AUSTRALIANS

A HISTORICAL ATLAS

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ACKNOWLEDGMENT

THE DIVISION OF NATIONAL MAPPING

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Illustration opposite

Mare del Sud *(the South Sea) published by Antonio Zatta, a Venetian printer, publisher and bookseller, in 1776. The description on the map reads:* New South Wales or New Holland was recently discovered by Lieutenant James Cook, captain of His Britannic Majesty's Ship called the Endeavour, in the year 1770 after having circumnavigated and explored the coast of New Zealand. *The map also charts the voyages of the British navigators Philip Carteret, John Byron and Samuel Wallis in the 1760s.*

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AUSTRALIANS

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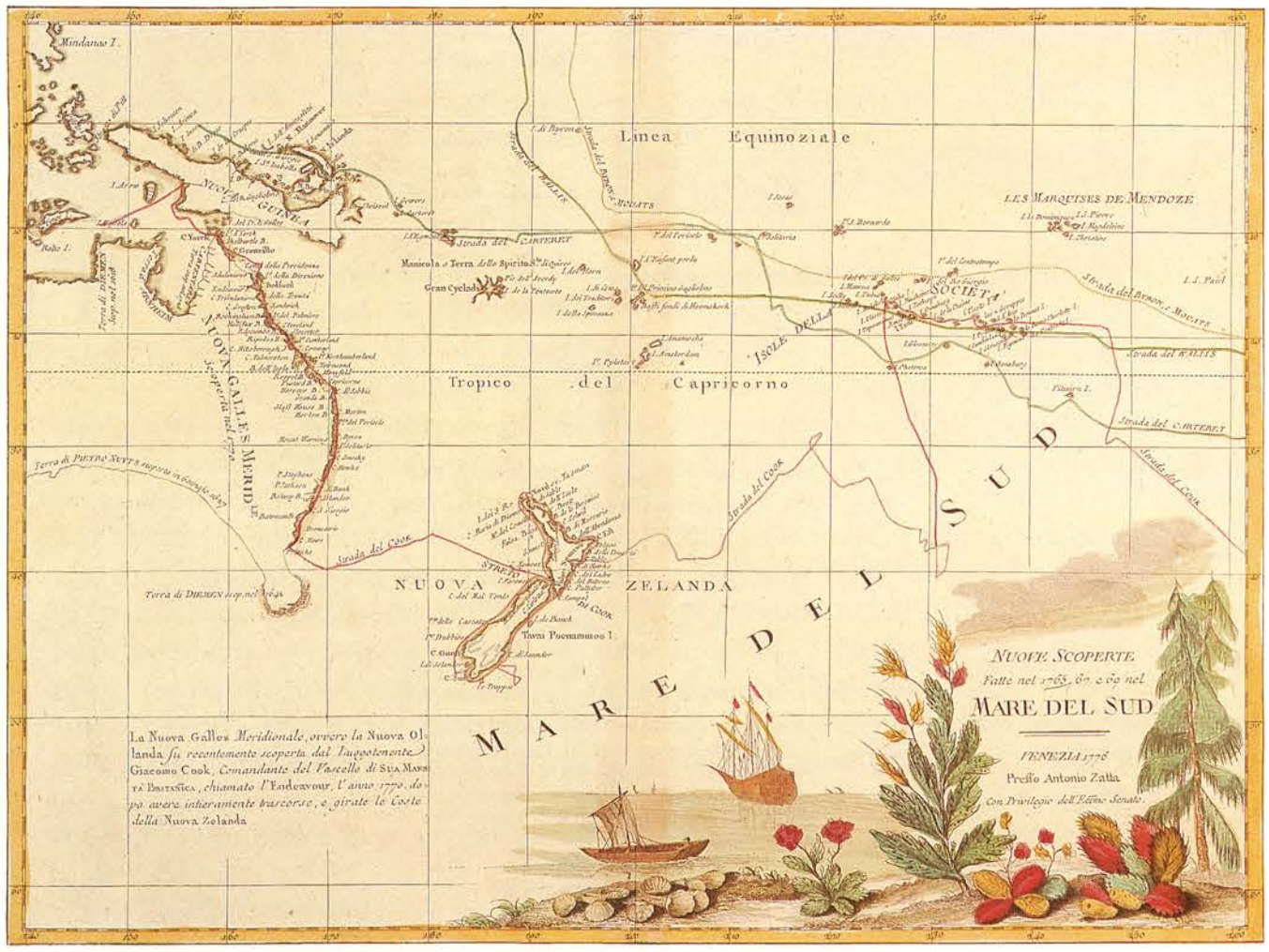

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AUSTRALIANS: A HISTORICAL ATLAS

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Photograph by John Bull.

FOREWORD

THIS BOOK and its ten companions have been ten years in the making. They have been created to mark the bicentenary of European settlement in this country, and they are the outcome of collaboration on a scale never before attempted in the writing of Australian history. Hundreds of people in and beyond universities have joined together to re-create the experience of people living in Australia since 1788 and to place that experience in the wider context of a human occupation that began tens of thousands of years ago.

The editors and contributors have worked in a variety of modes: from slicing into the past at fifty-year intervals (*Australians 1838, 1888* and *1938*) to laying out, in terse chronology, events as they happened year by year (*Events and places*), and from portraying processes and movements on maps of the country (*A historical atlas*) to briefing readers for explorations of their own (*A guide to sources*). The authors represent diverse approaches, in terms both of occupation – historian, economist, archaeologist, geographer, librarian, journalist – and of outlook. We have sought the best person for each part of the job, and not altered or muffled anybody's voice. We have also tried to make the work of scholars readily accessible to general readers.

In this aspiration we have been strengthened by a close working relationship with the publishers. From early days the project has benefited from continuous consultation with representatives of Fairfax, Syme & Weldon about its form and presentation. Their confidence in our enterprise has heartened us throughout the long journey.

Together, we and they present *Australians: a historical library* to the people of Australia as an offering for 1988 and beyond.

OLIVER MACDONAGH

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PREFACE

HISTORIANS are professionally interested in the passing of time, and in 1977 a few historians in Canberra began to think about 1988 as a year offering a special opportunity to their craft. That year, we guessed, would inspire a larger and more general commemoration than Australians had organised at the end of any previous half-century. The coming occasion was sure to be more *national* than those others, for advances in central government, transport and communication had accelerated the transformation of states that had once been separate colonies into provinces of a single polity, whose people travelled about as never before, talked to each other on STD, watched all over the continent the same prime ministerial news conference and the same cricket match. Moreover, Australian history itself was gaining a new popularity, as Stuart Macintyre comments at the end of the first chapter in *Australians: a guide to sources*. The names of Manning Clark and Geoffrey Blainey were better known than those of any scholarly historian in earlier times; historical and genealogical societies were burgeoning, and tourists flocked to Ballarat to see gold-rush days reconstructed at Sovereign Hill and to Old Sydney Town to see convict floggings re-enacted. Television viewers switched on to Australian costume dramas; and cinema audiences were offered, in 1977 alone, eight feature films based on life in the remote and recent Australian past.

All in all, it appeared likely that public and private enterprise would make 1988 a year for intense consciousness of Australian history. What might historians contribute? Individually, of course, whatever scholarly article or biography or general history an author was moved to attempt. Collectively? The Canberra group, consulting widely, found some antipathy towards the very idea of collaborative enterprise — 'history by committee' — and some particular doubts about proposed approaches. But it also found much interest and enthusiasm, and eventually enough support to embark on the project that has become *Australians: a historical library*.

The makers of these books do not see them as official history in any sense. The project has had no money from the Australian Bicentennial Authority. Money for general administration and for research on different volumes has been provided from universities (especially the Australian National University and the University of New South Wales), and from the Australian Research Grants Scheme. General and volume editors have taken on the job as part of their work in universities and colleges of advanced education. With few exceptions, contributors are also unpaid. Royalties will go into a fund to support Australian studies. Some advance royalties paid years ahead of publication, have been ploughed into research for the books.

That was a source of funds unforeseen when we began. Some potential publishers told us that they would need a subsidy; Fairfax, Syme & Weldon asked for no subsidy, anticipated larger sales than any other publisher we approached, and encouraged us to plan without any inhibitions the size of the books and the quantity and quality of illustrations. The scale on which the publishers have been willing to undertake the project has helped us keep two early resolutions: to write for general readers, addressing them with respect but without assuming prior knowledge and to illustrate the books richly, not for mere decorative effect but to integrate visual material with text.

Historians had long lamented the absence of a set of reference books that would deliver essential information about Australian history to students, authors and browsers. The *Australian encyclopaedia,* first published in 1925 and revised three times since, included much information about Australia's past, but its focus was not primarily historical. Many reference works were devoted to particular subject areas, from A. McCulloch's *Encyclopaedia of Australian art* and E. M. Miller and F. T. Macartney's *Australian literature* to C. A. Hughes and B. D. Graham's *A handbook of Australian government and politics* and the official histories of Australia's part in two world wars.

Taken together, such books made up a valuable reference library. Few people, however, possessed them all; and those who did still found large gaps in their library's historical coverage. The committee planning this project had an impressive precedent in the *Australian dictionary of biography,* a multi-volume enterprise which draws on scholars throughout the nation.

Australians lacked an atlas of their history and a convenient compilation of historical statistics. Information about other aspects of the past was scattered and hard to come by. We decided, therefore, that the series should include five reference volumes, presenting our past in an accessible and inviting format. This is the purpose of *Australians: a historical atlas, Australians: events and places, Australians: a historical dictionary, Australians: a guide to sources* and *Australians: historical statistics*.

These five volumes build on earlier generations of reference works, including encyclopaedias, colonial, state and commonwealth yearbooks, census reports, *Who's who,* the *Australian dictionary of biography* and atlases. Our editors, writers and researchers have also used many books published about aspects of Australian life and unpublished material in libraries, government and private archives and museums. We have drawn on the expertise of the staff of such institutions and of individual researchers across the nation.

Each reference book approaches the past in different ways. *Events and places* combines a chronology and a gazetteer, providing a reference that is both historical and geographical in approach. In the *Events* section we set out what we consider to be the most important

and interesting happenings in Australian history. We intend *Events* to have many uses: for example, to settle arguments about who was the first to do what; to help a reader imagine Australia in the year in which he or she was born or when a parent, grandparent or great-grandparent first arrived. The *Places* section provides a summary history of more than seven hundred cities, towns and geographical features. Some of the towns, especially those founded near goldfields, now scarcely exist. There are 32 regional essays in *Places* which put the localities in a wider historical and economic framework.

Australians: a historical dictionary has over 1000 entries on people, movements, ideas and institutions which have shaped Australia's past. Readers will find short biographies on such prominent Australians as Dame Nellie Melba, Jack Lang, Judith Wright and Rupert Murdoch. Historical developments including land settlement schemes and the spread of the railway system are explained, as are terms such as 'peacocking' and 'cabbage tree hat'. Readers can discover information on such diverse topics as the creation of Vegemite and the invention of the combine harvester.

Australians: a historical atlas is the most ambitious of all the reference volumes. Such a book has never been attempted before, as cartography is an expensive enterprise and requires contributions from people with a great variety of skills. Nine cartographers and a large number of scholars including geographers, economists, archaeologists and historians have worked to produce the atlas. Most of the maps and diagrams have been created for it. The atlas traces the evolution of the landscape from earliest times to the present, assessing the impact Australians have had on this landscape. Also shown are the origins and distribution of the population and the course of major events, such as wars and the Great Depression.

Australians: a guide to sources is the most wide-ranging of the reference books, directing readers to information sources. It opens with an account of the writing of Australian history, and a description of the principal repositories of information about Australia, including libraries, archives and museums. Our emphasis is on printed material, particularly books, because books provide readily accessible information, and those listed in *A guide to sources* are usually to be found in major libraries in every state. We do not ignore the computer revolution, for the creation of on-line databases is transforming the way we send and receive information.

In *Australians: historical statistics,* we offer long chronological runs of figures on a wide variety of topics, from public and private finance to sporting results and public opinion. Not all forms of human endeavour lend themselves to enumeration, just as in the atlas not all subjects lend themselves to presentation on a map or a diagram. *Historical statistics* covers the major aspects of Australian life, including economics, education, politics and religion.

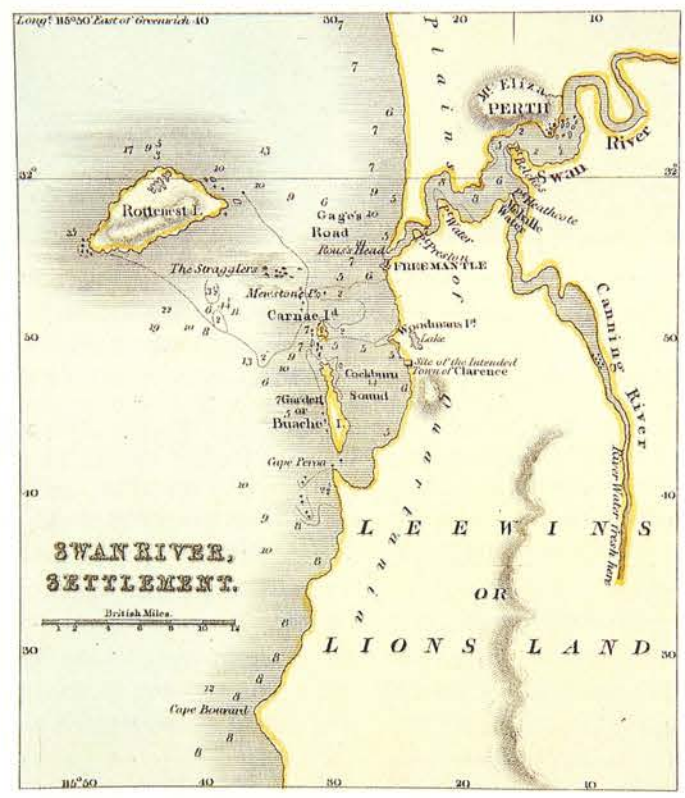
These reference books are more than compilations of facts. The facts are sometimes disputed, as in the events leading up to the Eureka stockade in 1854 or the dismissal of the Whitlam Labor Government in 1975. Historical processes, such as the growth and decline of cities, the gradual adoption of equal pay for men and women or the political fortunes of premiers, do not lend themselves to presentation as a series of discrete facts: they can be understood only in the social, political and economic climate of their time. It is here that historians have a special role to play, explaining such developments and pointing out where and why differing interpretations of the same process or event may arise. These volumes do not shy away from the need to exercise scholarly judgment.

The books complement one another. They serve best those readers who become familiar with them all. Someone wishing to learn about the gold rushes, for example, will find in the atlas maps of the major discoveries; in *Events and places,* a record of events on the goldfields and details about gold-rush towns; in the dictionary, entries on numerous subjects related to gold and on people whose lives were affected by the rushes; in *Historical statistics*, a tabular account of the economic impact of gold; and in the guide to sources, an indication of where to go for more information. A guide and index leads the reader to such information in all of the volumes, as well as providing a guide to the series as a whole.

Like every work of reference published, these volumes draw on original sources and the knowledge of researchers and specialists. Often original sources that might confirm a detail no longer survive, and often those that do survive cannot be relied on. There will be experts on particular topics, localities and events who will dispute our knowledge, unearth new facts and disprove old ones. We are keen to receive such information for additions or corrections to future printings.

Together, these five books provide the most extensive reference library ever produced on Australian history.

PETER SPEARRITT



Swan River Settlement, *drawn by John Dower and published by Henry Teesdale in March 1831, less than two years after the settlement was founded. The map is an inset in a map of the colony of New South Wales.*
NATIONAL LIBRARY

Canberra's growth was slow until after World War II. The federal government did not take up residence in the city until 1927 and the relocation of government departments from Melbourne was slowed by the Great Depression. From the mid-1950s, however, Canberra began to grow rapidly. Its current population is 250 000, ten times the population originally anticipated. This aerial photograph was taken in 1983. The ornamental lake, named in Griffin's honour, was built in the 1960s. Some seventy years after Griffin planned Parliament House on Capital Centre, construction of the new building is under way. Once maligned as the 'bush capital', Canberra is now Australia's largest inland city.

INTRODUCTION

THIS IS THE FIRST historical atlas of Australia. Although atlases have been produced in Australia and about Australia since the nineteenth century, and range from the school atlas to the weighty reference book, none contains more than a few pages devoted to Australia's past. Geographers, archaeologists, anthropologists, historians and other specialists have worked for six years assembling the information on which the maps are based. The maps themselves have been produced by a team of cartographers working at the Division of National Mapping in Canberra.

The atlas presents an overview of Australia's historical geography, frequently using case studies, drawn from around Australia, to illustrate national patterns and processes. The first section of the volume, 'Place' examines the environment, landuse and economic activity. The second section, 'People', examines aspects of Australia's social history. The third section, 'Landscapes', shows the impact of European settlement on both city and country landscapes. Maps and associated graphs are the main sources of information. A wide range of cartographic techniques has been used, including pie charts, computer mapping and flow line maps. Facsimilies of nineteenth and twentieth-century maps have also been included, not only to convey information but also to show how cartographic styles and techniques have changed. Relief shading, for example, has replaced the 'hairy caterpillars' commonly used on early maps to show mountain ranges.

An atlas of this nature and scope, which draws on the skills of people in a number of fields, has never been attempted before in Australia. Information is not as readily available to those producing a historical atlas as it is to cartographers who map present-day patterns and distributions, and compiling the necessary facts to produce even the simplest maps involved extensive research. A map of Australia showing the development of railways, for example, was compiled from seven different sources. For some topics, the available sources did not mention placenames, which are critical for mapping. Compounding these problems, numerous placenames have changed in the last two hundred years. Police reports on bush-ranging activity, for example, make liberal use of placenames now obsolete, and in South Australia many German placenames were changed during World War I. The routes of roads have also changed over the last two hundred years. Constructing a map of a region in the 1880s involved establishing the exact location of roads, and the placenames then current, to ensure the map's historical accuracy.

The sources traditionally used in researching Australia's past were important in overcoming these problems: statistics collected by government bodies during the nineteenth century, documents, official reports, government gazettes and manuscript material held in both official institutions and private hands. But the most important and valuable source used was Australia's rich heritage in maps.

Europeans first learned about the existence of the Australian continent not only from written accounts but also from the maps drawn by the early Dutch navigators and those who followed them. These maps illustrate the gradual revelation of the Great South Land. The image of a featureless landmass, placed by God in the southern hemisphere to balance the landmass of the north, was refined to the familiar outline of the Australian continent mapped by Matthew Flinders in 1803.

The first maps of the inland were drawn by European explorers. Some were simply lines showing a route against a barely suggested physical background. Others were meticulously detailed observations of flora, fauna, topographical features and geology. But mapping was not solely the preserve of explorers. During the nineteenth century a surveyor-general's department was established in every colony. Surveyors began to map the continent in detail, laying out towns and roads, plotting mountain ranges and the courses of rivers. Despite their efforts, and those of government mapping bodies since, parts of central Australia are yet to be mapped in as much detail as the more settled areas of the continent.

As the nineteenth century progressed, the range of subjects mapped expanded to include railways, goldfields and mineral deposits, ports and harbours, the growth of cities and the provision of water and sewerage facilities. In the early decades of the twentieth century, schools, hospitals, outbreaks of disease such as the plague, the provision of electricity and of recreational facilities and national parks were also mapped by government bodies. Such maps contain a wealth of historical information, but they have often been overlooked as a historical resource. So, too, have the atlases produced since the early nineteenth century. The compilers of this atlas have used these resources extensively as a means of obtaining and checking information.

This volume is a beginning and an exploratory step. Our aim has been to produce an atlas that depicts Australian history in a new way. We are sure that the volume will stimulate new interest in a hitherto neglected way of looking at Australia's past.

J. C. R. CAMM
JOHN McQUILTON

I
PLACE

ABORIGINES VIEWED THEIR continent not only as a resource but as a series of places with profound spiritual and religious significance. Few Europeans understood the importance of place to the Aborigines.

Europeans viewed the continent as an economic resource to be used and moulded at will. The early attempts to find the Great South Land, which led to the European discovery of Australia, were motivated as much by trade considerations as by scientific curiosity. Exploration during the nineteenth century was similarly motivated by the mixed desire to discover what lay beyond the settled areas and to search for new resources, particularly grazing land and minerals.

European settlement altered the face of the continent. Grazing, clearing, ploughing and the introduction of new animal and plant life changed the landscape.

So, too, did the growth of towns, particularly the metropolitan ports which handled the export of primary products and the import of all that Europe had to offer. By the turn of the century Australia boasted some of the largest cities in the Southern Hemisphere. Mining also brought changes to the landscape from its beginnings near Newcastle in the early nineteenth century to the massive mining ventures in the north-west during the 1970s. Underpinning all these developments was a changing pattern of transport networks.

