Res. Moorabool Res. diversion from Lal Lal Res.	68,300 in the City of Ballaarat and neighbouring Trusts		other Trusts supplied with bulk water: Smythesdale--Scarsdale, Linton, Rokewood, Buninyong, and Bungaree--Wallace
Bungaree--Wallace W.W.T.	The Ballarat Water Commissioners	320	95	water gravitates from B.W.C. main to Wallace and is pumped up to Bungaree
Buninyong W.W.T.	The Ballarat Water Commissioners	900	163	pumped supply from B.W.C. main
Bannockburn W.W.T.	Moorabool River	1,230	-	supplies Teesdale, Lethbridge, Shelford
Beaufort W.W.T.	headwaters on Fiery Ck and tributaries	1,540	330	
Creswick Shire Council. L.G.B. (Creswick Water Supply District)	Cosgrove Res. Dean Res. Russells Res	2,000	330	
Creswick Shire Council. L.G.B. (Smeaton Water Supply District)	Newlyn Res.	125	20	supply from Springhill W.S. District
Creswick Shire Council. L.G.B. (Springhill Water Supply District)	Newlyn Res.	550	140	supplies Allendale, Broomfield, Kingston, Newlyn, Newlyn North and Springhill

APPENDIX 9 (Continued)

WATER AUTHORITIES OPERATING IN THE BALLARAT AREA

Authority	Source of supply	Population served	Annual consumption (Ml)	Remarks
Linton W.W.T.	The Ballarat Water Commissioners	820	200	supplies Linton, Snake Valley and Carngham
Learmonth W.W.T.	bores tap underground water	210	31	
Lexton W.W.T. (Lexton Urban District)	Doctors Ck Res. (tributary of Loddon River)	200	32	water-quality problems
Lexton W.W.T. (Waubra Urban District)	bore taps underground water	100	15.4	works are under construction to supply Waubra
Rokewood W.W.T.	The Ballarat Water Commissioners	900	136	37 km of pipeline from B.W.C. works
Skipton W.W.T.	St. Enoch's Spring Broken Ck	550	130	proposed 8 Ml service basin and pumping station
Smythesdale--Scarsdale W.W.T.	The Ballarat Water Commissioners	800	120	pipeline from B.W.C. works; proposed 14 Ml service basin Nintingbool

Source: State Rivers and Water Supply Commission

APPENDIX 10

AUTHORISED DIVERSIONS FROM SELECTED SURFACE WATER RESOURCES (1976/77)

Water systems	State of regulation	No. of permits issued			Area irrigated (ha) pasture lucerne annual crop potatoes	Annual volume (Ml) irrigation
		Irrigation	Domestic & stock (1)	Indust-rial (2)		
Loddon River and tributaries (3)	natural flow	99	4	2	864	2,910
Moorabool River and tributaries	west branch regulated below Lal Lal Res.	42	1	-	248	682
Leigh River and tributaries	natural flow	31	11	1	199	1,466
Woady Yaloak Ck	natural flow	2	-	1	8	50
Hopkins River and tributaries	natural flow	9	7	1	40	196
Lake Bolac		2	10	-	78	469
Lake Burrumbeet		5	-	-	77	519
Lake Learmonth		6	-	-	40	126

Source: State Rivers and Water Supply Commission

Notes: (1) Domestic and stock use excludes those properties which enjoy a riparian right.

(2) Annual permits authorising diversion for various industrial purposes.

(3) Includes long term licences authorising diversion from the section of Bullarook Creek regulated by Newlyn Reservoir.

APPENDIX 11

AUTHORISED ANNUAL EXTRACTIONS FROM GROUNDWATER RESOURCES

Parish	No. of licences			Total area irrigated (ha) pasture, lucerne annual crops	Total authorised extraction (Ml)
	Domestic & stock (1)	Irrigation	Other (2)		
Addington	5	1		12	56
Ararat	1	1		12	41
Ascot		15	6	250	1,101
Ballarat	2				
Beaufort	1				
Buangor	1				
Bullarook	3		1		
Bungaree	39	24		306	962
Buninyong	1				
Burrumbeet	118	1	5	4	25
Burtwarrah	2				
Cardigan	1				
Carrah	1				
Clarendon	2				
Creswick	5				
Crowlands	1				
Dean	13	11		105	318
Doroq	4	1		2	5
Dowling Forest	7	1		4	24
Enfield	2				
Enuc	19				
Ercildoun	19	3	4	25	76
Eversley	4				
Glendaruel	18	9	1	242	1,022
Glenpatrick	2				
Haddon	1	1		8	28
Hesse	1				
Kerrit Bareet	16	2		28	85
Korweinguboora	1				
Lal Lal	10	1		8	48
Lawaluk	2				
Lexton	5				

APPENDIX 11 (Continued)

AUTHORISED ANNUAL EXTRACTIONS FROM GROUNDWATER RESOURCES

Parish	No. of licences			Total area irrigated (ha) pasture, lucerne annual crops	Total authorised extraction (Ml)
	Domestic & stock (1)	Irrigation	Other (2)		
Meredith	2				
Mininera	5				
Parupa	7				
Smeaton	5	2	2	28	111
Springhill	6	9		186	734
Streatham			1		
Tatyoon	2				
Tourello	5	2		72	301
Warrak	3				
Warrenheip	26	15	1	183	717
Windermere	4				
Woodnaggerak	4				
Totals	414	99	21(3)	1,475	5,654

Source: State Rivers and Water Supply Commission

Notes: (1) Domestic and stock - use is registered but no volumetric entitlement is granted.

Average usage may be of the order of 2.5 Ml per bore.

(2) Licences issued for other than irrigation use, authorise a volume of 45 Ml for 18 diaries and 75 Ml for commercial and urban use.

Parishes within the area but not tabulated, indicate no authorised groundwater use.

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