CHAPTER 15

WATER RESOURCES

This chapter is divided into two major parts:—water resources in Australia, and the management of these resources. The former provides information on such topics as the geographic background to water resources, surface and groundwater supplies and use and the drainage divisions in Australia. The latter summarises Australian and State assessment and management of water resources.

Official Year Book No. 51, pages 228–31, contains a description of recent developments in the measurement of Australia's water resources. For information concerning general, descriptive and historical matter *see also* Year Book No. 37, pages 1096–1141.

An article on droughts in Australia appeared in Year Book No. 54, pages 991–6.

Introduction

Rainfall, or the lack of it, is the most important single factor determining land use and rural production in Australia. The chapter Climate of Australia contains details on geographical and climatic features that determine the Australian water pattern. Australia is the driest continent in the world. The scarcity of both surface and groundwater resources together with the low rates of precipitation, which restrict irrigation and other uses (quite apart from economic factors), has led to extensive conservation programs of dams, reservoirs, large tanks and other storages.

Geographic background

General. Water resources are determined by rainfall, evaporation and physical features including soil, vegetation and geology. Chapter 2, Climate of Australia, contains a detailed description of the climatic features of the country. A brief description of the landforms appears in Year Book No. 61, pages 25–27. In assessing Australia's water resources, dependability and quality of supply must be considered, as well as amount.

Topography. The major topographical feature affecting the rainfall and drainage patterns in Australia is the absence of high mountain barriers; features range from sloping tablelands and uplands along the east coast Main Divide through the low plain and marked depression in the interior to the Great Western Plateau.

Drainage. Only one-third of the Australian land mass drains directly to the ocean, mainly on the coastal side of the Main Divide and inland with the Murray-Darling system. With the exception of the latter, most rivers draining to the ocean are comparatively short and account for the majority of the country's average annual discharge.

The interior lowlands exhibit endoreic drainage patterns and surface drainage is totally absent from some arid areas of low relief.

Climate. Australia's large area (7.7 million square kilometres) and latitudinal range (3,700 kilometres) have resulted in climatic conditions ranging from the alpine to the tropical. Two-thirds of the continent is arid or semi-arid, although good rainfalls (over 800 mm annually) occur in the northern monsoonal belt under the influence of the Australian-Asian monsoon and along the eastern and southern highland regions under the influence of the great atmospheric depressions of the Southern Ocean. The effectiveness of the rainfall is greatly reduced by marked alternation of wet and dry seasons, unreliability from year to year, high temperatures and high potential evaporation.

Settlement. The availability of water resources controls, to a large degree, the possibility and density of settlement; these, in turn, influence the quality of the water through production and disposal of waste. Most early settlements were established on the basis of reliable surface water supplies and, as a result, Australia's population is concentrated along the coast, mainly in the comparatively fertile, well-watered east, south-east and far south-west.

As settlement spread into the dry inland grazing country, the value of reliable supplies of underground water was realised. Observations of the disappearance of large quantities of the rainfall precipitated on the coastal ranges of eastern Australia eventually led to the discovery of the Great Artesian Basin which has become a major asset to the pastoral industry.

For further information on the influence of water resources on the spread of settlement in Australia *see* Year Book No. 61, page 860.

Surface supplies

Distribution and volume. As described above, permanent rivers and streams flow in only a small part of the continent. The average annual discharge of Australian rivers has been assessed at 343 x 10^9 cubic metres, of which 157 x 10^9 cubic metres is measured discharge and the remainder is estimated. This is small in comparison with river flows on other continents. In addition, there is a pronounced concentration of runoff in the summer months in northern Australia while the southern part of the continent has a distinct, if somewhat less marked, winter maximum.

Variability of flow. Even in areas of high rainfall, large variability in flow means that, for local regional development, most streams must be regulated by surface storage. However, in many areas evaporation is so great that storage costs are high in terms of yield. Extreme floods also add greatly to the cost of water storage, because of the need for adequate spillway capacity.

Potential development. Over 80 per cent of all water used in Australia is surface water. This quantity is about 14 x 10^9 cubic metres a year and represents about 11 per cent of the possible usable surface water available in Australia; it does not include the amount diverted for hydro-electric power generation and other purposes which does not affect the quantity of water available. However, the great variability of river discharge, high evaporation and lack of sites for storage on many catchments limit potential development. As an indication of the severity of the problem, Australia's runoff is estimated at 13 per cent of rainfall compared with 40 per cent in North America and Europe, 36 per cent in South America and Asia and 24 per cent in Africa, with the complementary figure representing the evaporation and transpiration percentage. There is, however, considerable scope for greater efficiency in water use.

Groundwater supplies

Groundwater is more important than surface water in about 60 per cent of the country. Australia's estimated annual groundwater recharge is 72 x 10^9 cubic metres, and annual groundwater usage is estimated at nearly 3 x 10^9 cubic metres or about 18 per cent of Australia's total water usage.

An indication of the variability in quality and quantity of Australia's groundwater resources is given in the map sheets accompanying the Australian Water Resources Council's publication, *Groundwater Resources of Australia (1975)*.

Groundwater is divided according to its occurrence in the three main classes of aquifer:

(i) *Shallow unconsolidated sediments* comprise alluvial sediments in river valleys, deltas and basins; aeolian (windblown) sediments which generally occur in coastal areas; and lacustrine (lake) sediments. These sediments are often highly permeable and porous. Permeability and porosity may vary markedly according to orientation. Unconsolidated aquifers of this group generally occur at depths of less than 150 m and are often readily accessible to sources of water for recharge. Marked seasonal variations in water level are common.

(ii) *Sedimentary rocks* are generally made up of consolidated sediments. The aquifers owe their porosity to small voids between the grains which are often well compacted and cemented. They often cover significant areas, being continuous and of appreciable thickness. Rock strata usually dip quite gently. Nevertheless, over the full extent of the larger sedimentary basins, aquifers may reach great depths. Areas where recharge takes place may be small in relation to the extent of the aquifers. Water quality in individual aquifers may be quite good and fairly uniform over large areas. Some sediments contain a number of permeable and impermeable layers, creating a vertical sequence of separate aquifers, and water quality may vary greatly between them.

(iii) *Fractured rocks* comprise hard igneous and metamorphosed rocks which have been subjected disturbance and deformation. Aquifers resulting from the weathering of any rock type are also included in this group. Water is transmitted mainly through joints, bedding planes, faults, caverns, solution cavities and other spaces in the rock mass.

The quality of groundwater varies considerably and sources are subject to pollution in much the same way as surface supplies. Locally, groundwater has also been polluted by poor drilling techniques which allow contamination of fresh or lower salinity waters by more highly saline waters, and also by the discharge of industries wastes into underground drainage bores. The Port Phillip Basin has the problem of discharge of industrial and domestic waste underground, and in the Western Port Basin there has been control of groundwater withdrawal since 1968 to prevent overdraft and salt-water intrusion.

For further details on the sources of groundwater and a table of the principal water-bearing basins in Australia, *see* Year Book No. 61, pages 865–6. A map showing the extent of known artesian basins throughout Australia is shown on page 273 of Year Book No. 48.

Drainage divisions and the conjunctive use of surface and groundwaters

Groundwater and surface water have, in the past, tended to be viewed as separate resources because of their modes of occurrence, assessment and development. They are complementary components of the hydrologic cycle and in any assessment of the water resources of a region are not necessarily additive.

To promote a unified approach, river basins or groups of river basins have been adopted as the primary units of assessment. The *Review of Australia's Water Resources* 1975 (Department of National Development, Australian Water Resources Council, A.G.P.S., Canberra) contains a summary of the 244 river basins grouped into twelve divisions, together with a map showing the divisions. (See below.)

The conjunctive approach to water resources, even to importing water from outside the region, generally makes more water available for use than would be the case with independent use of the various sources. Year Book No. 61, pages 867–8 contains details of the conjunctive use of surface and groundwaters.