Eucalypts, Mount Nelson, Tasmania. When Marcus Clarke described 'the weird melancholy of the Australian bush' in the 1880s, he touched on the ambivalence of Australians' attitudes to their native landscape. Whether regarded with affection or scorned as an offence to European sensibilities, the gum tree has come to embody the Australian sense of place. Photograph by Leo Meier.
WELDON TRANNIES

CHAPTER 1

ENVIRONMENT

Deforestation near the Johnston River, Melville Island. Photograph Leo Meier. WELDON TRANNIES

THIS CHAPTER PROVIDES the broad environmental background for the first section of the Atlas. The evolution of the present environment is described and its characteristics are summarised. Change and variability are the dominant themes. The environment is not static. It has changed with time, as the maps of Australia's palaeogeography show, and with human use, as the maps of the vegetation show. Its variability is indicated in the maps of rainfall, tropical cyclones, bushfires, droughts, floods and dust storms, all examples of the uncertainty and unpredictability of the Australian environment.

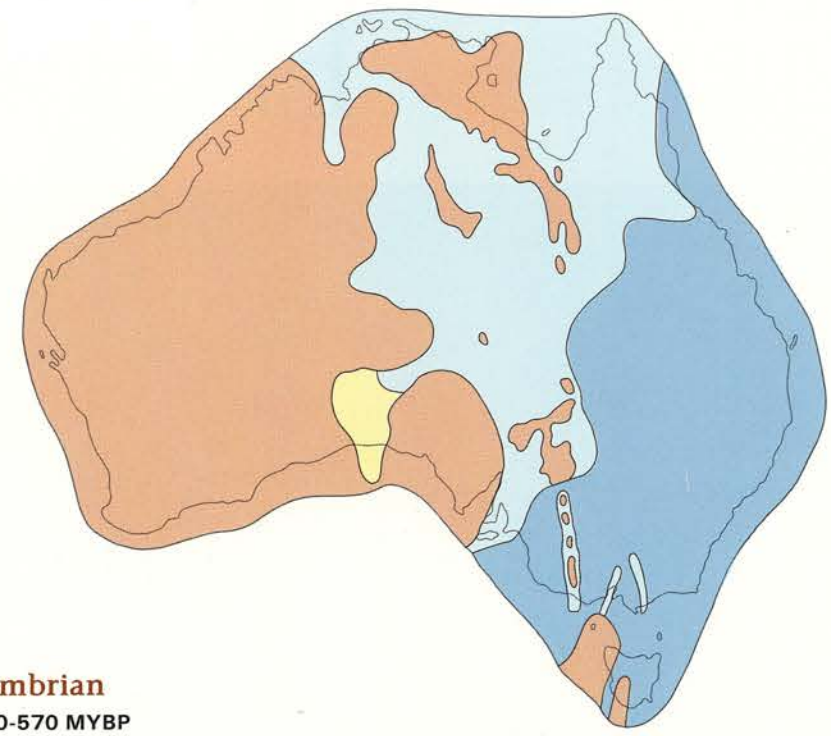
Palaeogeography

THE MAPS on these pages depict the palaeogeography, or ancient geography, of the Australian continent. Each of the maps represents the conditions at one point during a longer time span. A comparison of them shows that dramatic changes occurred between the periods. The distribution of land changed as vast areas rose from or subsided into the sea, climates changed and the forces of erosion and deposition varied. These changes help explain some of the major features, particularly landforms, that make up the present land environments of Australia.

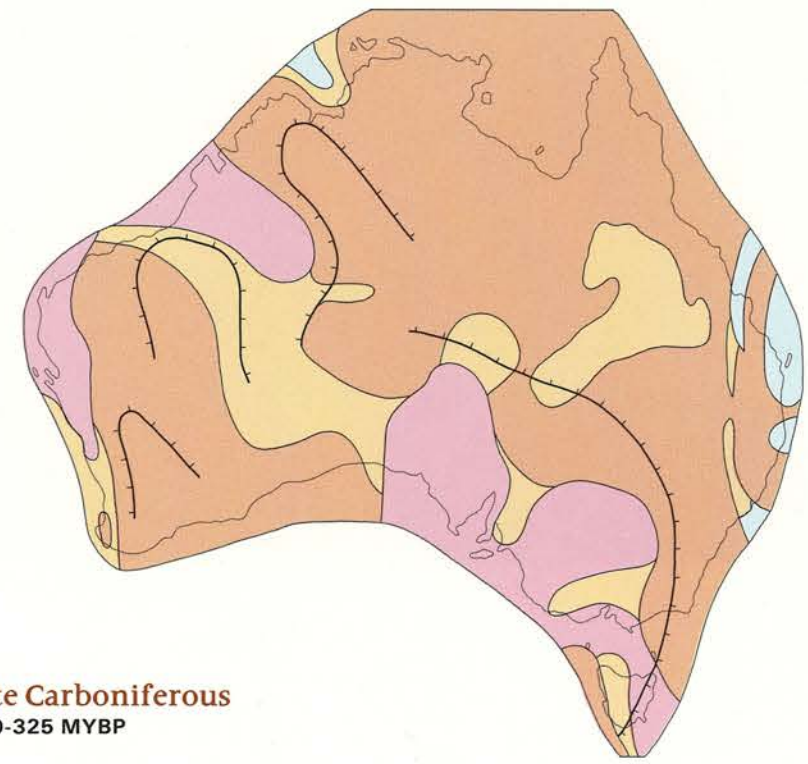
At the beginning of the Cambrian period most of the present continent of Australia formed part of the super-continent of Gondwanaland, which included Antarctica, India, Africa, the Middle East and South America, and possibly parts of the present South-east Asia. The map below shows how these present landmasses probably fitted together to form Gondwanaland. This broad arrangement remained more-or-less unchanged until about 160 million years ago when the various continents began to separate. Final separation of Australia from Gondwanaland seems to have taken place about 95 million years ago.

As Gondwanaland broke up, the various portions or plates drifted apart and new sea floors were created between them. The plates with the continents sitting on them are still in motion. Australia, for example, is moving away from Antarctica at a mean rate of about seven centimetres per year. The plate carrying Australia is colliding with the Pacific plate in the zone of Papua New Guinea and Irian Jaya. The idea of moving continents, implying changing dispositions of land and sea, helps explain some features of current plant and animal characteristics and distributions.

The map of the Cambrian period depicts conditions as they are thought to have been in about the middle of the period when half the present continent was covered by the sea. The eastern third was covered by deep water and most of the present Northern Territory and northern South Australia were covered by shallow water. The climate in the mid-Cambrian was hot and dry, and during this period shallower parts of the sea were occasionally cut off from the ocean and evaporated leaving salt deposits.

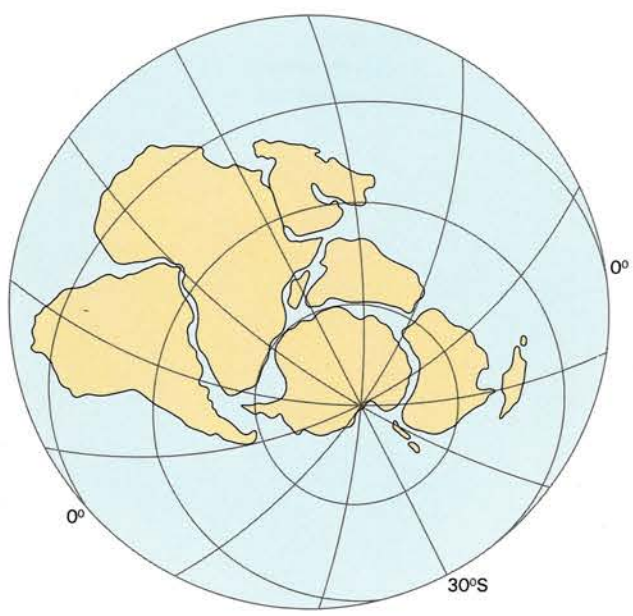


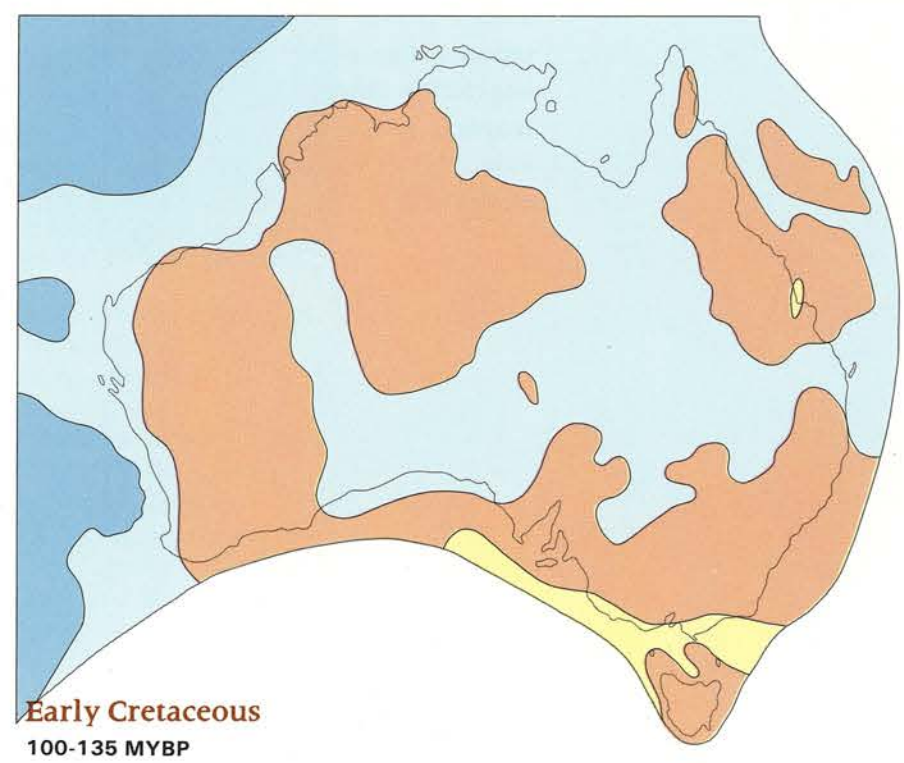
Cambrian
500-570 MYBP



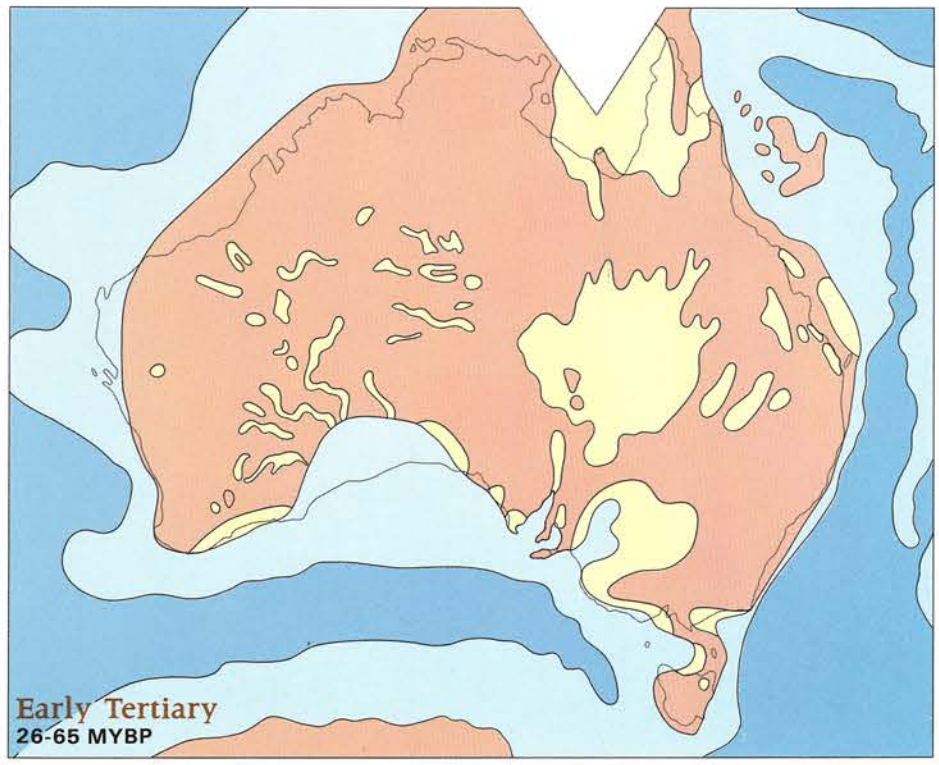
Late Carboniferous
290-325 MYBP

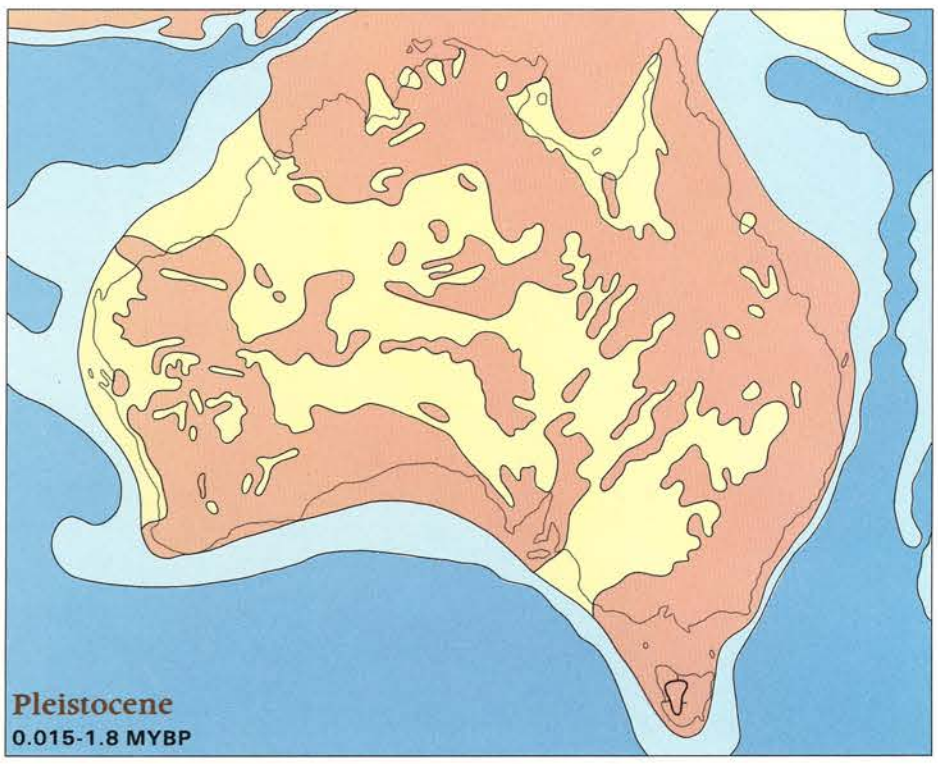
Gondwanaland
About 270 MYBP





Early Cretaceous
100-135 MYBP





Marine environments (Deposition)

- Deep
- Shallow

MYBP Million years before present

Continental environments

- Land undergoing erosion
- River, lake and wind deposition
- Fluvioglacial deposition
- Glacial deposition
- Possible extent of continental ice sheet

GEOLOGICAL TIME SCALE

Era	Period		Million years before present
	Precambrian		greater than 3800
Palaeozoic	Cambrian		570
	Ordivician		475-490
	Silurian		435
	Devonian		410
	Carboniferous		290-325
	Permian		235-290
Mesozoic	Triassic		230
	Jurassic		135-195
	Cretaceous		100-135
Caenozoic	Tertiary		65
	Quaternary	Pleistocene epoch	1.8
		Recent	0.015

During the next 200 million years, there were many further changes in the distribution of the land and sea. Some parts of northwestern Australia were flooded during the early Ordovician period. In the middle Ordovician, a shallow sea extended across central Australia, but it retreated eastwards at the end of the Ordovician until only northeastern New South Wales and southeastern Queensland were under the sea 360 million years ago. Most continental environments before 360 million years ago were eroded, but during the late Devonian material was extensively deposited in eastern Australia by water and wind.

By the late Carboniferous period Australia and adjacent parts of Gondwanaland were much nearer the South Pole than either before or since. Alpine glaciers covered the higher eastern parts of the continent and a large ice sheet covered most of the southern part. Much of the debris eroded and accumulated by the glaciers and ice sheet was deposited by rivers that formed as the ice melted. Although the continental ice sheet disappeared, relatively cold climates continued throughout the Permian period. During this period a predominantly continental or land environment favoured the formation of coal swamps, mainly in southwest and central Queensland, northern South Australia and eastern New South Wales. By the start of the Triassic period, the sea had totally disappeared from the continent. Some coal formation continued into the Triassic, and climates became warmer.

A major river system developed in the east of the continent during the Jurassic period, ultimately covering most of Queensland, northwestern New South Wales and northeastern South Australia. The Jurassic was dominated by continental environments, with widespread deposition by rivers, mainly in the east.

The early Cretaceous period saw a marked rise in sea level and much of the interior of the continent was flooded. The climate became progressively warmer and a greater variety of plants began to appear. During the late Cretaceous period the sea again retreated from most of the continent. Possibly because of a changed climate, many species of animal life disappeared at the end of the Cretaceous.

The separation of the Australian landmass from Gondwanaland began in the late Cretaceous. This allowed ocean waters to move around the southern coast of Australia, and by the early Tertiary the present outline of Australia had started to appear. A warm and wet climate characterised the period and coal swamps (rainforests) flourished along the south coast and in central Australia. In the late Tertiary, the sea again flooded the southern edges of the continent.

By the Pleistocene epoch the relatively widespread coal swamps and rainforests of the early Tertiary had given way to eucalypt-dominated open vegetation more like that of today. During the Pleistocene, ice sheets alternatively expanded and contracted at the poles. At times of maximum extent the polar ice sheets were much larger than they are today, and sea levels fell by as much as 200 metres. The map of the Pleistocene shows Australia's coastline about 120 000 years ago, when world glaciation was at a peak and sea levels were at their lowest. The present continental shelf was then land and the sea was low enough for the small areas of sea between Australia and Southeast Asia to be relatively easily crossed by plants and animals.

THE AUSTRALIAN landmass has a latitudinal range of approximately 3700 kilometres between Cape York in the north and South East Cape in southern Tasmania. Its longitudinal range is approximately 4000 kilometres from Cape Byron on the east coast to Cape Inscription in the west.

Australia is the smallest of the continents, with a land area of about 8.5 million square kilometres. Even when the continental shelf around the coastline is included, Australia is smaller than all the continents except Europe. If the margin of the continental shelf were to be included as part of the Australian continent, the mountains of New Guinea would then also be included since the shelf spans the 150 kilometres of Torres Strait. Australia has, proportionately, the largest continental shelf of all the continents. It is at its widest around the northern coast and at its narrowest around the southeastern and southwestern coasts.

The outline of the continent reflects control by the underlying structure of the earth's crust. The eastern margin of the continent, for example, was formed by differential block subsidence restricting the occurrence of coastal plains. In the southeast the coast runs obliquely to the structural 'grain' of ridges and valleys producing rocky headlands separated by narrow inlets. North of Cape Byron the coast runs parallel to the main structures, producing northwest trending promontories and bays. The trend of the coast in the southwest is determined by the Darling Fault, which defines the western escarpment edge of the Western Plateau. In the northwest the uplifted Hamersley and Kimberley basins form uplands separated by bays. Subsidence in the Carpentaria Basin accounts for the shallow Gulf of Carpentaria in the north, while northerly running faults have produced the Yorke Peninsula and its adjacent gulfs.

The present Australian landscape is the product of long periods of geological stability with correspondingly long episodes of erosion. Much of the Australian landscape is therefore very flat and monotonous, being relatively unchanging over hundreds of kilometres. Australia is the lowest of the continents, whether measured in terms of its highest point of 2228 metres at Mount Kosciusko or its average elevation which is only 330 metres. The relief of the continent is characterised by extensive plains and tablelands and the relative absence of high mountain ranges. Desert landscapes are common, particularly in the interior, where there are extensive windblown sand features, river systems which only flow occasionally, salt lakes and vast depositional lowlands. There are very few earthquakes and Australia is the only continent without active volcanoes. There are no mountain regions high or cold enough to have active glaciation, although there is evidence of former glaciation, mainly in the southeast of the mainland and in Tasmania.

The western half of the continent is predominantly plateaus between 300 and 600 metres high. The remainder consists largely of interior plains below 200 metres, fringed by an eastern belt of sloping tablelands and uplands, rarely exceeding 1200 metres. The interior lowland descends to a few metres below sea level in Lake Eyre.

Apart from the MacDonnell Ranges in the centre of the continent, most of the higher ground is around the edges and coastal plains are mostly very narrow. The main drainage divides therefore run close to the continental margins. Much of Australia is drained by large interior river systems, and most coastal river systems are much smaller.

ORIGINAL DRAWING PREPARED BY
DIVISION OF NATIONAL MAPPING,
CANBERRA, ACT

Land and seabed relief

SCALE 1:10 000 000

Kilometres 100 0 100 200 300 400 Kilometres

Simple Conic Projection with Two Standard Parallels (18°S and 36°S)

SURFACE ROCKS have been divided into four basic categories on this map: surficial (or surface) deposits and weathering mantles, sedimentary rocks, igneous rocks and metamorphic rocks.

Surficial deposits consist mainly of unconsolidated clays, silt, sand, gravel and evaporites (mineral salts) carried by wind or water from many different sources. Deep weathering mantles include laterite, silcrete (with a siliceous duricrust), calcrete (with a calcareous duricrust) and calcarenite (cemented sands). Duricrust is a hard surface layer.

Sedimentary rocks are formed by the depositing of material in layers in seas or lakes. Material deposited comes from existing rocks or organic sources (for example, vegetation). Sandstone, shale and limestone are familiar examples.

Igneous rocks are formed when molten magma cools and crystallises. Magma that reaches the earth's surface in lava flows cools to form extrusive igneous rocks; for example, basalt. Magma that cools below the earth's surface forms intrusive igneous rocks; for example, granite. Intrusive igneous rocks may be exposed in time. The amount of silica in igneous rocks allows them to be subdivided into basic (more silica) and acidic (less silica) categories.

Rocks that have been changed by heat or pressure beneath the earth's surface are called metamorphic rocks. For example, granite can change to gneiss, limestone to marble and shale to slate.

Although most categories of rocks are found throughout Australia, there are broad patterns of distribution. Surficial deposits and weathering mantles cover much of Australia, reflecting the continent's geological stability and age. These deposits have been laid down over millions of years. Sedimentary rocks are found along the eastern seaboard, through central Queensland, into the northern part of the Northern Territory and the adjacent Kimberleys, in the Pilbara of Western Australia and across the Nullarbor Plain. Igneous rocks are found mainly near the eastern seaboard and along the Great Dividing Range, in the Pilbara and in much of the western half of Western Australia. Metamorphic rocks are concentrated in Tasmania, throughout the Great Dividing Range, in the Kimberleys and scattered over the western half of Western Australia.

Surface rocks directly affect human activity. Their relationship to soils is discussed on the following pages, but other examples include construction works (from skyscrapers in the cities to roads and railways in rural areas) and, more significantly, mining.

Rocks also provide an indication of mineral bearing areas. Minerals found in sedimentary rocks are either organic in origin (for example, coal, oil and natural gas) or chemical precipitates (for example, phosphates). Sedimentary rocks with major coal deposits in Australia include the Sydney basin, the Bowen basin in central Queensland and the La Trobe valley to the east of Melbourne. Oil and natural gas are found in the Gippsland basin off the coast in eastern Victoria and the Carnarvon basin in Western Australia.

Most mineral deposits, however, are found in rocks that have been folded and metamorphosed. Specific metals tend to predominate in particular areas. These are known as metalliferous provinces and they are found mainly in the areas of igneous and metamorphic rocks shown on the map.

Important metalliferous provinces occur in the southwest of Western Australia (gold, iron, tin, nickel), in the Pilbara region (iron, manganese, tin, gold), between Maranboy and Darwin (uranium, iron, gold, copper, tin), Broken Hill (silver, lead, zinc, copper), the Middleback Ranges (iron), from Charters Towers to Cooktown (gold, copper, tungsten, molybdenum, lead, zinc, silver), in southeast Queensland (copper, gold, silver), in the Armidale region (tin, tungsten, molybdenum, gold, copper, antimony), from Ballarat to Cobar and Dubbo (gold, copper, tin), and in Tasmania (lead, zinc, copper, silver, gold, tin, iron, tungsten).

Surface rocks

Surficial deposits and weathering mantles

- Clay, silt, sand, gravel, evaporite
- Laterite, silcrete, calcrete, calcarenite

Sedimentary rocks

Metamorphic rocks

Igneous rocks

- Acid to intermediate
- Basic to ultrabasic

SOILS ARE CREATED by interaction between rocks, climate, topography, water, vegetation and human activity. This map shows soil resources, emphasising soil properties that affect human landuse (for example, agriculture and building construction). Australia's soils are grouped here in three major categories: soils generally without limiting physical or chemical properties, those with predominantly chemical limitations and those with predominantly physical limitations.

Soils generally without limiting properties are suitable for a wide range of uses although many may require the addition of phosphorus and nitrogen for agriculture. Plant roots can penetrate deep into these soils and take advantage of their high water-holding capacities. These soils cover relatively small areas of the continent and are mainly scattered around the periphery, particularly on the western slopes of the Great Dividing Range and along the southeastern coastal strip.

Nutrient deficiencies and salinity characterise soils with predominantly chemical limitations. They are found in all parts of Australia. Many different types of soils are part of this group. Some are deep soils with a high initial fertility that declines rapidly particularly with agricultural use. Others are naturally low in nutrients. Large areas of soils within this category suffer from high levels of salinity. Before they can be effectively used, nutrient deficiencies and salinity need to be treated.

The third group of soils suffers from predominantly physical limitations which affect both agriculture and construction. These include soils with textural and structural problems, soils prone to waterlogging and thin soils. Soils with textural and structural problems are prone to erosion or are difficult to use, for example, sandy soils with a low water-holding capacity and a high susceptibility to wind and water erosion. Others include the cracking clays, which swell when wet and shrink and crack when dry, and thin soils with hard-setting surfaces and dispersible clay subsoils. Soils with textural and structural problems are widespread through inland eastern Australia, in South Australia and in the northeast. Soils prone to waterlogging are widespread along the eastern side of the mainland, in Tasmania and in southwestern Western Australia. More than 25 per cent of Australia's surface is covered by shallow soils less than 60 centimetres deep. Most of these are found in rugged terrain.

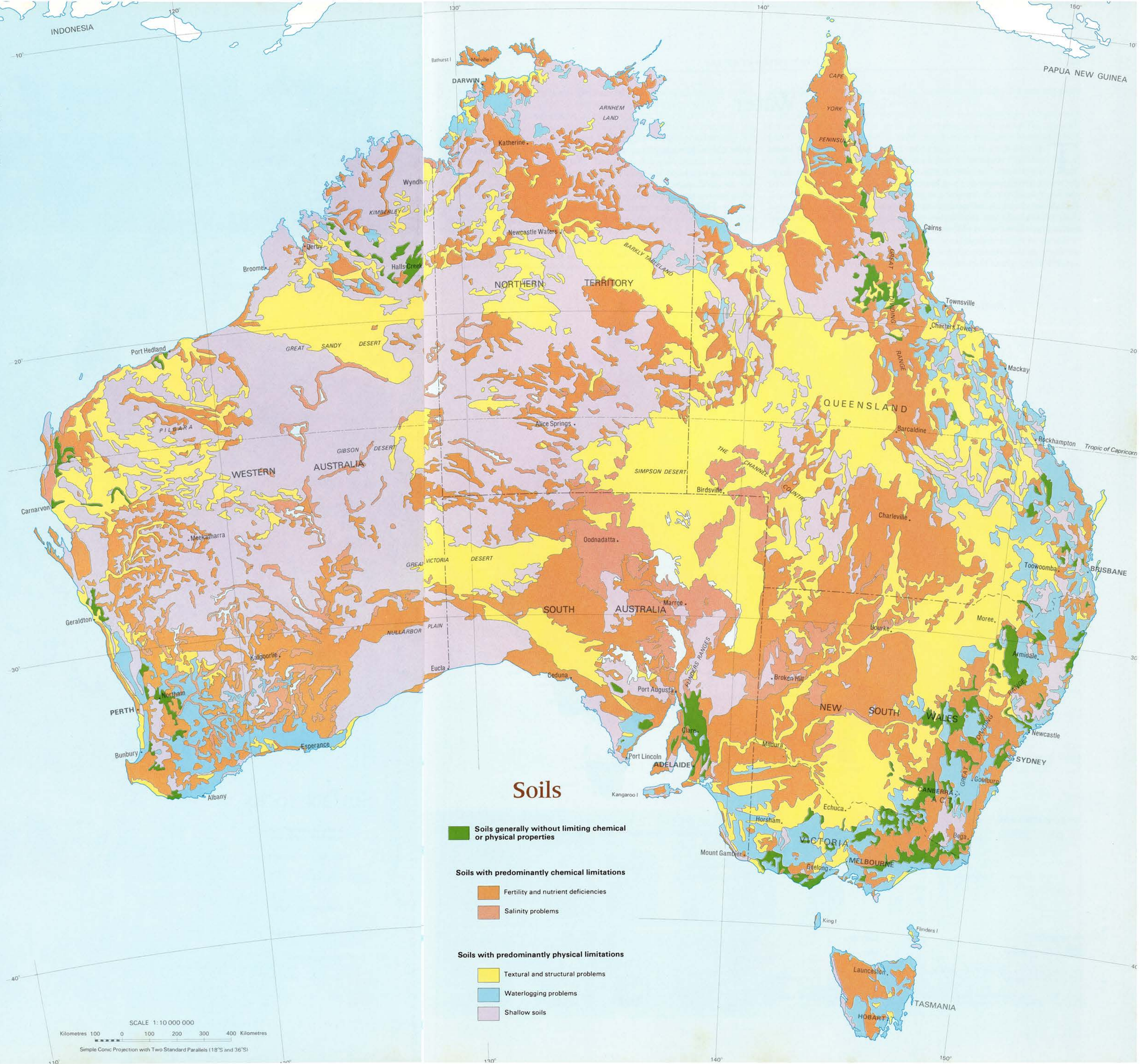
Human activity has had a profound impact on the soil, both directly and indirectly, particularly since 1788. Soil degradation is a major problem. It has been estimated that 50 per cent of the continent's topsoil has been lost, and one-third of Australia's soils overall need restoring.

In the arid zone, vegetation has been removed by animals introduced since 1788. Grazing by rabbits, sheep and cattle has left soils exposed and susceptible to wind and water erosion. Further damage has occurred from trampling by sheep, cattle and feral animals such as buffalo, pigs, goats, donkeys, horses and camels.

In 1978 a survey conducted for non-arid Australia established that 44 per cent of soils needed treatment. Most damage had been caused by water erosion following the replacement of forests by pastures and crops, and was accompanied by poor farming practices. Water erosion accounts for at least 70 per cent of land degradation in the non-arid area.

Salination caused by farming is also a widespread problem, especially in the wheatbelts of Victoria and Western Australia and in intensive cropping areas that rely on irrigation.

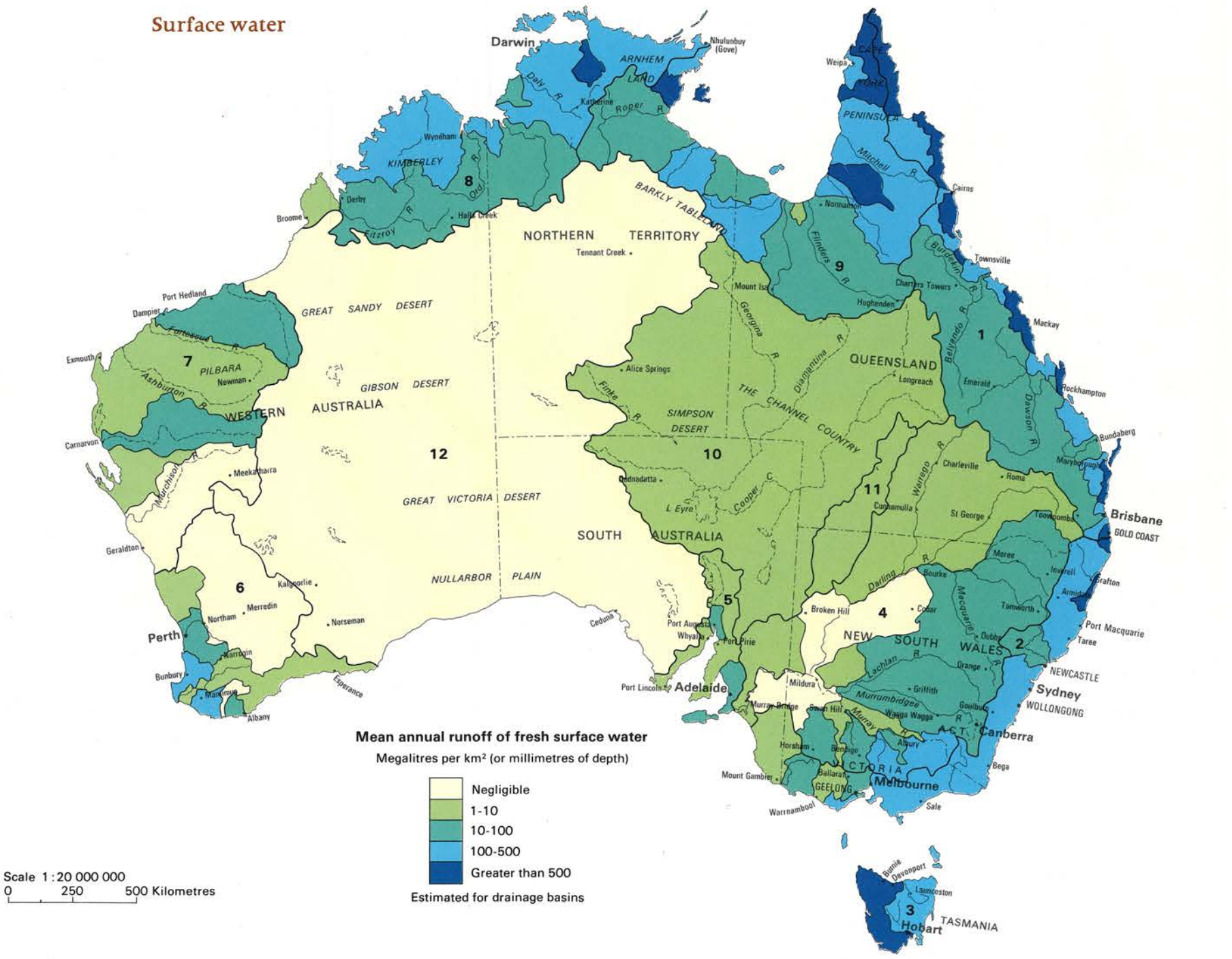
Other human activities have also affected Australia's soils. Mining activities removed large areas of topsoil in many parts of Australia, and urbanisation destroyed soils at the local level, forcing suburban Australians to purchase topsoil to establish their gardens.



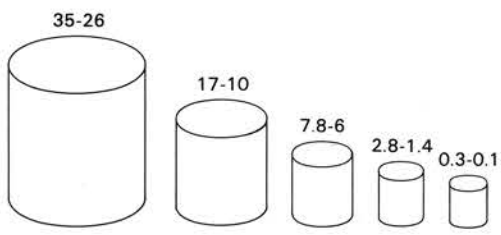
Water

THE ANNUAL VOLUME of water runoff for the continent under average seasonal conditions is estimated at 440 million megalitres. The contribution to this total by the various drainage divisions and the separate river basins varies, reflecting both the size of the river system and climatic conditions. The North-East Coast and Tasmanian divisions contribute the most surface runoff and many of their individual river catchments yield more than 500 megalitres of surface runoff per square kilometre.

Much of the annual surface runoff is lost through evaporation, particularly in the interior where evaporation exceeds rainfall in every month of the year. These losses reduce the available surface water to about 120 million megalitres annually. From this available supply only about 15 million megalitres is used. The largest untapped source of water is in northern Australia which is estimated to have two-thirds of the nation's water resources. For most drainage divisions current water use is a very small proportion of the available surface runoff. The Murray–Darling is the only drainage division in which more than half of the available water supply is used. In some years water usage in this division can be as high as 85 per cent. In other drainage divisions, water usage is much lower: in the South Australian Gulf division it is about one-third, in the South-West Coast division about one-eighth and in all other drainage divisions it is less than one-thirtieth.



Annual yield in millions of megalitres



Water quality

- Fresh or marginal
- Saline but less than 14000 parts per million of dissolved solids
- Saline including water with more than 14000 parts per million of dissolved solids

Suitability

- Most purposes
- Limited irrigation and/or livestock
- Includes water unsuitable unless desalinated

Drainage divisions	1 North-East Coast	2 South-East Coast	3 Tasmanian
Surface water Fresh and marginal only			
Groundwater			

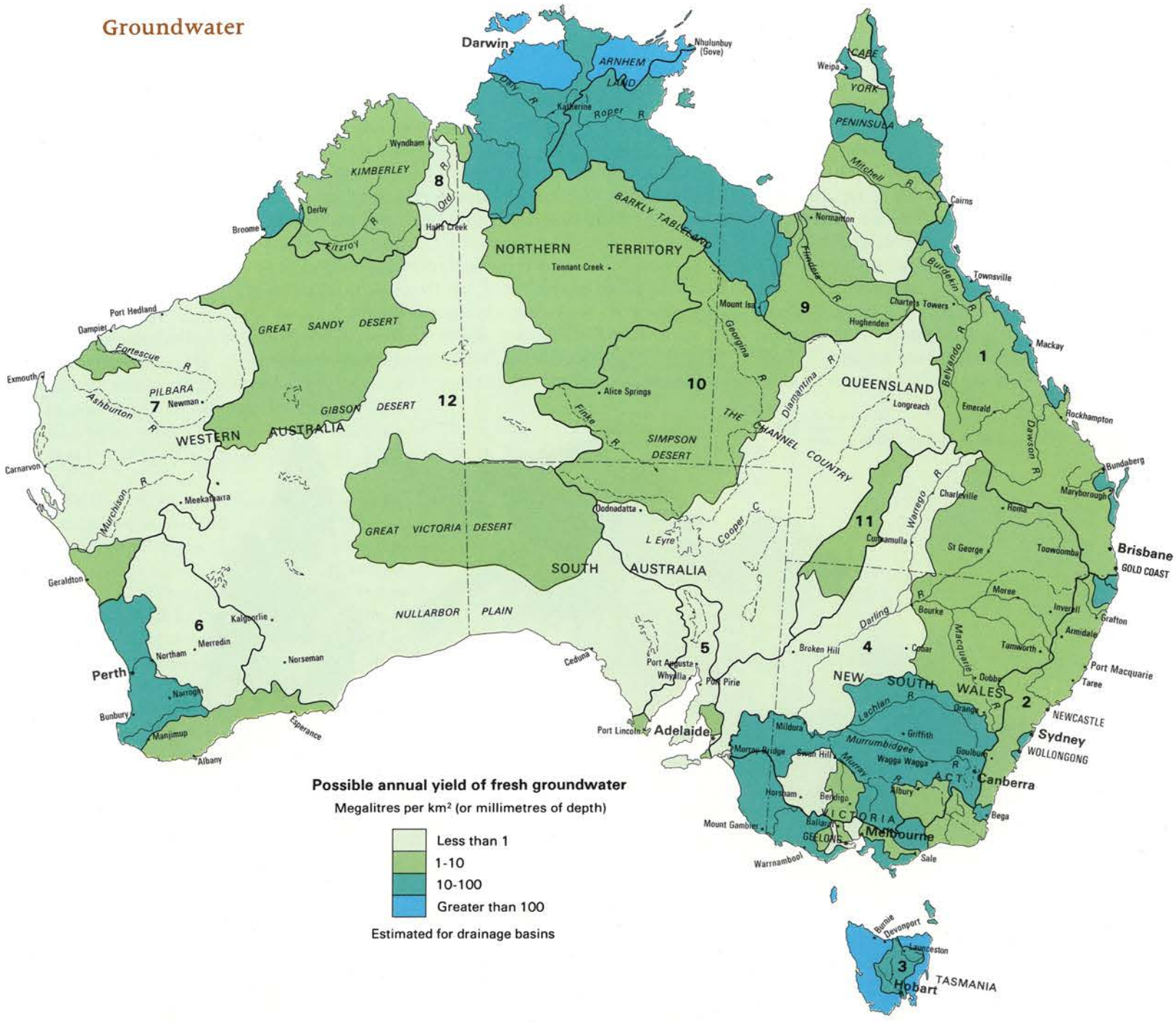
Accurate measurements of groundwater are not available and potential annual yields can only be estimated. Groundwater supplies in Australia are currently estimated to be 72 million megalitres. Yields per square kilometre in drainage divisions are much lower than those for surface runoff and rarely exceed 100 megalitres. Approximately 3.5 per cent of groundwater supplies, or approximately 2.5 million megalitres, is used.

Three categories of water quality and their suitability for particular uses are identified. All surface runoff is fresh or marginally fresh and can be used for most purposes. In contrast varying proportions of the groundwater supply in each drainage division are saline. Almost all of the estimated annual yield of 28 million megalitres of groundwater in the Western Plateau is salty and can only be used if it is desalinated. The third category includes potential sources of water such as treated waste, treated saline water, including sea water, and rainfall produced by cloud modification. Large quantities of brackish or saline water are found in Australia, particularly in locations where freshwater supplies are limited or remote, and are costly to develop.