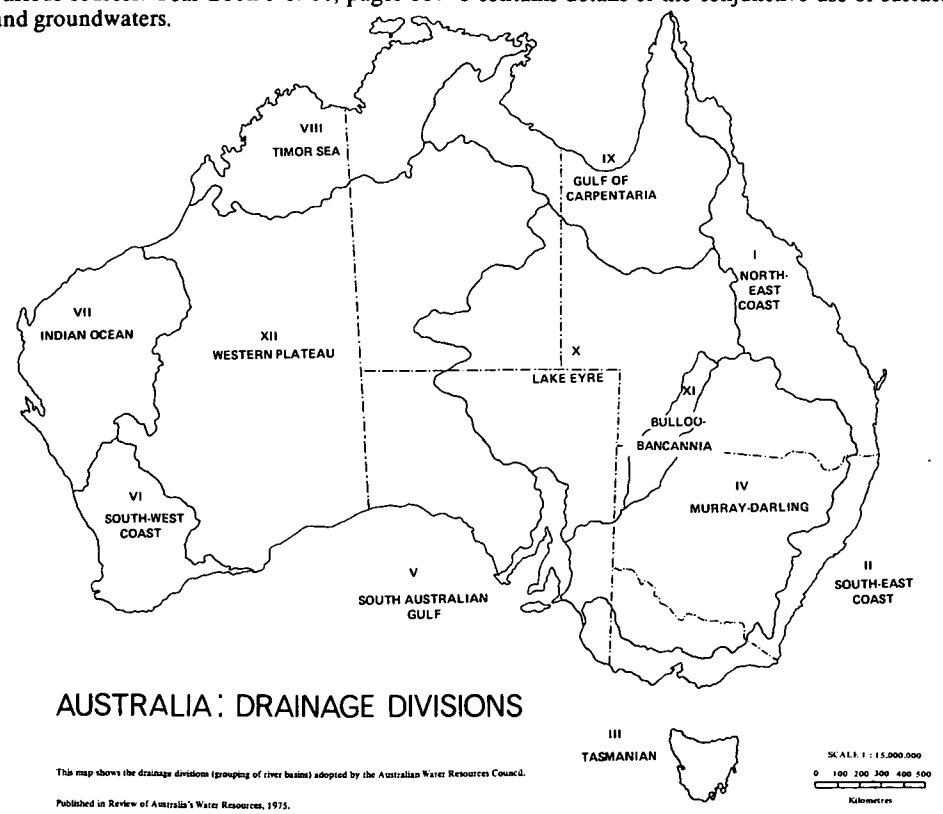

PLATE 32

In the *Review of Australia's Water Resources,* 1975 an attempt was made to assess the possible exploitable yield of surface water for each river basin (aggregating to Drainage Divisions) at the point of lowest practical downstream development, using the type of hydraulic structure considered technically feasible by the governments. These estimates take into account average annual flow, variability of flow, water quality and the availability of suitable sites for storage, but do not take into account economic factors.

The total annual commitment of surface water is about 30 x 10^9 cubic metres, which represents 24 per cent of the possible exploitable yield but only 8.6 per cent of the total runoff of Australian streams. The reasons for this low overall commitment are:

- economic resources are not fully developed.
- potential developments, while technically feasible, are expensive due to topographic and climatic limitations.
- bulk of surface water resources are remote from centres of population.

Surface water resources are developed for consumptive or non-consumptive uses. Consumptive use refers to domestic, industrial and agricultural uses and involves the removal of water from the stock of usable resources. The commitments for the table below are mostly for consumptive use in irrigation. Non-consumptive use comprises instream use of water and includes hydro-electric power generation, recreation and transportation.

AN ASSESSMENT OF THE POSSIBLE YIELD OF SURFACE WATER BY DRAINAGE DIVISION

(*Source:* Review of Australia's Water Resources, 1975)

Drainage division	*Adopted drainage area*	*Average annual discharge (a)*	*Annual commitments(a)*			*Possible exploitable yield*	*Commitments as a per centage of exploitable yield*	*Estimated total yield of drainage area*	*Possible exploitable yield as per centage of total yield*
			Present	*Authorised and planned*	*Total*				
	mil ha		mil. cubic metres					mil. cu. m.	
I North-East Coast	45	82,500	2,595	761	3,356	25,566	13	75,620	34
II South-East Coast	27	39,396	2,658	1,287	3,945	(*b*)15,992	24	37,499	43
III Tasmania	7	49,799	1,722	73	1,795	35,495	5	49,799	71
IV Murray-Darling	106	22,261	15,941	793	16,734	18,372	91	22,204	83
V South Australian Gulf	8	980	135	38	173	283	61	913	31
VI South-West Coast	31	7,290	343	27	370	1,841	20	4,935	37
VII Indian Ocean	52	4,160	–	75	75	490	15	3,815	13
VIII Timor Sea	55	74,260	3,083	45	3,128	16,423	19	74,260	22
IX Gulf of Carpentaria	64	58,230	76	86	162	10,094	2	49,180	21
X Lake Eyre	117	3,260	9	–	9	129	7	3,180	4
XI Bulloo-Bancannia	10	540	3	–	3	n.a.	n.a.	540	n.a.
XII Western Plateau	246	–	–	–	–	–	–	–	–
Australia	**768**	**342,676**	**26,565**	**3,185**	**29,750**	**124,685**	**24**	**321,945**	**39**

(*a*) Includes fresh and marginal water but excludes brackish and saline water. (*b*) Includes a small amount of brackish water.

Groundwater is an important substitute for surface water in many parts of the country such as in the arid interior where the Great Artesian Basin provides the only reliable continuous supply of water for stock and domestic purposes. This Basin underlies 23 per cent of the continent and some 30,000 holes have been drilled, about 2,900 of which are still flowing. The high ratio of sodium to calcium and magnesium ions has an adverse effect on soil structure, rendering it impervious and quite unsuitable for irrigation, but its freshness as opposed to the brackish or saline water provides watering points for stock and domestic supplies.

Groundwater is increasing in importance as a source of water for irrigation, industry and domestic supply. There are many areas of intensive groundwater development which, although small, accounted for over a third of all groundwater withdrawals in 1975. The areas shown in the table below rely almost exclusively on ground water from unconsolidated sediments.

Increasing use is made of conjunctive schemes, for example, where groundwater supplies are tapped to augment surface water or where, as in the Burdekin Delta, groundwater aquifers are artificially recharged during the summer wet season to enable water to be stored at low cost with negligible evaporation.

AREAS OF CONCENTRATED GROUNDWATER USAGE IN AUSTRALIA

(*Source:* Review of Australia's Water Resources, 1975)

Area	*Quantity*	*Use*
	mil. cu m/year	
Burdekin Delta (Queensland)	320	Irrigation of sugar cane
Namoi Valley (New South Wales)	108	Irrigation of small crops, including cotton
Condamine Valley (Queensland)	100	Irrigation of grain crops
Southeastern South Australia(*a*)	98	Irrigation, town supplies and industry
Bundaberg (Queensland)	94	Irrigation of sugar cane, industrial and domestic use
Lockyer Valley (Queensland)	70	Irrigation of small crops and fodder
Perth (Western Australia)	66	Irrigation of market gardens, domestic gardens and urban water supply
Hunter Valley (New South Wales)	53	Irrigation of small crops
Callide Valley (Queensland)	35	Irrigation of fodder and grain crops
Tomago Sands (New South Wales)	31	Urban water supply and industrial use
Pioneer Valley (Queensland)	31	Irrigation of sugar cane and domestic use
North Adelaide Plains (South Australia) (*a*)	21	Irrigation of market gardens
Botany Sands (New South Wales)	20	Industrial use
Sub-total	*1,047*	
Estimated total groundwater usage	**3,000**	

(*a*) Includes some water from limestone aquifers.

Major dams and reservoirs

A map entitled *Australia—Dams and Storages*, published in 1975 by the Department of Minerals and Energy (now the Department of National Development), shows the location, height of dam wall, capacity and purpose of Australia's major dams and water storages.

The table below lists major dams and reservoirs by State. It should be noted that the Hume Reservoir lies on the New South Wales-Victoria border.

MAJOR DAMS AND RESERVOIRS IN AUSTRALIA

Name and year of completion	*Location*	*Gross capacity (million cubic metres)(a)*	*Height of wall (metres) (b)*	*Purpose*
NEW SOUTH WALES				
Eucumbene (1958)	Eucumbene River	4,807	116	Part of Snowy Mountains H/E Scheme
Hume (1936, 1961)	Murray River, near Albury	3,038	51	Irrigation, water supply, H/E
Warragamba (1960)	Warragamba River	2,057	137	Water supply for Sydney, H/E
Menindee Lakes (1960)	Darling River, near Menindee	1,794	18	Conservation, storage for Murray River Agreement
Burrendong (1967)	Macquarie River, near Wellington	1,680	76	Conservation, FC, water supply
Blowering (1968)	Tumut River	1,628	112	H/E, irrigation
Copeton (1976)	Gwydir River	1,364	113	Irrigation
Wyangala (1936, 1971)	Lachlan River	1,218	85	Irrigation, stock, etc.
Burrunjuck (1927, 1956)	Murrumbidgee River	1,026	79	Irrigation, H/E
Talbingo (1971)	Tumut River	921	162	H/E
Jindabyne (1967)	Snowy River	688	72	H/E
Lake Victoria (1928)	Murray River, near S.A. border	680	–	Conserves supplies for S.A.
Keepit (1960)	Namoi River, near Gunnedah	426	55	Conservation, irrigation, H/E
Glenbawn (1958)	Hunter River, near Scone	362	78	Conservation, irrigation, FC
Tantangara (1960)	Murrumbidgee River	254	45	H/E
Avon (1927)	Avon River	214	72	Water supply for Sydney
Googong (1978)	Queanbeyan River	125	59	Water supply for Canberra-Queanbeyan
VICTORIA				
Dartmouth (1977)	Mitta Mitta River	4,000	180	Irrigation storage, H/E
Eildon (1927, 1955)	Upper Goulburn River	3,392	79	Irrigation, H/E
Waranga (1910)	Near Rushworth (Swamp)	411	12	Irrigation
Mokoan (1971)	Winton Swamp, near Benalla	365	10	Irrigation
Rocklands (1953)	Glenelg River	336	28	Domestic and stock water supply
Eppalock (1964)	Campaspe River	312	45	Irrigation, water supply
Cardinia (1973)	Cardinia Creek, near Emerald	287	79	Water supply for Melbourne
Upper Yarra (1957)	Yarra River	207	89	Water supply for Melbourne
Glenmaggie (1927, 1958)	Macalister River	190	37	Irrigation
QUEENSLAND				
Fairbairn (1972)	Nogoa River, central Qld	1,440	49	Irrigation
Somerset (1959)	Stanley River	893	50	Water supply for Brisbane, H/E
Monduran (1975)	Kolan River, near Gin Gin	586	52	Irrigation
Ross River (1974)	Near Townsville	417	35	FC, water supply
Tinaroo Falls (1958)	Barron River	407	47	Irrigation, H/E
Glenlyon (1976)	Pike Creek, near Stanthorpe	261	46	Irrigation
Wuruma (1968)	Nogo River, near Eidsvold	194	46	Irrigation
Koombooloomba (1961)	Tully River	180	52	H/E, irrigation
WESTERN AUSTRALIA				
Lake Argyle (Ord) (1971)	Ord River, near Wyndham	5,720	99	Irrigation, FC, H/E
South Dandalup (1973)	Near Mandurah	208	41	Water supply for Perth
Wellington (1933, 1944, 1960)	Collie River	185	37	Irrigation, water supply
Serpentine (1961)	Serpentine River	178	55	Water supply for Perth

(*a*) Includes 'dead water', i.e., water below the operational outlet of the reservoir. (*b*) As a general rule, the figures shown for height of wall refer to the vertical distance measured from the lowest point of the general foundation to the crest of the dam, i.e., the level of the roadway or walkway on the dam.

ABBREVIATIONS: H/E—hydro-electricity, FC—Flood control and/or mitigation.

MAJOR DAMS AND RESERVOIRS IN AUSTRALIA—*continued*

Name and year of completion	*Location*	*Gross capacity (million cubic metres)(a)*	*Height of wall (metres) (b)*	*Purpose*
TASMANIA				
Lakes Gordon and Pedder (1974)—				
Gordon	South West	11,671	140	H/E
Scotts Peak	South West	2,960	43	H/E
Serpentine	South West	2,960	38	H/E
Edgar	South West	2,960	17	H/E
Miena (1967)	Great Lake	2,390	18	Storage for H/E
Lake St Clair (1938)	Central Plateau	2,000 (est.)	3	Natural storage for H/E
Lake Echo (1956)	Lake Echo	725	19	H/E
Lake King William (Clark) (1949, 1966)	Derwent River	541	73	H/E
Arthur's Lake (1965)	Source of Lake River, near Great Lake	511	17	H/E
Devils Gate (1969)	Forth River, near Devonport	180	84	H/E
Rowallan (1967)	Mersey River	131	43	H/E
NORTHERN TERRITORY				
Darwin River (1972)	Darwin River	259	31	Water supply for Darwin

(*a*) Includes 'dead water', i.e., water below the operational outlet of the reservoir. (*b*) As a general rule, the figures shown for height of wall refer to the vertical distance measured from the lowest point of the general foundation to the crest of the dam, i.e., the level of the roadway or walkway on the dam.

ABBREVIATIONS: H/E—hydro-electricity, FC—Flood control and/or mitigation.

MAJOR DAMS AND RESERVOIRS UNDER CONSTRUCTION OR PROJECTED

Name	*Location*	*Gross capacity (million cubic metres)(a)*	*Height of wall (metres)(b)*	*Purpose*
UNDER CONSTRUCTION				
Wivenhoe	Brisbane River, near Fernvale, Qld	1,150	58	Water supply, FC, H/E
Thomson	Thomson River, near Erica, Vic.	1,110	160	Water supply, irrigation
Tallowa (Lake Yarrunga)	Confluence of Shoalhaven, Kangaroo Rivers, N.S.W.	135	43	Water supply
Julius	Leichhardt River, near Mount Isa, Qld	123	35	Water supply, mining
PROJECTED				
Mackintosh	Mackintosh River, Tullibardine River, near Queenstown, Tas.	922	77 24	H/E
Lower Pieman	Pieman River, near Queenstown, Tas.	641	120	H/E
Split Rock	Manilla River, Namoi Valley, N.S.W.	370	64	Irrigation
Windamere	Cudgegong River, near Mudgee, N.S.W.	353	69	Irrigation
Gunpowder	Gunpowder Creek, near Mount Isa, Qld	141	44	Mining, water supply
Spencer	Denison Creek, near Nebo, Qld	127	24	Mining, water supply
Bastyan (Lake Rosebery)	Pieman River, near Queenstown, Tas.	124	74	H/E

For footnotes and abbreviations *see* previous table.

The following table summarises dams and storages existing and under construction in each drainage division according to purpose, capacity and regulated discharge. Three storages counted as mainly for hydro-electricity in the South-East Coast Division and eight in the Murray-Darling are part of the Snowy Mountains Hydro-electric Scheme which, as a whole, makes a major contribution to irrigation.

LARGE DAMS–NUMBERS EXISTING AND UNDER CONSTRUCTION

(*Source:* Review of Australia's Water Resources, 1975)

Drainage division(a)	*Total number*	*Main purpose*				*Total capacity*	*Regulated discharge*
		Irrigation	*Hydro-electricity*	*Water supply*	*Flood control, recreation*		
						mil. cu. m	mil. cu. m.
I North-East Coast	33	12	1	20	–	4,100	1,300
II South-East Coast	99	5	5	87	2	10,700	2,700
III Tasmania	43	1	31	11	–	19,500	8,700
IV Murray-Darling	104	34	15	53	2	20,700	10,500
V South Australian Gulf	24	–	–	23	1	240	150
VI South-West Coast	24	8	–	15	1	870	360
VII Indian Ocean	1	–	–	1	–	(*b*)	(*b*)
VIII Timor Sea	8	5	–	3	–	6,100	1,900
IX Gulf of Carpentaria	4	–	–	4	–	140	10
X Lake Eyre	2	1	–	1	–	(*b*)	(*b*)
Australia	**342**	**66**	**52**	**218**	**6**	**62,350**	**25,620**

(*a*) Divisions XI and XII are not represented. (*b*) negligible.