Major water resource projects have been important in the nation's economy. Emphasis has been on meeting requirements for agricultural, urban and industrial uses rather than for environmental and social purposes.

A report on Australia's water resources to the year 2000 was issued by the federal Department of Resources and Energy in 1983. It identified several major issues facing the water industry over the next two decades. These included protection and improvement of water quality, more efficient use of available water supplies, the conservation of existing water supplies, co-ordinated management and use of water and land resources, adequate provision for in-stream uses and the need for improved data collection and analysis and dissemination of information. The report concluded that in general terms Australia has sufficient water supplies to meet anticipated demands to the year 2000.

Groundwater



Possible annual yield of fresh groundwater

Megalitres per km² (or millimetres of depth)

- Less than 1
- 1-10
- 10-100
- Greater than 100

Estimated for drainage basins

4 Murray-Darling	5 South Australian Gulf	6 South-West Coast	7 Indian Ocean	8 Timor Sea	9 Gulf of Carpentaria	10 Lake Eyre	11 Bulloo-Bancannia	12 Western Plateau
							Not significant	Not significant

Vegetation

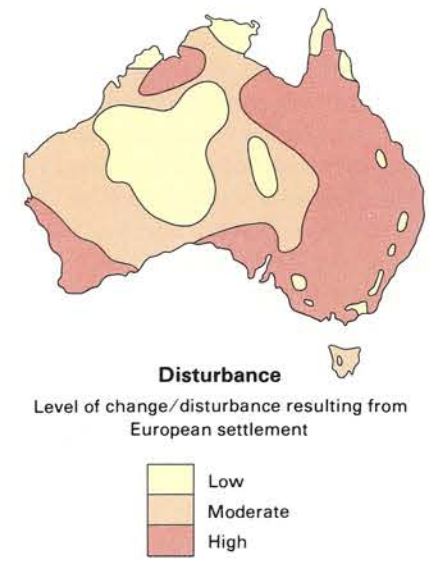
MUCH OF AUSTRALIA'S natural vegetation differs markedly from that of other continents. The most prominent and widespread of the essentially Australian elements are the eucalypts and acacias, but there are also many other significant groups, including the hummock grasses (commonly and misleadingly called spinifex).

The genus *Eucalyptus* consists of approximately 500 species of trees and shrubs, most of which are endemic to Australia. The genus *Acacia* is not confined to Australia, but most of the 600 or more Australian species have a distinctive foliage. The hummock grasses belong to the endemic genera *Triodia* and *Plectrachne*. Some other important elements of natural vegetation are also distinctively Australian, such as the genus *Casuarina*.

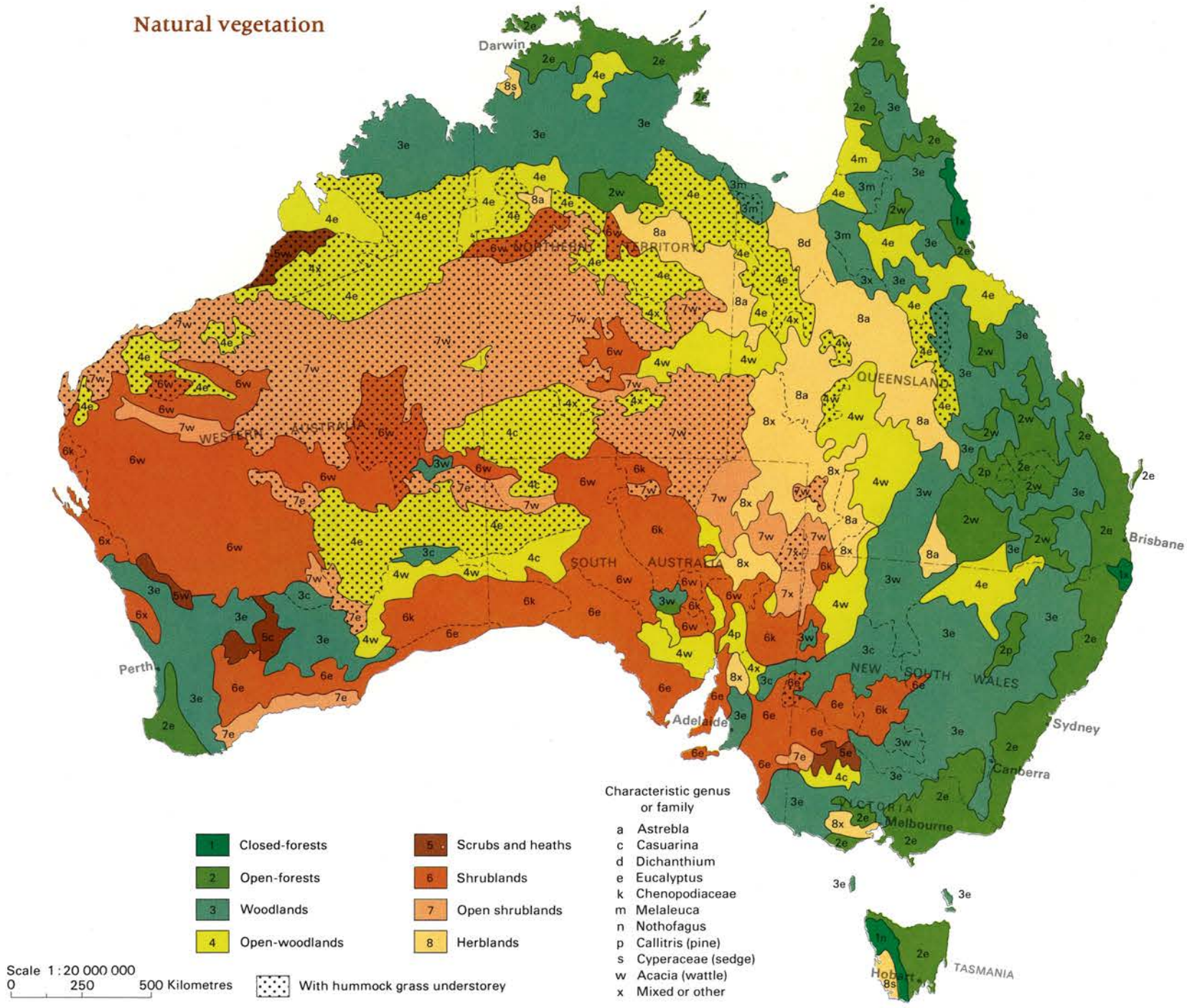
Native Australian trees and shrubs are predominantly evergreen, with generally hard and tough leaves (sclerophylls). In higher rainfall areas herbaceous species are predominantly perennials, although many lose their foliage during unfavourable seasons. In the areas with lower and more erratic rainfall foliage fluctuation is more marked and the proportion of annual or ephemeral species is larger.

Aboriginal modification of vegetation through firing is thought to be extensive; however, this is the subject of continuing research. The map 'Natural vegetation' shows what is thought to have been the broad character of Australian vegetation in 1788. Closed forests were found only in limited areas along the northeast coast and western Tasmania. Open forests and woodlands were widespread throughout eastern Australia and in southwestern Australia. Scrub and heathlands were scattered across the continent and shrublands were found in western, southern and central Australia. Open shrublands dominated the drier interior. Acacias were found across the continent but casuarinas were limited to the more arid zones of Australia. The dominant species in inland areas were the hummock grasses. Outside the arid areas, eucalypts and acacias were typical.

A broad indication of change resulting from European settlement is shown on the map 'Disturbance'. In many areas, most of the natural vegetation has been cleared and replaced by exotic pastures, crops or trees. Commercial forestry, urban areas, cropping and intensive animal production occupy much of the temperate areas of Australia. Extensive livestock grazing occupies nearly 60 per cent of the continent's total area. The effects of grazing on vegetation have been compounded by the removal of some woody plants through burning, and by the deliberate or accidental introduction of exotic plants and animals. The impact of such practices on vegetation has been exacerbated by changes in the soil environment, including changes following the use of agricultural chemicals. Even in areas of unused or relatively unused land, feral animals have had an impact upon natural vegetation.



Natural vegetation



Temperatures

THE MAPS ILLUSTRATE two features of Australian temperature patterns, the range of temperatures recorded and the number of days between the first and last frosts. Temperatures vary with latitude, season, time of day, distance from the sea and altitude. In general terms, they tend to be relatively high both in low latitudes (the tropics) and where cloudy days are few. The range between highest and lowest temperatures (both daily and annually) increases with distance from the sea and with increasing latitude. Temperatures fall as altitude increases. Average temperatures in Australia are higher than in other land masses in similar latitudes (for example, southern Africa) because of the absence of extensive areas of highlands and the size of the continent.

Average annual air temperatures in Australia range from 29°C along the northwest coast to 5°C in the alpine areas of the southeast. July has the lowest monthly average temperature over the whole continent with the coldest areas being the highest parts of the southeast. Some of the highest alpine areas have a July average minimum as low as −8°C. The warmest month varies over the continent, being January or February in the south, and December in the north, except for the extreme north and northwest where it is November (before the onset of cloudiness associated with the northern wet season).

In January, large areas of the centre and the northwest have average maximum temperatures of over 30°C, and in some places the average maximum exceeds 39°C. Areas with lower summer maxima are either close to the coast or at relatively high altitudes.

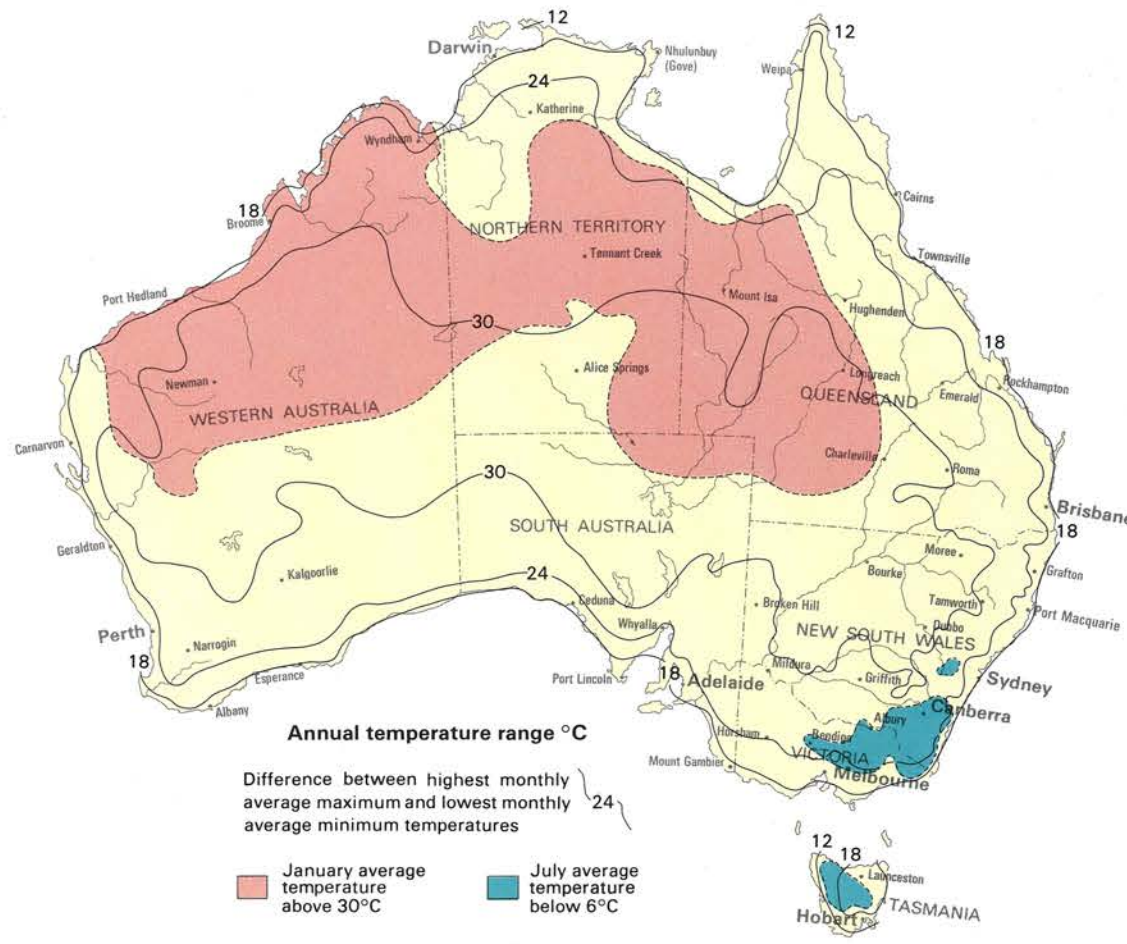
Much of the continent's interior has an annual temperature range of over 30°C, rising to 33°C in the western interior. Ranges decrease towards the coast and tend to be smallest in the far north of the continent. Extreme temperature ranges of over 50°C have been recorded in much of western New South Wales, southern Queensland, South Australia and the southern interior of the continent.

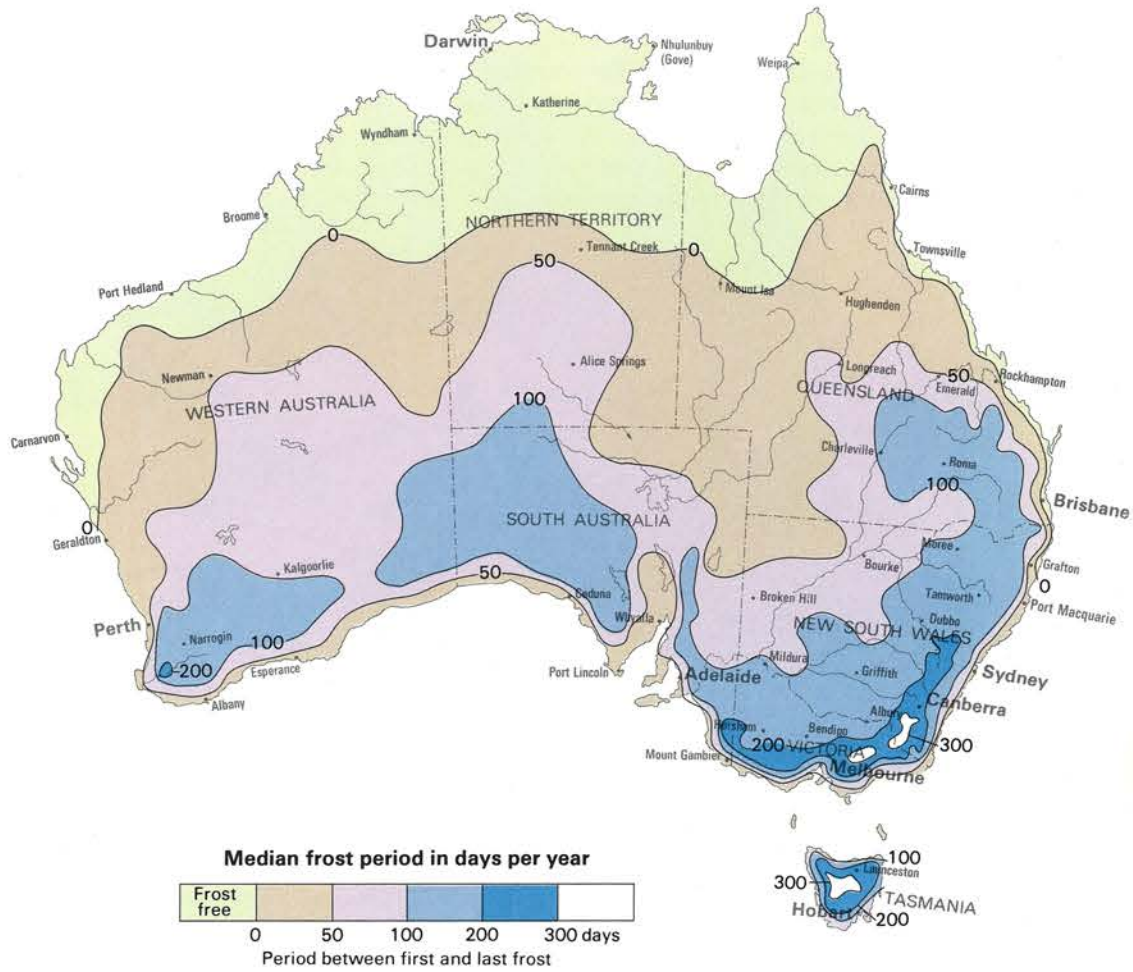
Heatwaves, where daily maximum temperatures exceed 38°C are not uncommon. Along the coast, their duration is rarely more than two or three days. Inland, spells of up to twenty days are common, increasing to more than 60 days in western Queensland, northwestern Western Australia and in the centre of the Northern Territory. Heatwaves of up to 160 days have been recorded in the Marble Bar district inland from Port Hedland. In large urban areas, heatwaves have major impacts on rates of morbidity and mortality and on energy demands.

Frosts are a serious hazard for rural industries. The chance of frost is shown by the median frost period map which shows the number of days between the first and last frost (frosts do not necessarily occur every day in between).

The frequency of frosts increases with increasing altitude and distance from the sea and they occur mainly in winter and spring when slow-moving high pressure systems bring clear skies and light winds. The median frost period varies from over 300 days per year in the highest parts of the southeast and in Tasmania to zero in northern Australia. Frosts may occur in any month of the year in the southeast highland areas and in much of Tasmania, but elsewhere they mostly occur between April and October. Even in tropical latitudes at higher altitudes or in valleys close to the coast, frosts occur.

Like all other components of the environment, temperatures are not unchanging. Records suggest a slight rise in mean annual temperatures during the last 30 to 40 years although it has not been uniform over the continent.





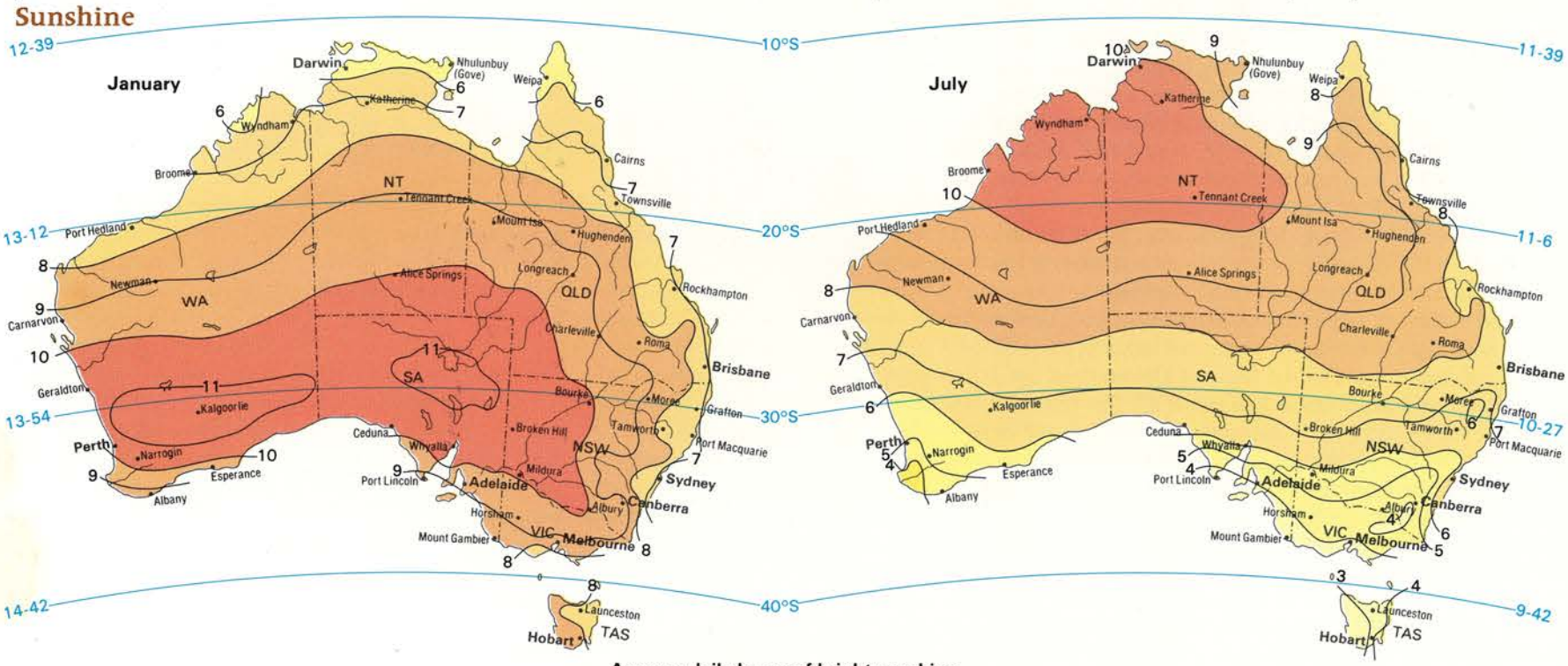
Sunshine and cloud cover

MOST OF AUSTRALIA experiences long periods of sunshine, but seasonal variations in cloud cover cause variations in the number of hours of sunshine per year.

Most of the continent, except for Tasmania and a narrow fringe around the northern, eastern and southern coasts, averages more than 3000 hours of sunshine annually. This is about 70 per cent of the possible total. However, parts of Tasmania average less than 1750 hours per year.

Daily average sunshine hours range from 11 per day over the southern interior in January and about 10.5 per day over the northern interior in July, to less than 4 per day in southern coastal areas in July. Average daily sunshine hours over the whole year range from about 5 in western Tasmania to more than 10 in the northwest of Western Australia. More than 75 per cent of Australia averages at least 8 hours sunshine per day throughout the year. Even in the middle of winter, 75 per cent of the country receives at least 6 hours of sunshine per day.

Sunshine

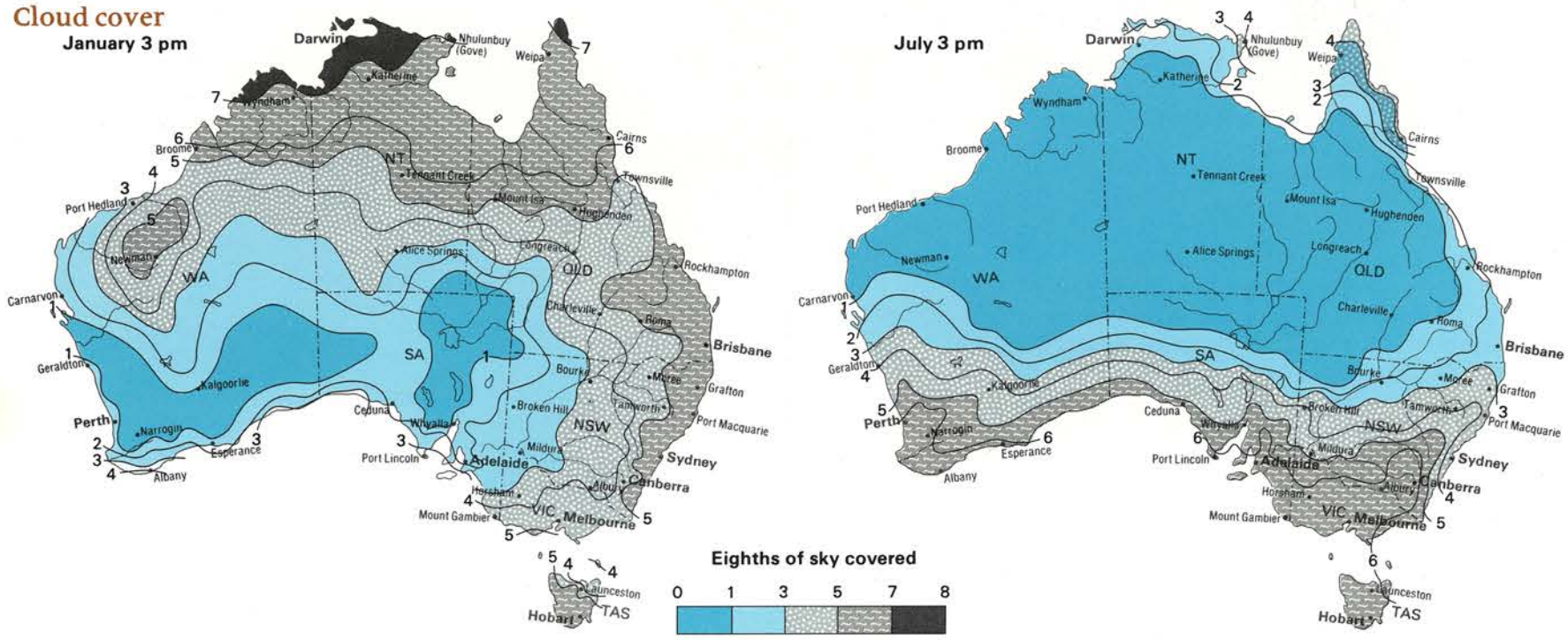


CLOUD COVER TENDS to be greatest close to the coast and on the windward or coastal slopes of the eastern highlands, and least over the dry interior of the continent.

The relationship between the duration of bright sunshine and the duration of cloudiness is illustrated in the maps. Seasonal changes in cloudiness are themselves closely related to the seasonal distribution of rainfall. In the southern parts of the continent, the winter months also tend to be cloudier than the summer ones, particularly in coastal and low-lying areas. Over northern Australia, however, there is more cloud during the summer wet season, while winters are relatively cloud-free.

Significant daily variations in cloud cover occur, with a tendency for coastal areas to have slightly more cloud in the early morning, but the interior to have more during the afternoon.

Cloud cover



Winds and seasonal rainfall

THE TWO MAPS on this page show average wind patterns in the middle of summer (January) and in the middle of winter (July). Together they indicate the changing nature of wind flow across the continent throughout the year. The maps also show the seasons of maximum rainfall across the continent.

Wind patterns are largely controlled by high pressure systems moving across the continent. The path of the high pressure systems changes with the seasons. In late summer, they move basically along the parallel 38° south. In late winter, they cross the continent at about 28° south. Air circulates in an anti-clockwise direction away from the centres of these high pressure systems (producing easterly winds on their northern edges and westerlies on their southern edges) and flows towards the pressure systems that straddle the tropics. The tropical low pressure systems or trough also moves with the seasons. In summer, it lies across northern Australia. In winter, it lies near the Equator.

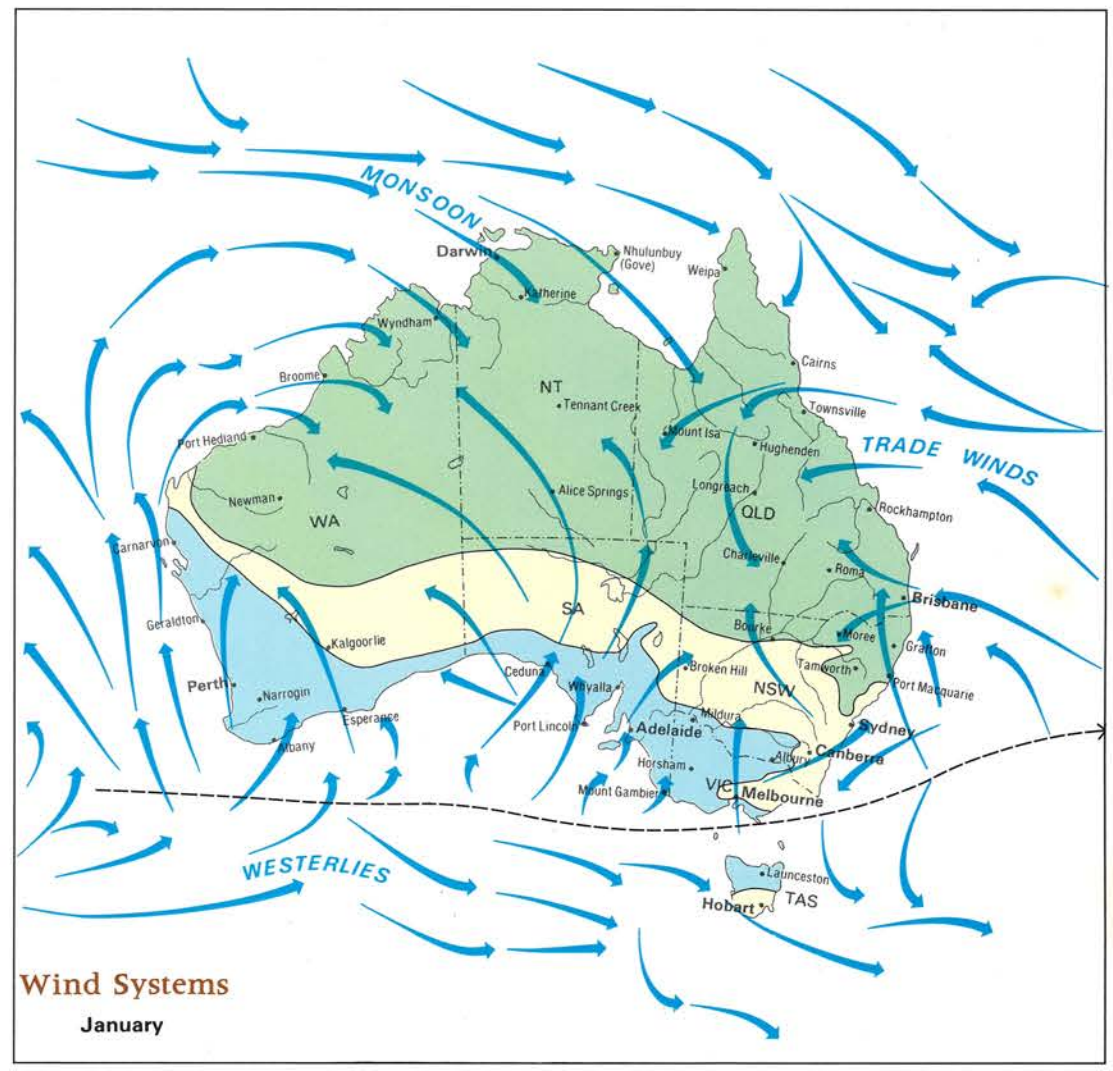
In the summer half of the year (November to April) the high pressure systems flow across the continent much further south, directing easterly winds over most of the continent. In southern Australia these are basically dry winds. The high pressure systems also produce stable weather conditions in the south, where the summer months are drier than the winter months. In northern Australia, summer heat and the southward shift of the equatorial trough produces the so-called 'monsoon' northwesterlies which bring widespread and prolonged cloud cover and rain to much of the north.

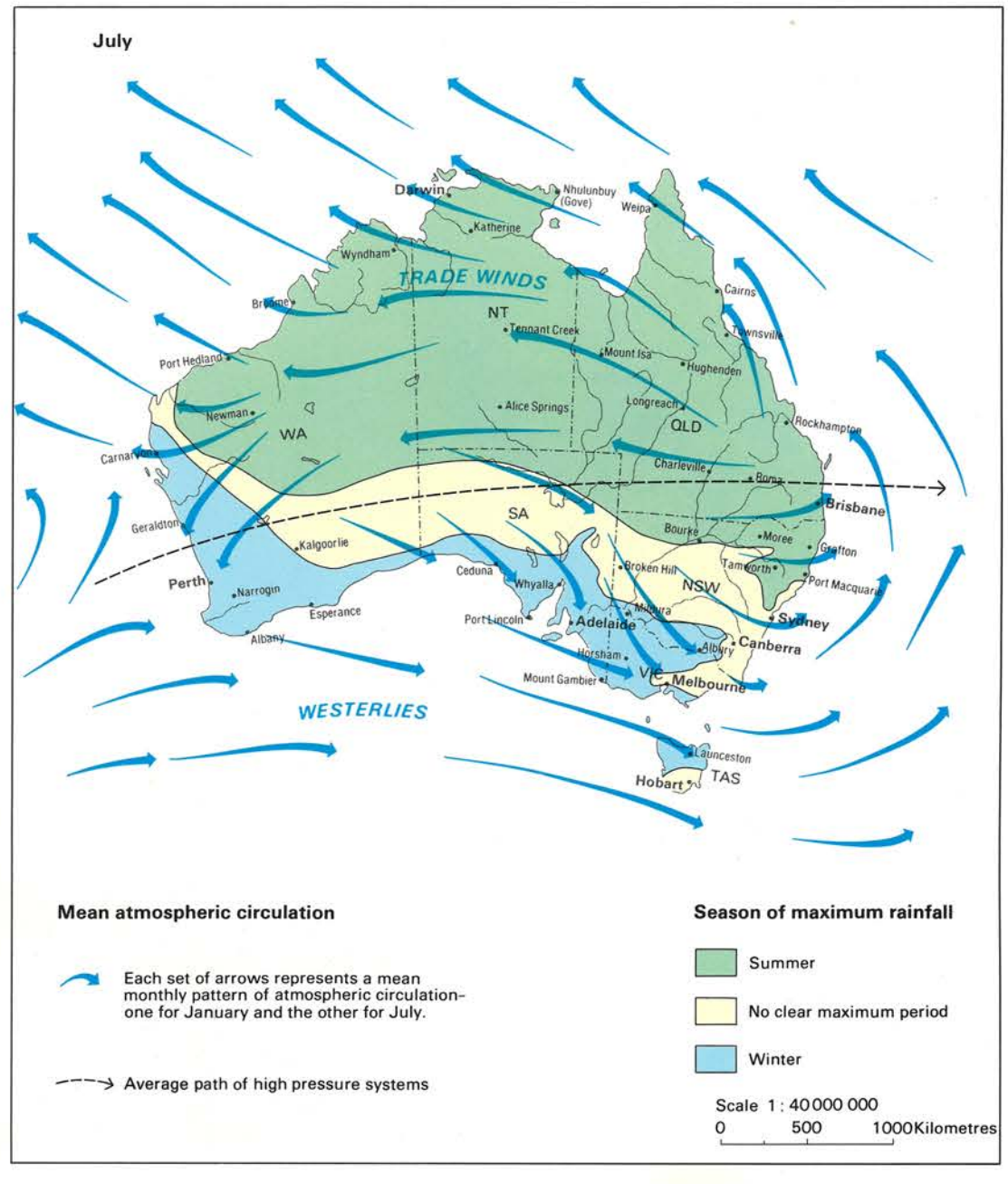
During the winter half of the year (May to October) when the high pressure systems move across Australia at relatively lower latitudes than during summer, cool westerly winds flow across the southern part of the continent. Embedded in and part of these westerly winds are low pressure systems that bring rain to much of southern Australia. Northern Australia is under the influence of southeasterly winds (the Trade winds) flowing offshore. These are dry.

The seasonal movement of high and low pressure systems and the subsequent change in wind patterns are mainly responsible for Australia's rainfall patterns. In winter, it is wet in the south and dry in the north. In summer, the pattern is reversed. The north experiences maximum rainfall while the southern part is mostly dry.

Between the two lies a transitional zone with no marked seasonal dominance. Rainfall there is more evenly distributed throughout the year.

The two maps show the pattern of rainfall but not the amount. Both Townsville and Tennant Creek, for example, experience summer maximum rainfall. The amount, however, and even the likelihood of receiving consistent rainfalls from year to year differ markedly between the two. These characteristics of rainfall are discussed on the following pages.





January

April

July

October

Median monthly rainfall

Millimetres

500 400 300 200 150 100 75 50 25 10 0 No rain

Scale 1 : 30 000 000

Rainfall

Median annual rainfall

Amount of rainfall equalled or exceeded in 50 per cent of years

100 400 800 1200 1600 2400 3200

Millimetres

Scale 1 : 15 000 000

0 200 400 600 Kilometres

THE MAP ABOVE shows median annual rainfall amounts (that is, the amount of rainfall equalled or exceeded in 50 per cent of the years). The pattern of rainfall reflects the interplay of the major features of global atmospheric circulation and the shape and topography of the Australian continent. Monsoonal influences and tropical cyclones are major rain producers in the tropics; mid-latitude cold frontal systems bring much of the rain experienced in the southern half of the continent; moist easterly winds are important rain-bearers along the east coast; and unpredictable thunderstorms may add significantly to rainfall totals anywhere in the continent.

Annual rainfall decreases rapidly inland around the northern, eastern and southwestern mainland coasts. The Great Divide has a strong influence in localising heavier falls along the east coast. Pockets of relatively high rainfall along the east coast and in western Tasmania are caused by local mountains. The highest average annual falls occur along the Queensland coast north of Townsville, reaching about 4500 millimetres per year in some places. Low rainfall in the centre and along the west coast reflects distance inland and the influence of frequent, stable high pressure systems.

The four maps of median monthly rainfalls show in some detail the considerable seasonal variation already discussed. The contrast between the wet summers and dry winters of the north and the wet winters and dry summers of the southwest are particularly marked.

A different and important aspect of rainfall variability is illustrated in the maps showing monthly rainfall ranges (the difference between highest and lowest falls each month). For the selected months, these show the ranges between highest and lowest falls recorded, in most cases the lowest readings being zero or close to it. The maps emphasise the extreme unpredictability and unreliability of rainfall over most of Australia and point to the potential problems for activities such as agriculture that depend on adequate and reliable water supplies. Ranges tend to be greatest in areas of high seasonal rainfall totals. For such areas the real significance of the large ranges lies in the possibility of receiving very low falls at times when high rainfall would normally be expected. Smaller ranges are generally characteristic of lower rainfall areas, although occasional heavy falls occur in the drier central and northwestern areas, especially in summer and autumn.

Monthly rainfall range

Millimetres

1200 800 400 200 100 50 0

Difference between maximum and minimum rainfall recorded for the specified month

Droughts and floods

Rainfall variability

Highest annual rainfall on record

Very much above average (top 10% of values)

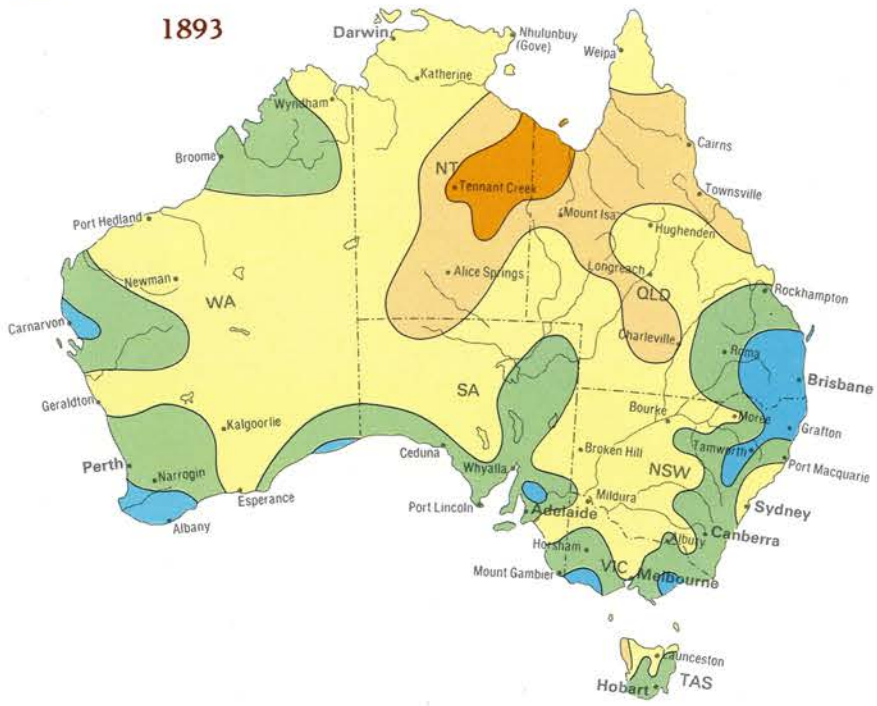
Below or much below average (above bottom 10% but below the middle values)

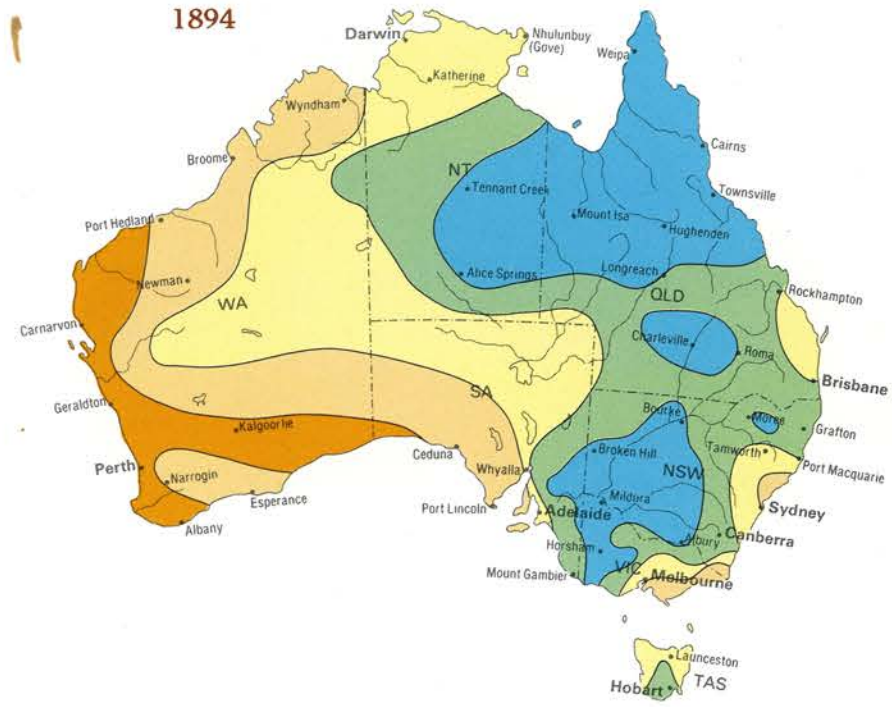
Average (middle 40% of values)