NOTE: 1. Although most dams are used for water supply, the greatest volume of water is reserved for irrigation.
2. 'Total capacity' of storages is not the same as 'gross capacity' which includes an estimate for water below the operational outlet of the reservoir.

Water quality

Quality of water may be highly variable over time. Runoff resulting from rainfall may pick up a whole range of contaminants in passing over and through the soil; evaporation results in the concentration of these dissolved solids while, on the other hand, storm waters can dilute the concentration of pollutants. Water quality, while being generally related to the quantity of flow, may vary with the depth and breadth of a body of water.

In the long term, land use changes generally affect the quality of groundwater where runoff enters aquifers. For example, the replacement of deep rooted trees in the south-west of Western Australia by shallow rooted grasses for agriculture has disturbed the natural water and salt balance, increasing stream salinity. About four million hectares of land have been rendered sterile and difficult to till.

Although some Australian rivers are naturally saline, the quality of surface water is generally good. However, most types of water pollution experienced in advanced industrial countries also occur in Australia. The main problems relate to sewerage, industrial effluents and increasing salinity caused by agricultural activities. In some parts of Australia untreated or inadequately-treated sewage and trade effluents are discharged into inland and coastal streams used for town water supplies. Mining activities cause pollution by the discharge of ore-processing wastes or mine water into streams or by leaching from waste dumps as in the Molonglo River in New South Wales where zinc is leached from tailings and slime dumps at Captains Flat. Remedial work at Captains Flat is currently being undertaken to prevent further erosion and leaching of the waste dumps, and to minimise the flow of mine water discharging through springs into the Molonglo River.

The increasing salinity of the Murray River in recent years is a source of concern as the river is vital for irrigation and domestic water and provides much of Adelaide's water supply. The problem is the increasing salinity of water discharged from irrigation areas, compounded by concentration through evaporation. This is in addition to the river's quite high natural salt load. As the sedimentary beds of the river basin were laid down under a marine environment, the groundwater is saline and, when drainage does return to the river, it carries large amounts of salt. Salinity levels in the river, however, vary seasonally. During the irrigation season and drought periods and following prolonged floods, the concentration of salts may increase significantly, approaching the salt tolerance limits of many crops. Citrus growers in some areas have had to install under-tree sprinkler systems to prevent defoliation of trees caused by saline water from overhead sprinklers. Present control measures include the provision of evaporation basins for the disposal of highly saline drainage water and the regulation of river flow to control water quality by dilution.

Water quality is an important factor in determining the potential use of a particular water resource. Its management is essentially aimed at maintaining each resource in a condition suitable for the beneficial use or uses considered appropriate by the community.

Water management

Australia's attitudes to water resources management have changed substantially over the last twenty years. Water management is no longer seen just in terms of storing water and regulating streams for consumptive use, but also in terms of conserving unregulated streams in an unmodified landscape for wild life preservation or recreation purposes or for possible social or economic use by future generations. In addition, agricultural, industrial and urban development has led to greater attention being paid to water quality management. Increasingly, these changing attitudes have led to the perception that water and other resources need to be managed as an integral part of national and regional planning in relation to social, ecological and economic goals.

In October 1975, the Australian and State governments adopted a policy setting out the basic principles and goals underlying the approach to the development and management of water resources in Australia. This policy states that the conservation and management of water resources must take place in the broad framework not only of development and management of resources generally, but also of overall economic, environmental and social planning. A balanced approach to water resources management would include the following desirable goals:

(*a*) the provision of water supplies, adequate in quantity and quality—
  (i) to meet the needs of people throughout Australia;
  (ii) to meet the needs of, or to stimulate, primary and secondary industry in such a way as to be compatible with both projected market outlooks for the commodities concerned, and the resources and characteristics of the region concerned;

(*b*) the development and management of water resources so that, where practicable and desirable, other purposes such as flood mitigation, power generation, recreation and wildlife conservation are achieved in parallel with the purposes referred to above;

(*c*) the development of waste water treatment facilities in conjunction with water supply systems and the encouragement of recycling and re-use where appropriate;

(*d*) the adoption of water pricing policies which enable water needs to be met at a fair and reasonable price, but which provide an incentive to all water users to avoid wasteful and environmentally harmful practices and which encourage the efficient allocation of resources;

(*e*) the continued development of policies and practices, as far as possible consistent throughout Australia, aimed at achieving appropriate water quality objectives and the highest practicable level of pollution abatement;

(*f*) the adoption of the general principle that direct costs, or costs related to loss of amenity attributable to pollution, should be borne by the polluter, and that, although the immediate and full implementation of this principle may not be feasible, it is none-the-less a goal to be pursued;

(*g*) the zoning of flood-prone land with a view to its orderly management;

(*h*) the maintenance of an adequate sample of undisturbed aquatic environments as reference areas and the preservation of appropriate wetlands for the benefit of native wildlife;

(*i*) implementation of a program of public education aimed at ensuring a proper understanding of the factors affecting the development and use of water resources and a sense of responsibility in these matters;

(*j*) the encouragement of an active interest and involvement of the community in the planning and management of water resources.

Australia's water resources are managed by about 800 irrigation authorities, metropolitan water boards, local government councils and private individuals. State authorities dominate the assessment and control of water resources as, under the Commonwealth Constitution, primary responsibility for management of water rests with the individual State governments. The Commonwealth Government is responsible for matters relating to its Territories, and participates indirectly through financial assistance or directly in the co-ordination or operation of interstate projects through bodies such as the River Murray Commission. In other instances where political boundaries intersect some river basins, co-operation between governments has been necessary to develop resources.

The maintenance of both quantity and quality of water and the ecological balance of the environment in general are essential to the proper management of water resources. Misuse of water results in erosion, flooding, siltation and pollution and, conversely, poor land management practices can interfere with catchment efficiency through overstocking, bushfires and the destruction of vegetation cover. All States and the Commonwealth Government have initiated forestry policies which provide for reafforestation and the preservation of catchments. There is a more unified approach to catchment, water, forestry and land use factors, which are now regarded as part of a single problem.

Research and continuing assessment of water resources

Australian Water Resources Council

A widening awareness of the need for a co-ordinated Australian approach to water utilisation led to the formation in 1962 of the Australian Water Resources Council by joint action of the Commonwealth and State governments. The Council comprises the Commonwealth and State Ministers primarily responsible for water resources, with the Commonwealth Minister for National Development as Chairman, and is serviced by a Standing Committee consisting mainly of the heads of Departments responsible to these Ministers, and by three permanent technical committees with a number of supporting groups.

The primary objective of the council is the provision of a continuing comprehensive assessment of Australia's water resources, and the extension of measurement and research to provide a sound basis for the planning of future development. In terms of its objectives and functions, the council has dealt with a wide range of topics, making recommendations and stimulating action by appropriate bodies.

See Year Book No. 61, page 869 for further details on the work of the AWRC.

Water resources research

Comprehensive programs of research and investigation are being pursued by State water and agricultural authorities, the Commonwealth Scientific and Industrial Research Organization and the Australian Water Resources Council, often in collaboration. Special attention is being given to the following: high water tables due to the application of water; surface accumulation of salt and other soil changes associated with irrigation; methods of applying water efficiently; soil treatments to improve the physical condition of irrigated heavy clay soils; the utilisation of irrigated pasture by stock; and growth problems affecting plants and trees and reduction of salinity in river systems.

See Year Book No. 61, pages 863–4 for additional data on research activities in Australia.

International aspects

International water organisations

Australia liaises with international bodies and United Nations agencies concerned with water resources and participates in their activities in various ways.

Organisation for Economic Co-operation and Development (OECD). Australia's membership of the OECD since 1970 has involved participation in the work of the Water Management Group which investigates and rationalises problems which are the subject of international concern, and develops strategies—economic, legal and technical—which might resolve them.

United Nations Educational, Scientific and Cultural Organization (UNESCO). The International Hydrological Decade (IHD) (1965–1974) was a period in which participating countries implemented an international program designed to advance the science and practice of hydrology. Following the conclusion of the IHD, an International Hydrology Program (IHP) was commenced and an Australian UNESCO Committee for the IHP (AUCIHP) was formed to co-ordinate Australian input to the IHP.

World Meteorological Organization (WMO). A Commission on Hydrology has recently strengthened its role in operational hydrology. There is an advisory Committee on Operational Hydrology on which Australia and the Philippines are represented on behalf of the WMO Regional Association V (S.E. Asia). In Australia, hydrological activities and meteorological activities relative to water resources are co-ordinated by the Australian Water Resources Council.

Economic and Social Commission for Asia and the Pacific (ESCAP). This Commission, through its committee on Natural Resources, reports on water policy issues in addition to other activities. By participation in this conference and in seminars arranged on selected topics, Australia contributes to, and benefits from, identification of the main problems of water resources management in a densely populated, developing region.

United Nations Environment Program (UNEP). Australia participates in a world registry of major rivers covering discharge and pollutants and of clean rivers so defined and in the development of methodology for analysis and planning of water resources management.

International Commission on Irrigation and Drainage (ICID). Set up in India in 1950, this Commission promotes the development and application of the science and technique of irrigation, drainage and flood control in their engineering, economic and social aspects. Australia has been a member of ICID since 1952.

United Nations World Water Conference. A Water Conference, addressed to policy-making, was held in Argentina in March 1977.

The AWRC and AUCIHP function as the Australian National Committee.

National and interstate schemes

In the section on *Water Management* above, reference was made to the responsibilities of government on the national, state and local authority levels. In this section, some additional details are provided on their roles in the management of water resources.

The Murray-Darling Drainage Division's surface water resources are the most highly developed in Australia, with 91 per cent of the possible exploitable yield currently committed for use. The Division contains the continent's largest river system which can be divided into three main groups of rivers:

(*a*) the Darling River and its tributaries;
(*b*) the Murrumbidgee River and its tributaries; and
(*c*) the Murray River and its tributaries upstream from the confluence of the Murrumbidgee and the Murray.

The river basins that comprise the area under the control of the River Murray Commission are the nine basins in group (*c*) above and the three basins adjacent to the lower reaches of the Murray.

River Murray Commission

The Commission was established in 1915 to regulate the river for the three States concerned—New South Wales, Victoria and South Australia. Year Books prior to No. 39 contain brief summaries of the historical events leading to the Agreement of 1915 which provided for a minimum quantity of water to pass to South Australia. Further details on the River Murray Waters Agreement and subsequent amendments may be found in Year Book No. 61, pages 870–2.

Until the completion of the Dartmouth Dam—Australia's highest—in 1977, the key storage regulating the flow of the river was the Hume Reservoir. A series of regulating weirs to feed irrigation areas in New South Wales and Victoria also reduced losses from the river. An amendment to the Agreement to provide for the construction of a large storage at Chowilla was ratified in 1964, but for various reasons, including costs and water quality in the Lower Murray, this was deferred. An investigation of alternative sites led eventually to the completion of the Dartmouth Dam, constructed for the Commission by the State Rivers and Water Supply Commission of Victoria and funded by the four governments. The Dartmouth Dam will complement the Hume Reservoir to increase the total supply. When it is filled, the minimum share of water for South Australia will be increased.

New South Wales–Queensland Border Rivers Agreement

This agreement came into effect in July 1947 and provided for the construction of a dam and several weirs on the rivers that constitute part of the boundary between the two States. Unfavourable foundation conditions were encountered at several dam sites before a suitable site for the Glenlyon Dam on Pike Creek was eventually found. The dam was completed by 1977. The two States also considered proposals for the Balonne–Culgoa River System and by 1974 four regulating structures had been completed.

Snowy Mountains Hydro-electric Scheme

This scheme was set up in 1949 by the *Snowy Mountains Hydro-electric Power Act*. Its prime purpose was to generate large quantities of peak load power and, by diverting the southern-flowing Snowy River through trans-mountain tunnels, to augment the flow of the Murray and Murrumbidgee Rivers to permit continuing expansion of irrigation in the fertile river plains. All storage works are now completed.

Details of the diversions and associated power works, together with details of construction, are given in Chapter 18, Electric Power.

States and Territories

The foregoing text deals with water conservation and irrigation in Australia generally and with international, national and interstate aspects. The following survey covers the local pattern of water resources and the steps taken by the State Governments to bring about their development. In the various States, water policies tend to assume a distinctive and characteristic pattern closely allied with climatic conditions and specific local needs.

In Victoria, almost every form of water scheme is in operation. In New South Wales, major emphasis at present is on irrigation and stock development in the dry areas along the Murray and Murrumbidgee Rivers, though a substantial scheme of intensive irrigation is being conducted in the Murrumbidgee Irrigation Area. In Queensland, up to the present, the predominant emphasis has fallen on water (mainly underground sources) for stock and the development of small irrigation schemes in sub-humid and humid areas, principally to stabilise production of such crops as tobacco, sugar, cotton and pastures. Apart from regular irrigation practices along the Murray River, South Australian

authorities are vitally concerned with reticulated supplies for rural areas and towns. Western Australia has developed unique rock catchments and piped supplies for agricultural areas and towns in dry districts. Tasmanian interest relates almost exclusively to hydro-electric generation. The Northern Territory is concerned primarily with water supplies for population centres and mining and pastoral industries.

New South Wales

Administration

The Water Resources Commission of New South Wales (formed in April 1976 by a reconstitution of the Water Conservation and Irrigation Commission) consists of three commissioners appointed by the Governor. The operations of the Commission cover water conservation, control of irrigation areas, the establishment, operation and maintenance of works for domestic and stock water supply, irrigation districts, flood control districts, sub-soil drainage districts, constitution of water trusts, the issue of licences for private irrigation, artesian and shallow boring, assistance under the provisions of the farm water supplies scheme, and river improvement works. An important function of the Commission is planning for the co-ordinated development and allocation of the State's water resources. This entails the assessment and projection of demand for all purposes and also involves the quantitative and qualitative assessment of the available resources. Another important planning function relates to flood plain management. The *Water Resources Commission Act*, 1976, has widened the initiatives which the Commission is able to take in the fields of flood plain management and flood mitigation management. The search for, and surveillance of, groundwater for water supply is another important planning activity.

Under the *Water Act*, 1912–1955 the right to the use and flow, and the control of water in all rivers and lakes which flow through, or past, or are situated within, the land of two or more occupiers, is vested in the Commission for the benefit of the Crown. A system of licences operates for the protection of private works of water conservation, irrigation, water supply, drainage and prevention of inundation.

For particulars of the New South Wales–Queensland Border Rivers Agreement ratified by Acts of both States in 1947, *see* page 342 of this chapter.

Schemes summarised

The bulk of irrigated land is along the Murray and its tributary, the Murrumbidgee. Smaller areas are served by the Wyangala Dam, Lake Cargelligo and Lake Brewster on the Lachlan (a tributary of the Murrumbidgee), by Glenbawn Dam on the Hunter River, by Keepit Dam on the Namoi River, by Burrendong Dam on the Macquarie River, by the Menindee Lakes Storage on the Darling River and by Copeton Dam on the Gwydir River. None of the other rivers is regulated by large head storages, though weirs and dams have been provided for town supplies, etc. in many places. In addition substantial use is made of artesian and sub-artesian water in pastoral areas.

New South Wales legislation provides for the constitution and control of various schemes having different characteristics and including irrigation areas, irrigation districts, water trust districts, flood control and irrigation districts, and river improvement districts. There are nine irrigation areas, although two of these, Yanco and Mirrool, are generally described under the one heading, namely, the Murrumbidgee Irrigation Area. Others are: Coomealla, Curlwaa, Hay, Tullakool, Buronga, Mallee Cliffs and Coleambally.

A detailed description of the Murrumbidgee Irrigation Area is contained in Year Book No. 61, pages 875–7. The Water Resources Commission controls land transactions and water supplies for the MIA, but has no jurisdiction over land transactions in neighbouring irrigation districts (although it is responsible for the operation and maintenance of the water supply in these areas). The other irrigation areas follow the same administrative pattern as the MIA.