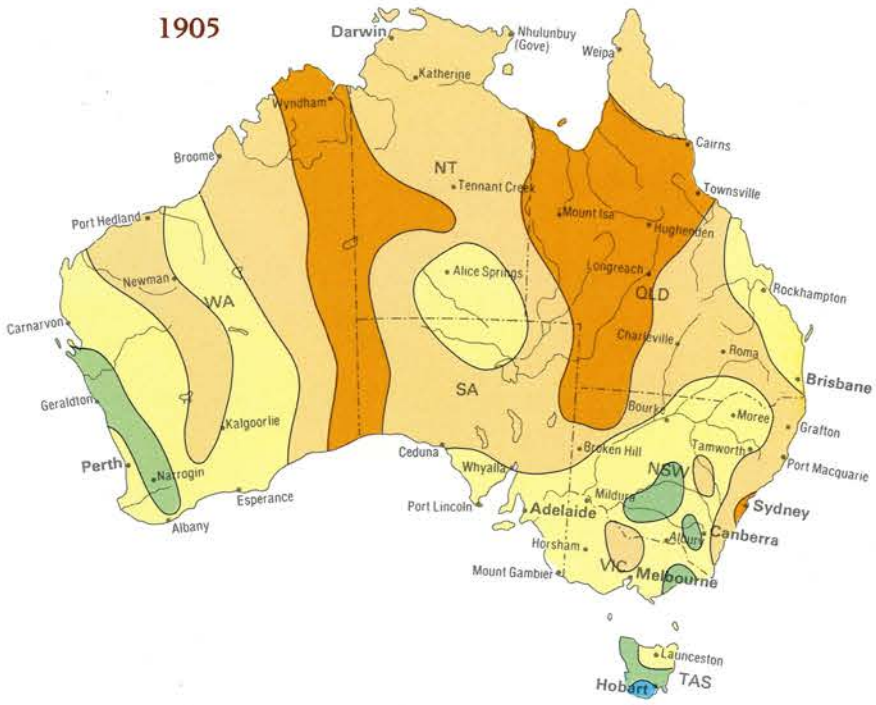
Lowest annual rainfall on record

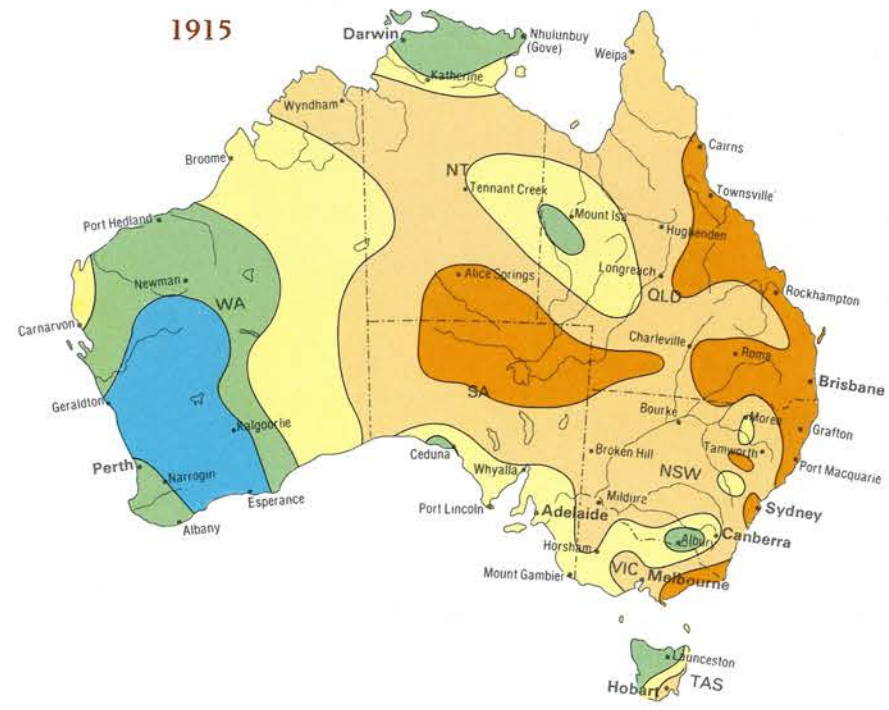
Above or much above average (below top 10% but above the middle values)

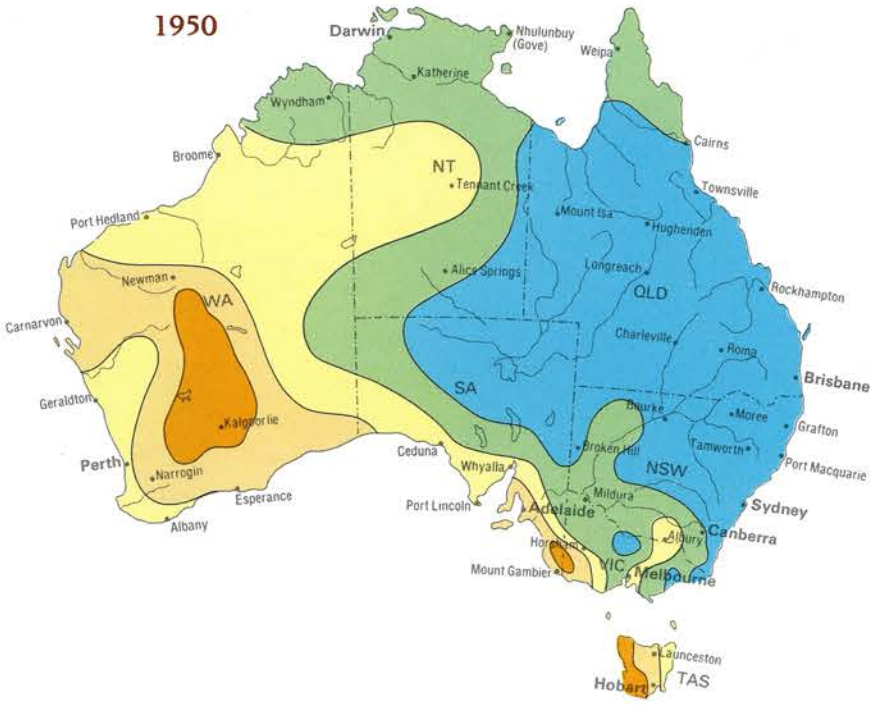
Very much below average (bottom 10% of values)

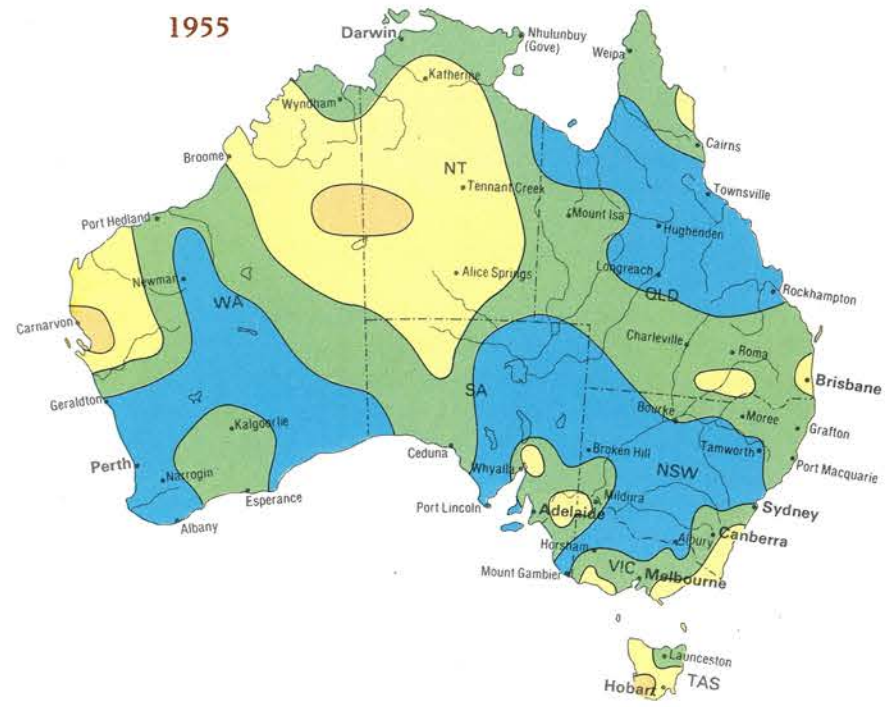






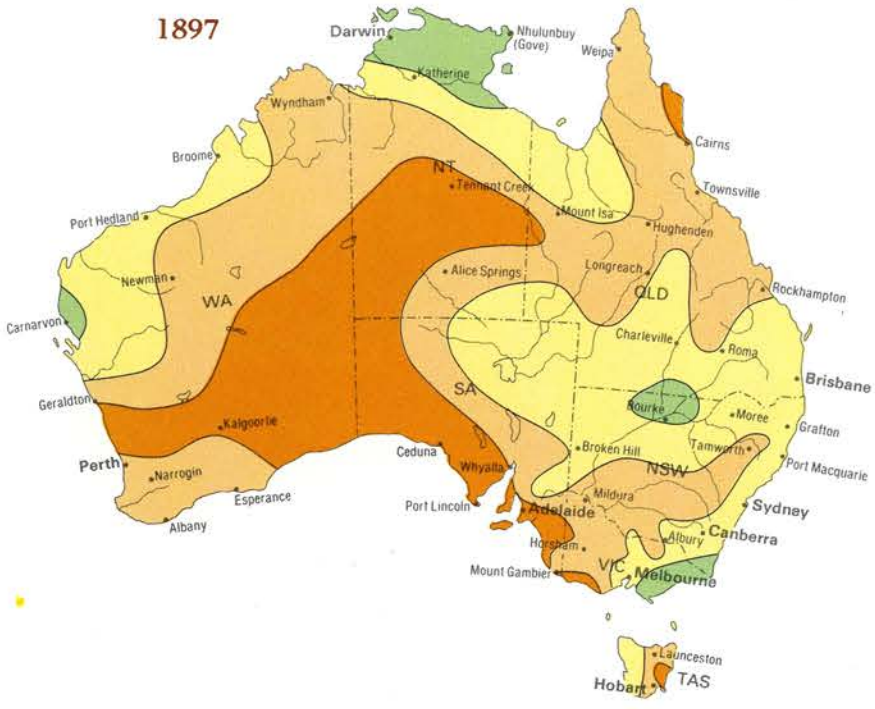


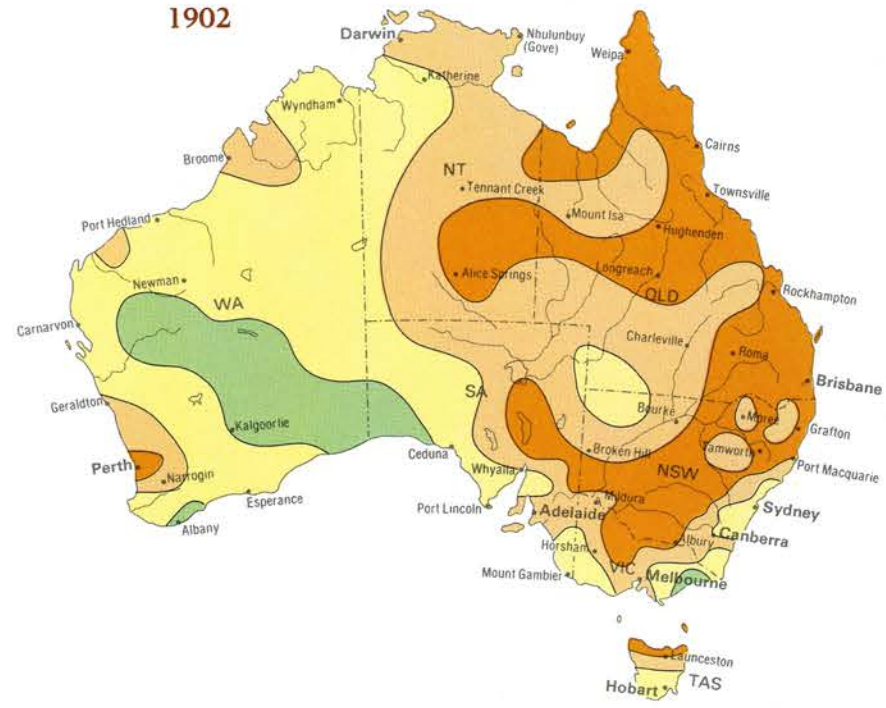


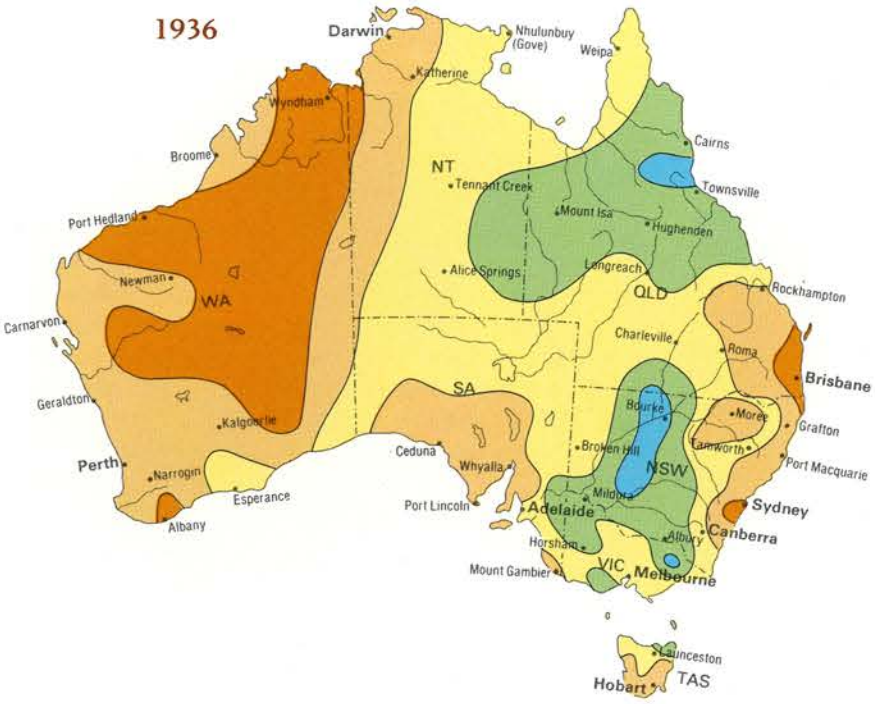


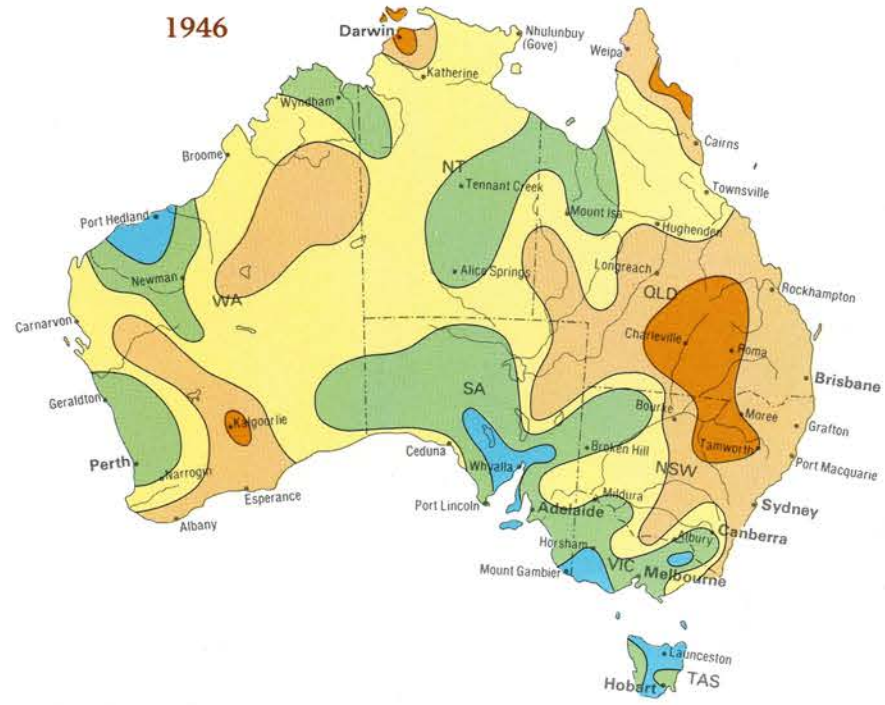
THESE MAPS REFLECT the variability of rainfall that leads to droughts and floods in Australia. They have been selected to illustrate the variability possible both within a year and between years. Most maps show rainfall patterns in years of major droughts or floods in different parts of the country. Rainfall substantially above the average in one region, perhaps producing floods, has often been accompanied by rainfall substantially below the average and drought in other regions. It is unusual for the entire country to experience very high or very low rainfalls at one time, though there have been drought years such as 1897, 1902 and 1905 and flood years such as 1955 and 1974. It is also not unusual for an area to experience devastating floods in one season or year, only to be plunged into severe drought in the following period. There can be close juxtaposition of areas of flood and drought.

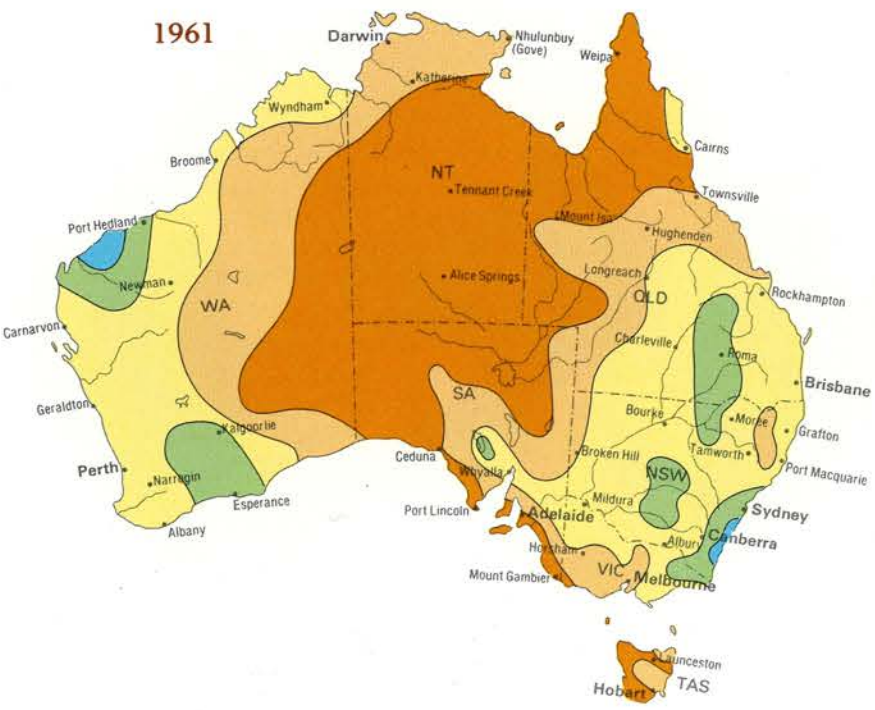
In the years mapped, various parts of the country had major floods in 1893, 1894, 1950, 1955, 1974, 1976 and 1983. Major droughts occurred in 1897, 1902, 1905, 1915, 1936, 1946, 1961, 1965, 1972 and 1982. However, not all the maps have been included to illustrate specific flood or drought episodes. Some show variations between the regions within Australia in which above average, average and below average

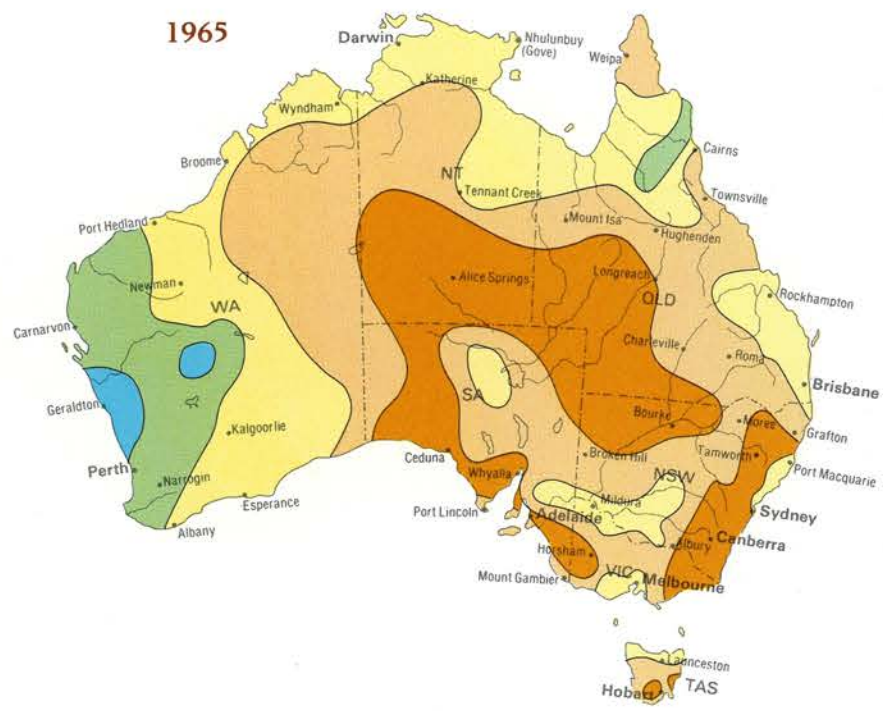








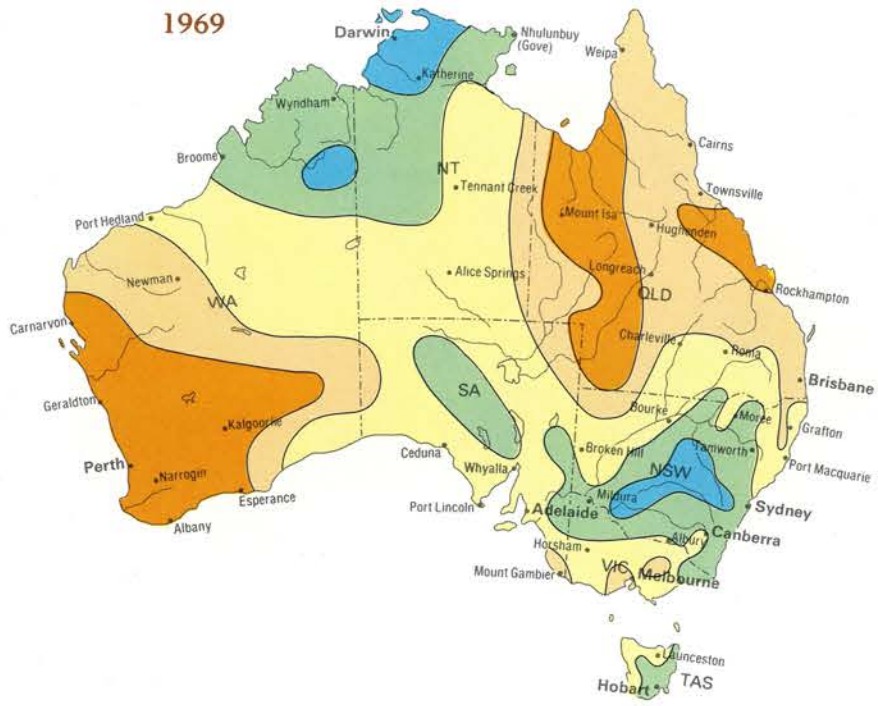


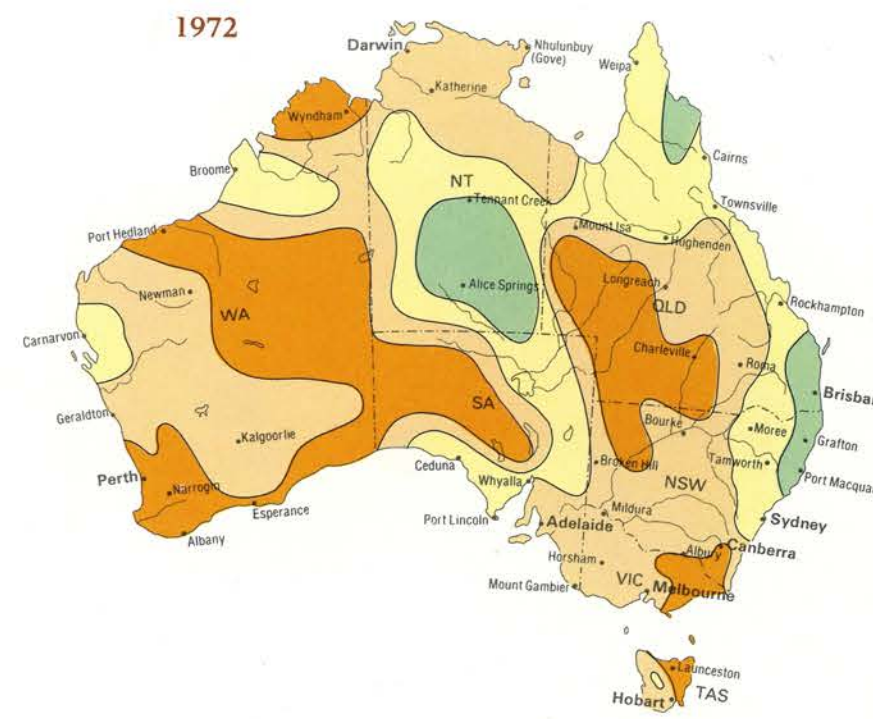


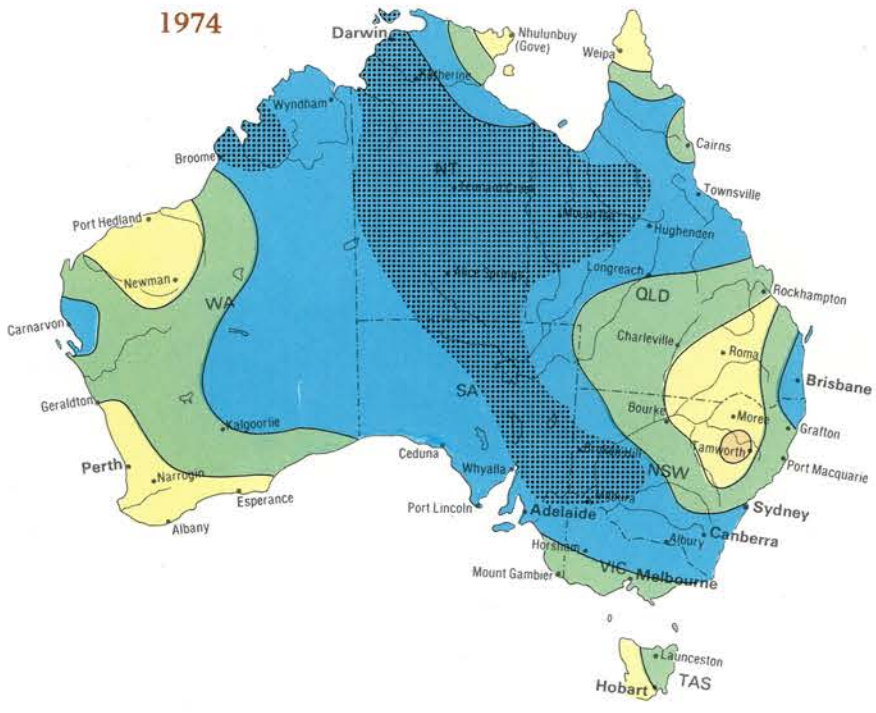
rainfall occurred in the same year, for example, in 1893, 1946 and 1983.

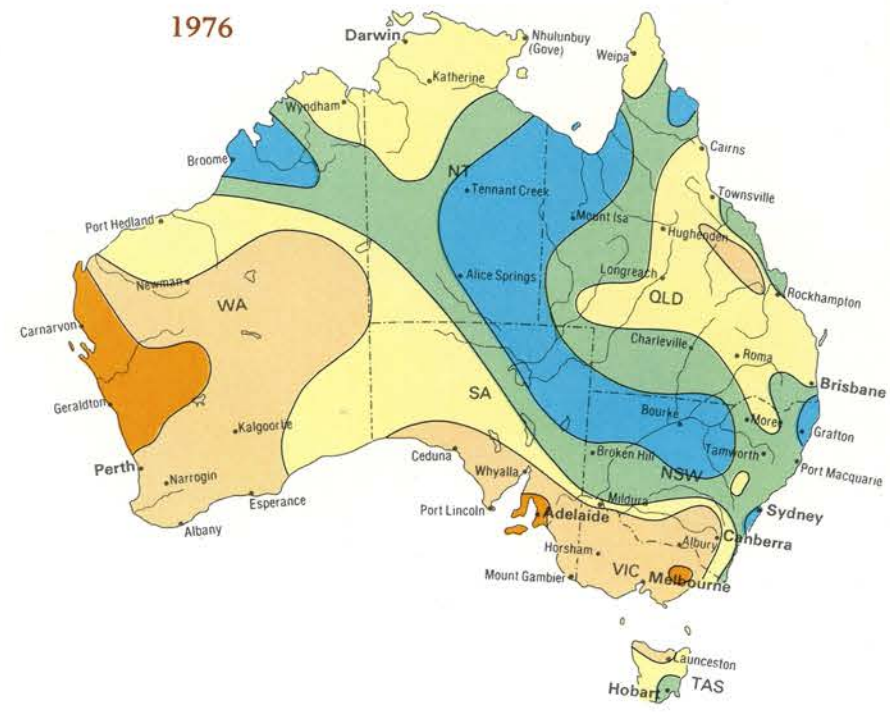
The best-known floods of the nineteenth century occurred in February 1893 in southeast Queensland. In the twentieth century, the northern New South Wales floods of February 1955 were particularly widespread, but were most severe in the Hunter valley. Flooding in January to March 1974 affected much of central and northern Australia, as well as southern Queensland and northern New South Wales.

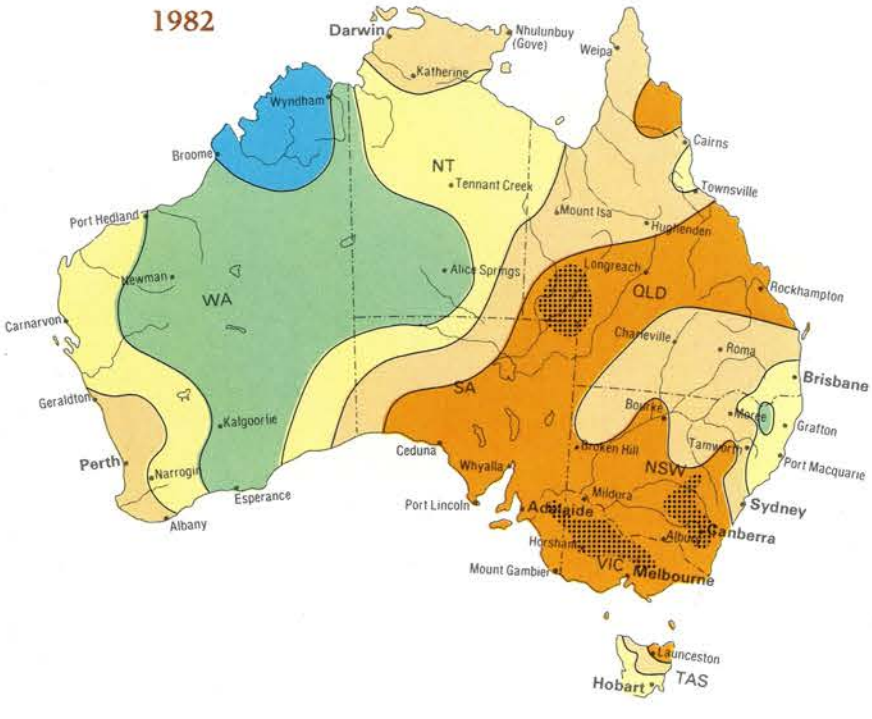
What might have been the most severe drought during the last 200 years lasted from 1895 to 1903. It is interesting, however, that in 1894, immediately before the onset of this devastating drought, much of eastern Australia had above average rainfalls. Such extreme variability from one year to the next over large areas also characterised the most recent, and perhaps equally devastating, drought of 1982-83 in eastern Australia. It was followed in mid-1983 by floods in southern Queensland and northern New South Wales. In 1982, while eastern Australia was drought-stricken, much of Western Australia was enjoying good rainfall. The situation was reversed in 1983. This contrast between east and west is a characteristic feature of the occurrence of drought and flood in Australia and may be seen in other years such as 1894, 1915, 1950 and 1976.

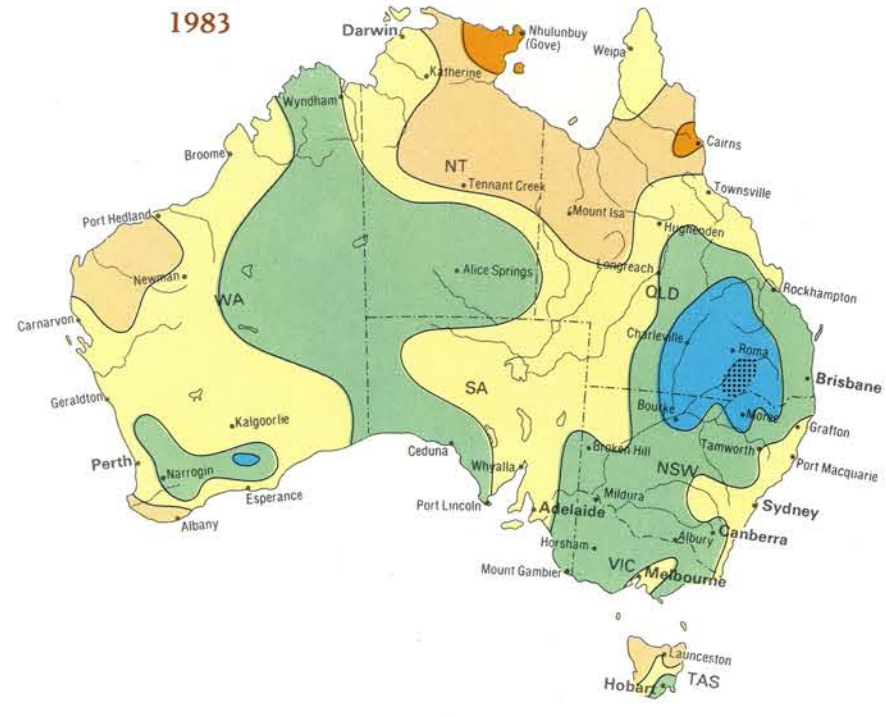












Bushfires

FIRE HAS LONG been part of the Australian environment and has played an important role in shaping flora and fauna. Many species are fire-adapted; some are even considered to be fire-dependent. Some of the fire-dependent plant species have characteristics that contribute to the development and spread of high-intensity fires.

By the time Aborigines arrived in Australia, most of the continent was subject to a fairly high natural fire frequency, with lightning starting fires when the vegetation was dry enough. Aboriginal burning probably had a limited effect on vegetation and was probably most marked in the wettest areas, where natural fires were rare and small. Such burning probably maintained small, relatively clear patches in eucalypt forests, woodlands and grasslands.

The arrival of Europeans caused significant changes in the intensity, frequency and seasonality of fires. Europeans used fire with insufficient understanding of its long-term impact. They suppressed fire to protect life and property and deliberately used it to clear land for cropping and pastoral purposes, and to reduce the likelihood of major bushfires. Natural fire regimes were altered. So too were patterns of species distribution.

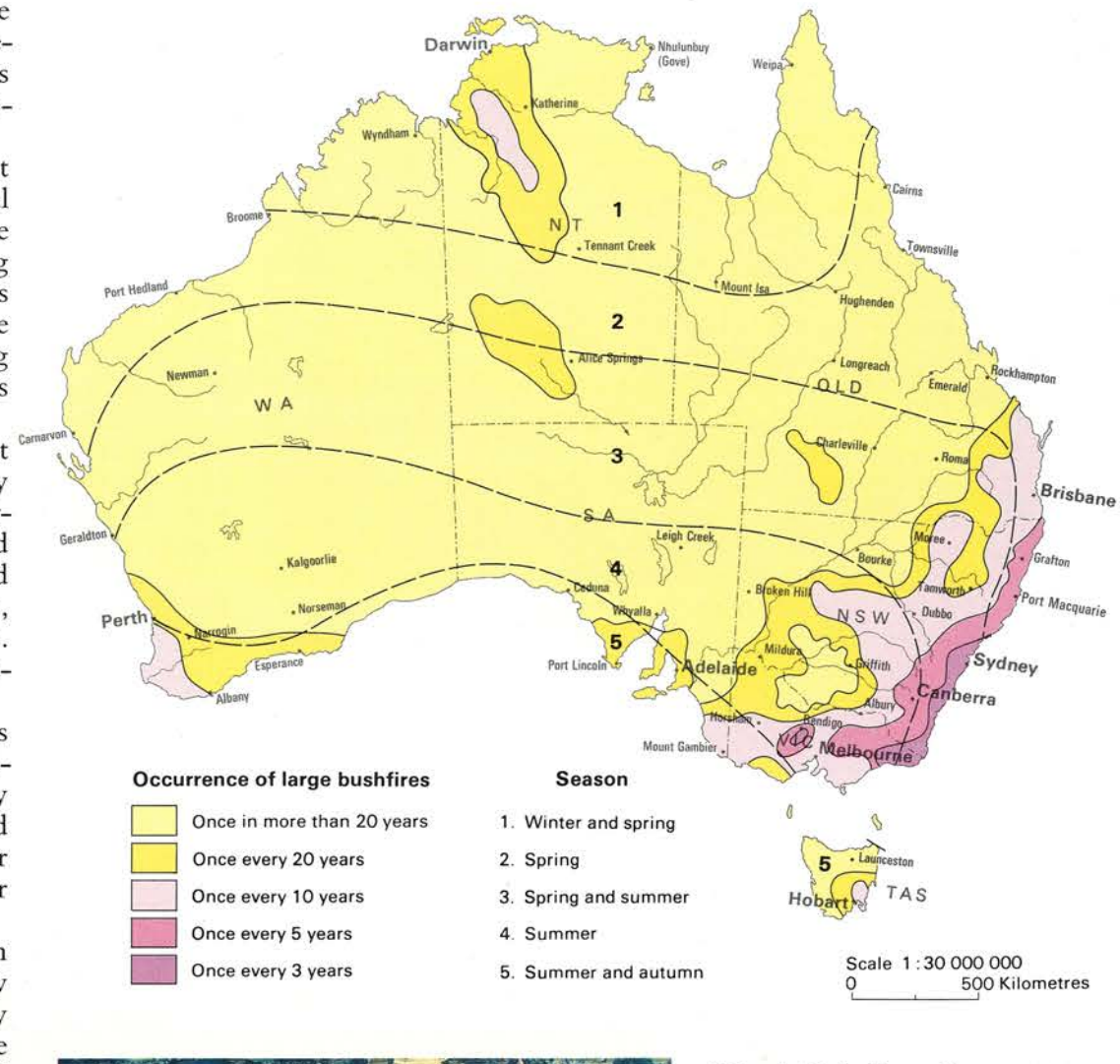
It has been estimated that three or four times as many bushfires now occur as occurred before European settlement. This increased frequency is partly due to the deliberate use of fire already discussed and partly to accidental ignition through carelessness or modern technology. Embers from steam trains, for example, ignited many fires.

The frequency of large bushfires ranges from once every three years in the coastal districts of New South Wales and eastern Victoria to once every twenty years or more in most of the interior of the continent. The most hazardous areas in terms of actual and potential losses are the suburban developments in the bush around Sydney, Melbourne, Hobart and Adelaide. The most devastating fires in terms of monetary damage and lives lost have occurred when fires have burned into the suburban fringes of these major cities, although extensive fires in the rural areas can also cause loss of pastures and stock worth many millions of dollars.

From 1945 to 1975, there were large fires somewhere in Australia in all but five of the fire seasons. The most extensive fires were in central Australia during the 1974–75 fire season, when an estimated 117 million hectares were affected. During the same thirty-year period there were seven major fire seasons, including 1960–61, when one fire in Western Australia lasted for more than fifty days between Norseman and the South Australian border, and 1966–67, which saw the disastrous Hobart bushfires.

More recently, on Ash Wednesday, 16 February 1983, a series of bushfires broke out in South Australia and Victoria. More than 70 lives were lost, more than 1700 homes and buildings were destroyed, stock losses were about 350 000, and about 500 000 hectares of country were burnt out. Total insurance claims approached $200 million.

The bushfire hazard is still a major problem in many areas. Although awareness of the dangers of fire and fire-fighting methods are highly developed in rural areas, many Australians either ignore, or are ignorant of, the hazard and have not learned the lessons from disasters such as Ash Wednesday.



Although it looks like an abstract painting, this Landsat image of c1981 shows bushfire activity north of Mount Singleton in the Northern Territory. The lighter-coloured shapes are areas burnt out by fires over the years. Note the characteristically erratic path taken by many of the fires.
AUSTRALIAN LANDSAT STATION

Part of the destruction wreaked by the Ash Wednesday bushfires which swept through bushland in South Australia and Victoria in February 1983. This photograph was taken in the Adelaide Hills. Photograph by Gunther Deichmann.
WELDON TRANNIES

Tropical cyclones

TROPICAL CYCLONES ARE intense low pressure systems that form over the warm oceans of lower (tropical) latitudes. They are major contributors to the summer rainfall of northern Australia.