Irrigation districts are set up under the *Water Act*, 1912–1955 for (*a*) domestic and stock water supply and (*b*) irrigation. The essential difference between an 'Area' and a 'District' is that, in the case of the former, all the land to be included in the area is acquired by the Crown and then subdivided into such number of separate holdings as may be determined. Within the District, however, existing ownership of land is not disturbed other than to acquire land required for water distribution works. Since the completion of the Hume Reservoir, several such districts have been established along the Murray to utilise the New South Wales share of the Storage. The schemes are based on 'extensive' irrigation, that is, water rights are allotted to holdings on the basis that only a portion of each holding will be irrigated, but additional water, when available, may be obtained by landholders. 'Water right' is the annual quantity that will cover 1 hectare to a depth of 100 mm.

The *Irrigation Act*, 1912–1966 provides for the constitution of Trust Districts for domestic and stock water and irrigation, and empowers the Commission to construct, acquire or utilise necessary works. When the works are completed, they are handed over to trustees to administer. The trustees are elected by the occupiers of the land and act with a representative of the Commission. They are empowered to levy and collect rates covering the cost of the works repayable to the Crown by instalments and also the cost of operation and maintenance of the works. The rates are struck according to the area of land which benefits.

Irrigation Trusts are established under the same Act and are administered by trustees in a similar way. There are seven of these trusts.

The Lowbidgee Flood Control and Irrigation District, the first of its kind, was constituted in 1945. Its purpose is to provide flood irrigation for pasture lands on the lower Murrumbidgee by water diverted from the Maude and Redbank Weirs. Another district, Medgun, near Moree in the north-west, is also in operation.

Future program

The program of development in hand includes the provision of additional dams, storages, weirs, flood mitigation and drainage schemes and stream clearing works. Copeton Dam on the Gwydir River and Brogo Dam on the Brogo River were completed in 1976, Chaffey Dam on the Peel River, Windamere Dam on the Cudgegong River, Cudal Dam on Boree Creek and Split Rock Dam on the Manilla River have either been commenced or authorised for early construction. An ongoing program of investigations is being carried out to identify desirable additional projects which should be considered for implementation as funds become available. Increasing attention is being given to efficiency of water use and to economic, social and environmental factors in water management policies.

Victoria

Administration

Victorian Governments have been active in the development of country water supplies since the 1860's when major works to supply the Bendigo goldfields were undertaken. Local trusts to construct and operate waterworks under Government supervision were provided for in the *Water Conservation Act* 1881. Development under the trust system was greatly stimulated by the *Irrigation Act* 1886, which provided for the construction of national headworks by the State, and vested in the Crown the right to the use and control of all surface waters. By 1900 there were 33 irrigation trusts and 18 other rural water supply trusts, but the system of local control was then breaking down under financial difficulties.

The *Water Act* 1905 established the State Rivers and Water Supply Commission to take over the Irrigation Trust districts (except the still-existing First Mildura Irrigation Trust) and to exercise the State's functions in the further control and development of surface waters outside the metropolis. The Commission now supervises all private diversions from streams and directly administers irrigation districts, rural waterworks and urban districts, flood protection districts and urban water supplies. It also supervises the activities of local urban water supply authorities, and local sewerage, river improvement and drainage authorities.

Works summarised

The State Rivers and Water Supply Commission's storages are augmented by Victoria's half share in River Murray Commission storages. Most of the water is for irrigation. However, about one quarter of irrigation production is from lands irrigated by 'private diverters', i.e., irrigators who are authorised to take water from streams, lakes, etc., but who do not come within the boundaries of an irrigation district.

Rural water supply systems

The principal irrigation systems in Victoria are:

- *Goulburn–Campaspe–Loddon.* The main storage is Lake Eildon with a capacity of 3,392 million cubic metres. The main products in these systems are dairy products, fruit, wool and fat lambs. Annual production of deciduous canning fruits in the eastern part of the system is about two-thirds of Australia's total.
- *Murray River System.* The Murray Valley Irrigation Area and the Torrumbarry Irrigation System are irrigated by water diverted at the Yarrawonga and Torrumbarry Weirs respectively. These areas are devoted mainly to dairying, fat lambs and canning fruit (Murray Valley) and dairying, fat lambs, vineyards, orchards and market gardens (Swan Hill). Downstream from Swan Hill, the Mildura Irrigation Trust and four Commission Districts are supplied by pumping and produce mainly dried vine fruit, citrus fruits, and table and wine grapes.

- *Southern Systems.* The Maffra-Sale-Central Gippsland district, supplied from the Macalister River and regulated by Lake Glenmaggie, is devoted mainly to dairying.
- *Werribee and Bacchus Marsh.* These Districts produce fresh fruit, vegetables and dairy products mainly for the local domestic market. Irrigation is supplied from the Werribee River system which is regulated by three main storages, viz. Pykes Creek and Melton Reservoir and Lake Merrimu.
- *Wimmera-Mallee Domestic and Stock Supply System.* Storages in the Grampian Ranges ensure farm water supplies over the riverless pastoral and cereal lands to the Murray. Without this supply, occupation of the region would be extremely hazardous. There are small areas of irrigation supplied from this system near Horsham and Murtoa.

Future Programs

The Victorian Water Commission's current Six-Year program of capital works for the period 1978-79 to 1983-84 reflects the continuing change in emphasis towards increasing expenditure on urban water supply, sewerage, environment protection and water quality. The basic principles that have been adopted were that the environmental impact of new projects should be taken into account with emphasis on multi-objective planning and that each project should be economically sound and viable.

Major provisions in the program include—

- the commencement of four major water conservation dams for urban, industrial and irrigation supply;
- the construction of large trunk pipelines to augment supply to and to enhance the operating capabilities of the Mornington Peninsula water supply system;
- the continuance of groundwater control programs in the Shepparton Region;
- the commencement of salinity control works in the Sunraysia and Kerang Regions;
- the continuance of surface drainage programs in the Northern Irrigation Districts

The program requires an allocation of $351 million (at December 1977 prices) over the program period, subject to the availability of funds..

Queensland

Administration

The important primary industries of Queensland are subject to relatively frequent and serious losses by either drought or extensive flooding.

The right to the use and flow and to the control of water in watercourses, lakes, springs and artesian wells is vested in the Crown, and the Commissioner of Irrigation and Water Supply is authorised to take measures to conserve water and provide for its more equal distribution and beneficial use. Under the *Land and Water Resources Development Acts* 1943 to 1946, he is required to (*a*) prepare a complete description of the natural water resources of the State, both surface and underground, (*b*) undertake and carry out a survey of such resources, and (*c*) keep a record of all such natural, surface and underground water resources. As required under the *Water Act* 1926-76, rights to underground and surface water are allocated and their use is controlled by a system of licensing of all artesian bores and sub-artesian bores in areas proclaimed by the Governor in Council and all conservation and use (other that for stock and domestic supplies) of flow in watercourses. The Commission is required to control use to share supplies as equitably as possible in periods of shortage of supply.

The Commissioner is required to prepare a co-ordinated program of work for the conservation, utilisation and distribution of water resources, and to make recommendations to the Government regarding the carrying out of works in this program. He is principally responsible for water conservation and supply works for rural purposes, including irrigation, stock and domestic supply. In planning such storages, economies to all users are accrued by providing, where possible, for dual or multi-purpose use of works for irrigation, rural, urban and industrial uses including power generation and mining purposes.

Summary of schemes

Unlike other States, the greater part of the area irrigated in Queensland is by individual private pumping plants draining supply from streams or underground sources, spread widely through the State, rather than in constituted irrigation areas where supply is provided by channel systems delivering water to farms. Because of the predominance of irrigation by private diversion pumping, most of the storages are used to release water downstream to maintain supplies for such purposes.

SOURCES OF IRRIGATION WATER, 1976-77

Source of supply	*Area irrigated*	*Percentage of total area irrigated*
	('000 hectares)	%
Underground supplies(*a*)	113.6	54
Surface supplies–		
State irrigation schemes	32.1	22
Rivers, creeks, lakes etc.(*b*)	47.1	15
Farm dams	16.7	8
Total	*95.9*	*46*
Town or country reticulated water supply	0.1	..
Total, all sources	**209.6**	**100**

(*a*) Naturally or artifically replenished. (*b*) Includes regulated and unregulated streams.