Tropical cyclones constitute the major environmental hazard for communities around the northern Australian coast, although, compared with some other countries in tropical cyclone regions, they are relatively infrequent. The main dangers to people and property arise from three quite distinct hazards induced by tropical cyclones: violent winds, storm waves and storm surges, and flood-producing rains. Direct impact is not necessary to produce extensive cyclone-related damage.

The map shows the number of known occasions when cyclones have crossed the northern Australian coast. This map masks the considerable year-to-year variation in frequency of tropical cyclones. Their variability can be gauged by the maps on the opposite page which show examples of cyclone tracks for selected years.

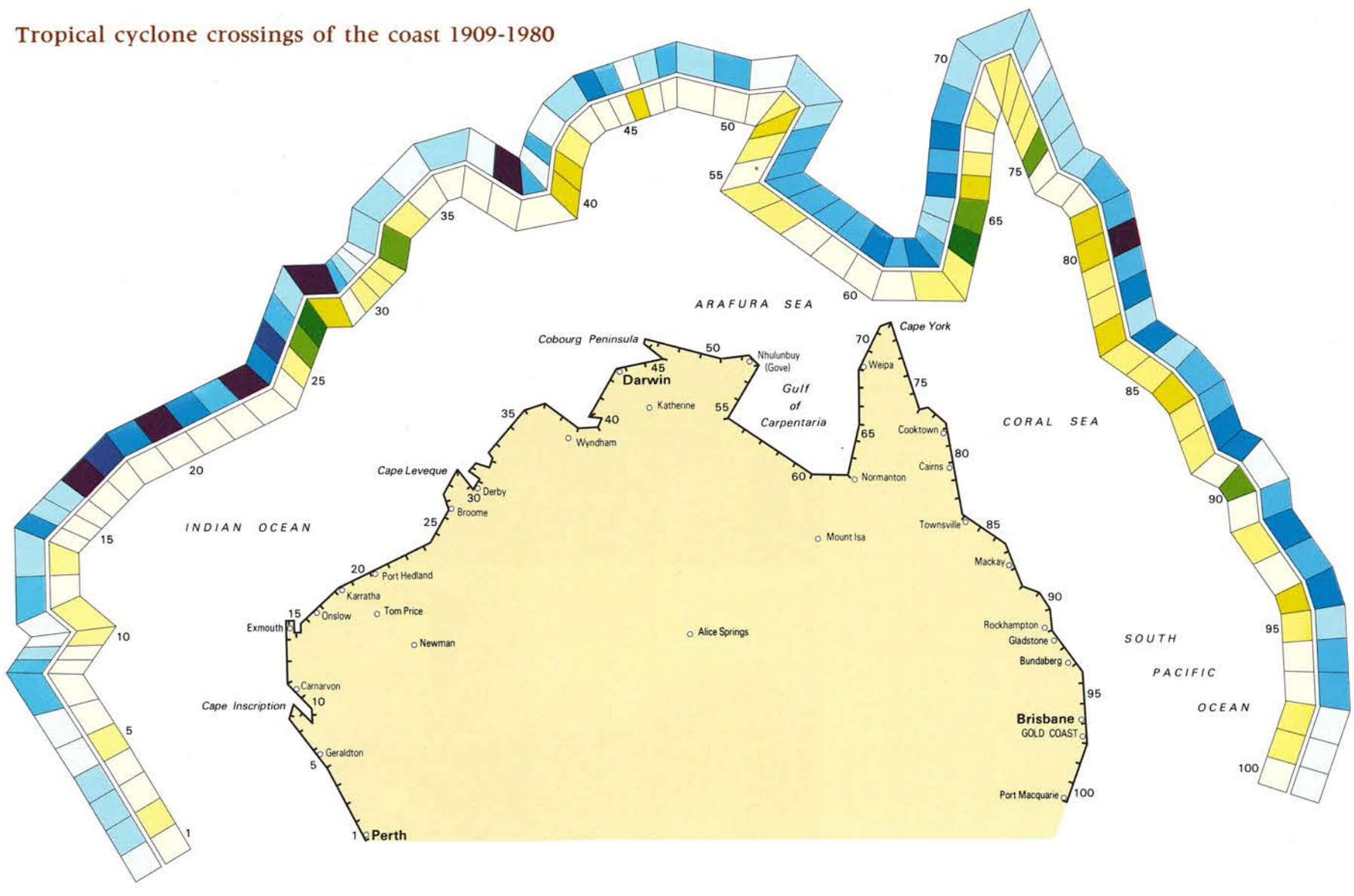
The tracks taken by these storms are extremely variable. It is still difficult for weather forecasters to predict accurately the formation of a tropical cyclone or its likely course. The highest recorded tropical cyclone wind gust in Australia was 245 kilometres per hour at Onslow on 19 February 1975, but there is no doubt that stronger gusts have occurred.

Storm waves and surges leading to flooding and coastal damage are generated by a combination of extreme winds and a rise in sea level produced by the relatively low atmospheric pressures that occur with tropical cyclones. The central north coast of eastern Queensland and parts of the Gulf of Carpentaria are particularly susceptible, although the overall flood hazard from storm surges in Australia is relatively moderate. There are numerous reports of surges exceeding 3 metres in eastern Queensland, the Gulf of Carpentaria and Western Australia. Maximum reported storm surge levels are a probably doubtful estimate of 12.2 metres at Bathurst Bay, north of Cooktown, in 1899 and 7.01 metres at Groote Eylandt in the Gulf of Carpentaria in 1923.

The extreme unpredictability of the tropical cyclone hazard is well illustrated by the events near Port Hedland in January and February of 1980. Prior to that time, a total of 17 tropical cyclone crossings had been recorded since 1909 along the 300 kilometres of coast centred on Port Hedland. In only five weeks in early 1980 there were three crossings on this stretch of coast. Tropical cyclones Amy, Dean and Enid caused extensive damage and disruption to Port Hedland and mining towns in the region, and to oil-drilling operations on the North-West Shelf. Wind gusts to 230 kilometres per hour were reported. Flooding was extensive and there were reports of surges of water 30 kilometres wide rushing towards the coast. Damage to buildings was estimated to be about $20 million. Much rebuilding was required, roads and railway lines had to be cleared and reconstructed, and mining activities and oil-drilling operations were severely disrupted.

By global standards cyclone Tracy, which hit Darwin on Christmas Day 1974, was a relatively small storm, though wind gusts reached 240 kilometres per hour. For Australia, however, it was a major disaster. Tracy claimed about fifty lives and several people were listed as missing at sea. Winds in the Darwin area were destructive over a path about 28 kilometres wide, but luckily the storm surge effect was limited because it coincided with neap (extremely low) tides. The centre of the storm

Tropical cyclone crossings of the coast 1909-1980

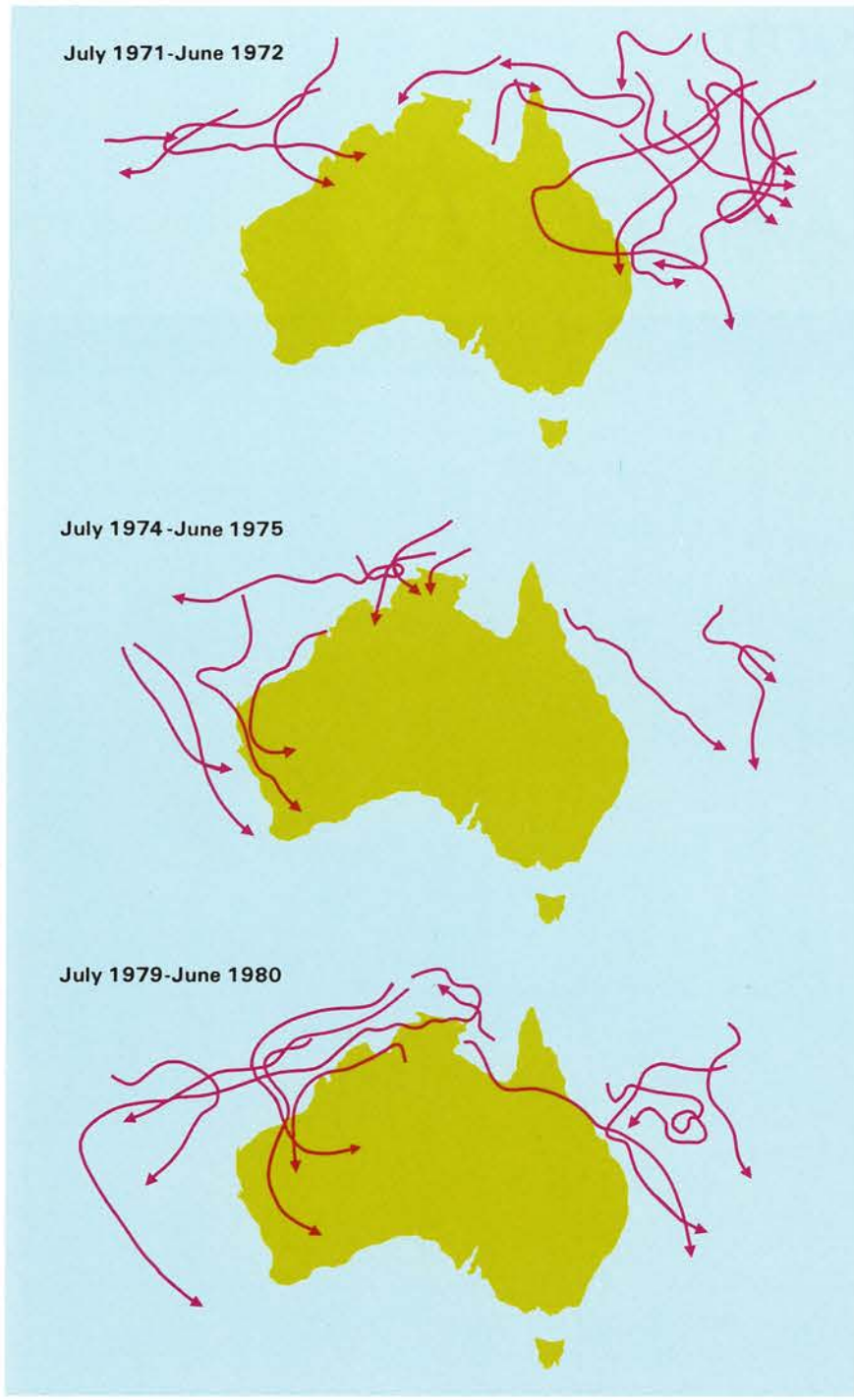


This map shows, for a 71 year period, the number of known crossings for each 100 km segment of the coast. The segments are numbered 1—100.

	0	1–2	3–4	5–6	7–8	9–11
Water to land crossings						

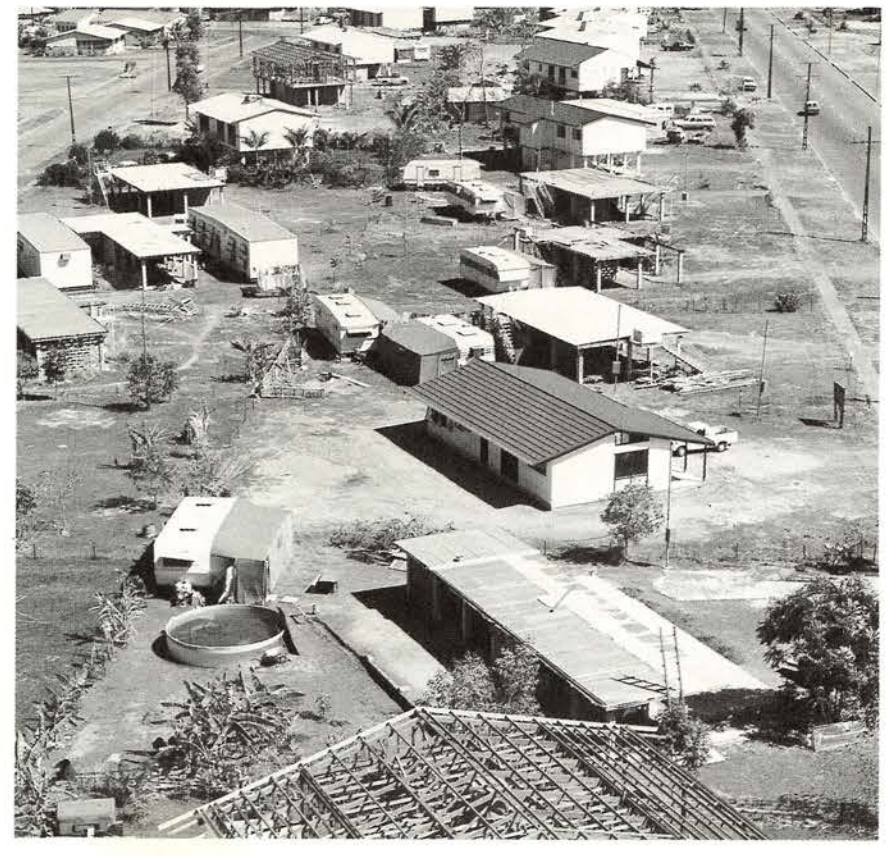
	0	1–2	3–4	5–6	7
Land to water crossings					

Tropical cyclone tracks



passed directly over Darwin. About 80 per cent of the buildings in the city were damaged, 50 to 60 per cent beyond repair, and the city was left without electricity, water, sanitation and communications. The total costs of the damage have been variously estimated to be between $500 million and more than $3000 million.

Tropical cyclones occur at many places around the Australian coastline, but nowhere is the threat greater than on the Queensland Gold Coast. This is Australia's premier holiday resort area, which has attracted retired people from elsewhere in Australia in increasing numbers. Canal estates, beachfront residences, retail trade outlets and high-rise buildings have extended onto the foredune, an unstable area of sand. Tropical cyclones have approached the area in the past and have caused widespread damage to private and public property, but recent developments seem to have ignored the possibility of future damage from severe tropical cyclones.



Cyclone Tracy struck Darwin on Christmas Day 1974. Its destructive power left only the foundations of houses. However, buildings outside its direct path suffered comparatively minor damage. With government assistance, the people of Darwin cleaned up the debris and began to rebuild. Many lived in caravans and tents until their homes were rebuilt. One family in this street promptly replaced their above ground pool, providing escape from Darwin's notorious humidity.
MAGAZINE PROMOTIONS

Dust storms

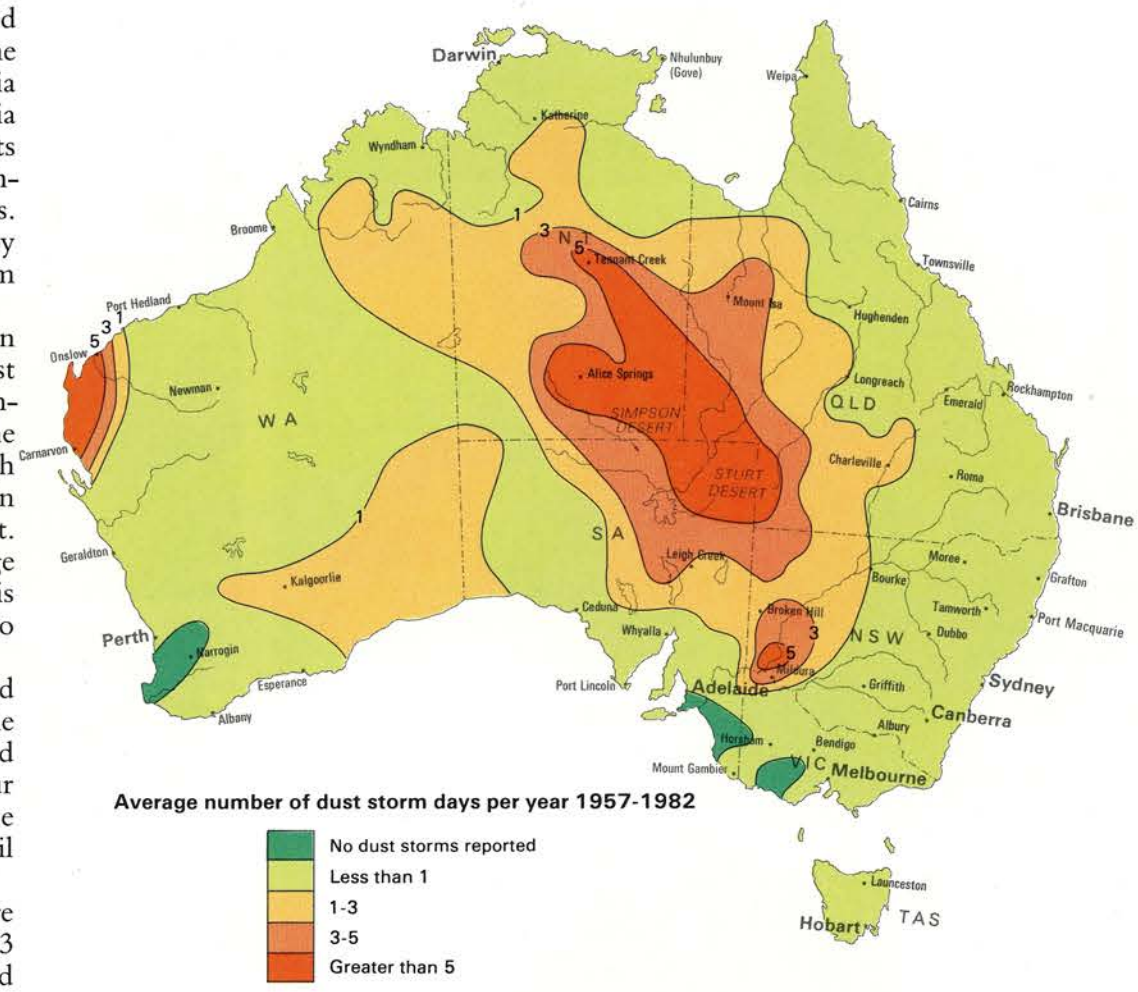
A DUST STORM day is defined as one on which dust reduces visibility to less than 1000 metres. Dust storms have been reported from all parts of Western Australia except the extreme southwest, from all areas of Tasmania except the west coast, from all districts of Victoria except an area west of Melbourne, from most parts of South Australia and from all parts of the Northern Territory, Queensland and New South Wales. The greater part of Australia is affected by dust storms, although many areas experience them too infrequently to represent any serious hazard.

The average frequency of dust storms is shown on the map, with the greatest frequency in the most arid region centred on the Simpson Desert, stretching from Alice Springs and Tennant Creek to the Sturt Desert. Two smaller areas of relatively high frequency are centred on Mildura and between Onslow and Carnarvon on the dry northwest coast. The Alice Springs area has the highest annual average number of dust storms with 10.8, but frequency is variable from year to year, ranging from 65 to zero between 1957 and 1982.

Dust storms tend to be features of late spring and late summer. There is no clear-cut and simple relationship between the patterns of dust storms and rainfall, though major dust storms tend to occur during severe droughts. There may be some relationship between duststorm frequency and soil type or general soil characteristics.

The dust storm that occurred during the severe drought in southeastern Australia in early 1983 provided ample evidence of the environmental and economic consequences of dust storms. A particularly dramatic dust storm enveloped Melbourne on 8 February 1983. Dust from the severe erosion of the drought-stricken Mallee topsoils in northwestern Victoria reduced visibility to less than 100 metres, and brought air, road and rail transport in and around the city to a standstill. Power lines were blown down, telephone exchanges were jammed with emergency calls and people suffered irritation to eyes and throat. The dust in the storm was raised by hot dry northwesterly winds averaging 33 kilometres per hour, with gusts of up to 80 kilometres per hour, as they blew over the open grazing and wheat lands of northern Victoria and southwestern New South Wales, which was a virtual desert after one of the worst droughts on record. The storm extended about 500 kilometres from Mildura to Melbourne, and was up to 100 kilometres wide. Aircraft reported dust as high as 3650 metres in the Mildura area, but the height approaching Melbourne was about 320 metres. It was estimated that the storm deposited 106 kilograms of dust per hectare in Melbourne's suburbs.

Dust storms were common during the prolonged 1895-1903 drought in southeastern Australia. Vast areas were tilled for wheat, and the soil, no longer compacted by moisture, became powdery and was blown away by the winds. Fences were submerged by the drifting soil and stretches of roads and railway lines were buried. In Melbourne on 21 November 1902, the afternoon sun was blotted out. In many inland towns the dust storm was reported to have turned the day into virtual night. There were also reports that cattle became invisible from only five steps away. Dams were silted and the mechanical pumps that lifted water from bores were halted by the clogging dust.



On 8 February 1983 at 3 pm a dust storm hit Melbourne. Winds of up to 100 kilometres per hour showered dry topsoil over the city from the drought-stricken hinterland. Photograph by N. Bade.
SCOOPIX