Irrigation areas

About 22 per cent of the area under irrigation is concentrated in the six established Irrigation Areas constituted under the *Irrigation Act* 1922–1974, where the supply is generally reticulated by channel systems (by means of gravity or by pumping) from the storage. In addition, some supply is also provided from streams regulated by the storage. A summary is set out below; further details are shown on page 883 of Year Book No. 61.

Irrigation areas	*Comments*
Dawson Valley	Around Theodore on Dawson River; cotton, graincrops and urban usage in Theodore and Moura.
Burdekin River	Complex system of conservation, irrigation, industrial and other uses; sugar cane, rice and seed crops; artificial recharging of underground water supplies from unregulated flows (Burdekin River)
Mareebah-Dimbulah	Hinterland of Cairns; tobacco and urban/hydro-electric uses.
St George	Balonne River; cotton, soya beans and cereals, and urban uses.
Emerald	Joint Federal-State undertaking based on State's largest storage–Fairbairn Dam; industrial and urban use, irrigation, cotton, soya beans and cereals.
Bundaberg Scheme	Joint Federal-State undertaking; sugar and urban supplies for Bundaberg.
Eton Scheme	Hinterland of Mackay; sugar cane and water supply in Mackay area.

A number of other schemes have been established under the *Water Act* 1926–1976, where water from storage is released downstream to maintain adequate supplies for pumping under licence to adjacent lands. Details on these and others currently under construction are in Year Book No. 61, pages 883–4.

Rural, stock and domestic supplies

Improvements to stock and domestic water supplies are assisted by Rural Water Supply Schemes and Bore Water Supply Areas (constituted under the *Water Act*). Investigation, design and administration of these schemes are carried out by the Irrigation and Water Supply Commission.

Underground water supplies

The availability of underground water, particularly the Great Artesian Basin, has played a major part in the development of the pastoral industry in Queensland. Underground water is also used extensively for irrigation on individual farms, particularly along the coastal fringe, and for domestic purposes. Over half the area irrigated in Queensland receives its supplies from underground sources. In accordance with the requirements of the *Land and Water Resources Development Act* 1943 to 1946, the investigation of availability of underground water is being pursued by geological mapping, investigation drilling and hydro-geological assessment. The most important areas where water from this source is used for irrigation are the Burdekin Delta, Condamine Valley, Bundaberg, Lockyer Valley, Callide Valley and Pioneer Valley. The table on page 336 of this chapter provides the quantity and purpose of groundwater usage in these areas.

South Australia

Administration

All major water resources and most public water supply schemes in South Australia are administered by the Engineering and Water Supply Department under the various statutes mentioned below.

- The *Waterworks Act*, 1932–1977, which empowers the Minister of Works to impound or divert the water from any lake, watercourse or underground source for the purpose of establishing and maintaining public water supply schemes to serve proclaimed water districts throughout the State.
- The *Water Conservation Act*, 1936–1972, which relates to the provision of small dams, wells, bores and other waterworks to assist development in the more remote areas of the State or to provide water for travellers and travelling stock in such areas.
- The *River Murray Waters Act* 1935–1971, which ratifies the River Murray Waters Agreement, and under which the Engineering and Water Supply Department operates and maintains Lake Victoria storage, nine weirs and locks downstream of Wentworth, N.S.W., and barrages at the river mouth.
- The *Water Resources Act* 1976, which came into force from 1 July, 1976 and superseded the *Control of Waters Act* 1919 and the *Underground Waters Preservation Act* 1969, represents the culmination of the Government's water resources policy involving the management of all aspects of water—surface and underground, quality and quantity. The Act provides for the control or diversion of surface waters from Proclaimed Watercourses and for the control of the withdrawal of underground waters from Proclaimed Regions. At the time of commencement of the Act, the River Murray was the only Proclaimed Watercourse, the Proclaimed Regions being the Northern Adelaide Plains and Padthaway. The legislation provides for control over the construction or modification of most categories of wells over the whole State and for the abatement of pollution of all waters. It establishes a South Australian Water Resources Council and Regional Advisory Committees as vehicles for public involvement in the water resources management process. At the time of commencement of the Act, Regional Committees operated in respect of the River Murray, the Northern Adelaide Plains, Padthaway and the Arid Areas. In addition, the Act provides for a Water Resources Appeal Tribunal to give individuals the opportunity to appeal against decisions of the Minister pursuant to the Act.

Summary of schemes

Australian irrigation originated in the upper Murray in South Australia and the Mildura area of Victoria. South Australian irrigation commenced with an agreement involving the Chaffey brothers in 1887 whereby an area was made available for the establishment of certain irrigation works at Renmark. From this start, government, co-operative and private irrigation areas totalling more than 42,000 hectares have been developed in the South Australian section of the Murray Valley. The major authority controlling River Murray irrigation is the Engineering and Water Supply Department which administers government controlled areas. The principal high land crops comprise citrus and stone fruits, and vines. The reclaimed swamps along the lower section of the Murray are used almost exclusively for pasture and fodder crops. Vegetable crops of various kinds are important in both types of irrigated lands.

Except for quantities held in various lock pools and natural lakes, no water from the Murray is stored within South Australia for irrigation purposes. Usage of the River is therefore planned on the basis of the minimum monthly flows to which South Australia is entitled under the River Murray Waters Agreement. This factor, plus the need to reserve water for city, town and rural water supply systems, has resulted in the expansion of irrigation from the River being rigidly controlled by the Government. In addition to irrigation from the River Murray there are considerable areas irrigated from underground sources by individual landholders in South Australia. The most important of these areas are the North Adelaide Plains (market gardens) and the Padthaway district of the south-eastern region (pastures, fodder, seed crops and vines).

Adelaide Metropolitan Water Supply

About 30 per cent of Adelaide's normal water supply needs are currently piped from the River Murray, with the percentage rising with urban and industrial development. The principal sources of supply for the ten reservoirs in the Mount Lofty Ranges are the Rivers Torrens, Onkaparinga, South Para and Myponga.

Country reticulation supplies

A number of reservoirs in the Barossa Ranges and other local sources are augmented by the Morgan-Whyalla, Swan Reach-Stockwell and Tailem Bend-Keith pipelines which provide River Murray water to extensive country areas. A network of branch mains provides the means of conveying water to numerous towns and large areas of farmlands.

Surface and underground resources have been developed to supply most country centres not covered by the larger schemes. Victor Harbor and adjoining south coast resort centres are supplied from reservoirs and the River Murray. A reservoir on Kangaroo Island supplies Kingscote and adjacent farmlands. Underground resources of the lower south-east supply all towns in the region, the city of Mount Gambier and nearby farmlands being reticulated from the well-known Blue Lake. At the far northern opal mining town of Coober Pedy a reverse osmosis desalination plant provides a potable supply from brackish groundwater. Other centres in the far north obtain supplies from the Great Artesian Basin. For details on underground water resources in South Australia see Year Book No. 55 and earlier years.

South-eastern drainage

A section of the South-East Coast Drainage Division extends into South Australia but has no co-ordinated drainage pattern to form a significant surface water resource. However, high rainfall in the area is related to underground resources. Surplus water is not easily disposed of in the valleys and low range terrain, and drainage systems have been undertaken by the Government in co-operation with landholders. For further details see Year Book No. 61, pages 888–9.

Murray River Irrigation Areas

Where irrigation water in excess of plant requirements has been applied, perched water tables develop. Rising to the level of tree roots, these cause the death of orchards from salination and waterlogging. Most orchards and vineyards are now drained by plastic and tile drainage systems, thus restoring their health and productivity. At present, disposal of drainage water is achieved by pumping to basins on river flats where it evaporates or is discharged into the river when it is in flood. It may also be discharged into underlying sand and limestone aquifers. The usefulness of these aquifers is declining as they are becoming fully charged with water.

Investigations are being made, in the light of the new *Water Resources Act,* into alternative disposal schemes to provide added protection to both the river and the associated underground aquifers.

Western Australia

Administration

The Minister for Water Supply, Sewerage and Drainage administers the departmental irrigation schemes under the *Rights in Water and Irrigation Act,* 1914–1971. He is advised by an Irrigation Commission representing the local irrigationists and government, technical and financial branches. He also administers, under the *Country Areas Water Supply Act,* 1947–1964, the water supplies to certain country towns and reticulated farmland. As Minister for Works he controls minor non-revenue producing supplies to stock routes and a few mines and agricultural areas with their associated communities. A small number of town supplies are administered by local boards under the *Water Boards Act,* 1904–1969, which provides a large degree of autonomy with ultimate Ministerial control.

Irrigation

Irrigation schemes have been established by the Government on the coastal plain south of Perth in the Waroona, Harvey and Collie River and Preston Valley Irrigation Districts between Waroona and Donnybrook, the water being channelled from dams in the adjacent Darling Range. The success of dairying and stock raising and, to a lesser extent, vegetable growing, which have replaced citrus growing, has led to a gradual but substantial extension of irrigation areas in the south-west.

Although not yet comparable in size with the south-west irrigation districts, the irrigation areas at Carnarvon and on the Ord and Fitzroy Rivers in the Timor Sea Drainage Division in the north of the State are of increasing significance.

Since the mid 1930s, a centre of tropical agriculture has been developed at Carnarvon, near the mouth of the Gascoyne River. Private pumping from sands of the Gascoyne River is the principal source of irrigation water for the 167 plantations. Because of the high risk of drawing in surrounding saline ground waters by over-pumping, the usage of water by the planters is controlled strictly by the Government. The Government is developing up-river sources and delivers water by pipeline to 109 plantations in the district. Bananas for the Perth market and fruit and vegetables for the Perth and Adelaide markets are the principal crops. A tropical research station is maintained at Carnarvon by the Department of Agriculture.

The Ord River Irrigation Project in the Kimberley Division provides for the eventual development of an irrigation area of 72,000 hectares of land, one third of which is in the Northern Territory. The first stage, in which water was supplied from the Kununurra Diversion Dam (capacity 98.7 mil. cubic metres) to 30 farms averaging 270 hectares plus a 970 hectare pilot farm was completed in 1965. Cotton was the principal crop, with grain sorghum and fodders for cattle fattening also important. Completion in 1971 of the Ord River Dam, which stores 5,720 mil. cubic metres in Lake Argyle,

has allowed expansion of the area to be irrigated into the second stage. Five farms averaging 388 hectares were allocated in 1973. Since then, cotton has been phased out due to high off-farm costs and increasing costs of insect control specific to the cotton industry. A downturn in the Australian beef industry coincided with this and farming activity was reduced. Rice and peanuts are now showing promise commercially.

The Camballin Irrigation District on the Fitzroy River flood plain in the West Kimberleys is dependent on diverted river flows and a small volume of storage behind the diversion structures on the Fitzroy River and Uralla Creek. Grain and fodder sorghums are the main crops.

Country water supplies controlled by Department of Public Works

Since 1947 enlargement and extensions of the Goldfields and Agricultural Water Supply and the development of the Great Southern Towns Water Supply have been carried out, mainly in accordance with a project known as the Modified Comprehensive Scheme. Under this scheme water has been supplied to towns and farms in the cereal and sheep districts of the State. Two years after the completion of the 1.7 million hectare scheme in 1961, an extension of 1.5 million hectares was agreed to with Federal-State funding.

Goldfields and Agricultural Water Supply

Water for the Eastern Goldfields is supplied by pipeline from Mundaring Reservoir in the Darling Range. With extension to towns and agricultural areas, the scheme now serves over 110 towns and localities and the water is being reticulated to 2.7 million hectares of farmland.

Great Southern Towns Water Supply

This scheme provides water from Wellington Dam to towns on the Great Southern Railway from Brookton to Katanning, supplying 32 towns and being reticulated to 0.6 million hectares of farmland.

Underground water

Considerable use is made of groundwater by individual farmers, pastoralists, market gardeners and others, although the water quality varies from place to place and much of it is too saline for irrigation or even stock purposes. Artesian wells throughout the State and non-artesian wells within 'declared' areas must be licensed under the *Rights in Water and Irrigation Act,* 1914–1971. Industries also use groundwater in substantial quantities, especially in the processing of titanium, iron and alumina, and this demand has intensified the search for groundwater.

Tasmania

Main purposes of water conservation and utilisation

Because of the generally more adequate rainfall in Tasmania, scarcity of water is not such a problem as it is in most mainland areas, though not all streams are permanently flowing. The only large-scale conservation by reservoirs is for hydro-electric power generation, but there are some moderately-sized dams built by mining and industrial interests and by municipal authorities for town water supplies. 'Run of the river' schemes are quite adequate for assured supply in many municipalities. The main supply for Hobart and adjacent municipalities originates from a 'run of the river' scheme based on the Derwent River. The river is controlled in its upper reaches by eight dams, built for hydro-electric power generation, and these tend to stabilise river flow.

Until a few years ago irrigated areas were negligible except for long established hop fields, but there is a rapidly expanding use of spray irrigation on orchards, pastures, potatoes and beans and peas. Until recent years there has been almost complete dependence on natural stream flows, but the need for some regulating storages has become apparent. Increasingly, farmers are constructing storages of their own and the extension of this practice is foreseen as the logical solution in most areas, as valleys are narrow and steep sided. Single large reservoirs cannot economically serve large areas of suitable land, as nearly every valley is separated from others by pronounced hills, prohibiting the construction of cross-country channels.

Underground water suitable for stock, minor irrigation works and domestic use is exploited in the consolidated rocks of southern, midlands and north-western Tasmania. In the south and midlands, nearly all groundwater is obtained from Permian and Triassic rocks. In the north-west, water is recovered from a variety of rocks ranging from Precambrian dolomites, quartzites and schists to Tertiary basalts and Quaternary sands. The highest yields are obtained from the dolomites and the basalts. In the central north and north-east, unconsolidated Tertiary clays and gravels yield water of variable quality. In some coastal areas, notably King and Flinders Islands, water is obtained from aeolian sands.

The Mines Department is charged with the investigation of underground water resources. There is a great reserve of untapped permanent streams in the western half of the State, which is largely unsettled. The State's largest rivers discharge in the west, but diversion to the eastern half of the watersheds is not regarded as practicable. The Hydro-Electric Commission, however, has planned for the future development of four storage dams in the West Coast region on the Pieman, Murchison and Mackintosh Rivers.

Administration

In Tasmania, water supply was once exclusively the responsibility of local government authorities, but three statutory authorities, the Metropolitan Water Board, the Rivers and Water Supply Commission and the North West Regional Water Supply Authority, now operate bulk supply schemes, piping water for distribution by the local government authorities in the Hobart, Launceston and N.W. Coast regions, and directly to certain industrial consumers. The Board is responsible for the supply of water in the Hobart, Clarence, Glenorchy and Kingborough local government areas, while the Commission exercises a general control over the utilisation of the State's water resources and has specific functions in relation to local government authority water, sewerage and drainage schemes. The Authority controls the supply of water to the municipalities of Latrobe, Devonport, Ulverstone, Penguin, Kentish and Wynyard.

Rivers and Water Supply Commission. The Commission is empowered by the *Water Act* 1957 to take water at streams and lakes, or to issue others with licences to do so; licensing covers supply to specific industries and municipalities as well as for irrigation. The Commission is concerned with drainage trusts' operations, river improvements (including repairs after flood damage), stream gauging, its own regional water schemes, and with water supply, sewerage and drainage of towns. It operates in a similar manner to the Metropolitan Water Board in controlling the water schemes serving the East Tamar region (North Esk Regional Water Supply), the West Tamar area (West Tamar Water Supply) and the Prosser River Scheme, which was originally constructed to supply water to a sodium alginate industry at Louisville near Orford and to supplement the water supply of the township of Orford. The sodium alginate industry ceased production in December 1973. The North Esk Regional Water Supply was constructed to meet industrial requirements of the alumina refinery and other industries at Bell Bay, and to provide bulk supplies to surrounding municipalities on the eastern bank of the River Tamar and is now being augmented by a construction of a dam on the Curries River to supply the northern end of the Tamar Valley. The West Tamar Water Supply was constructed primarily to meet domestic requirements of urban areas in the Beaconsfield municipality. The local government authorities retain primary responsibility for reticulation and sale to consumers, except to certain industrial users.

In municipalities not serviced by the Metropolitan Water Board, the Rivers and Water Supply Commission or the North West Regional Water Supply Authority, the supply of water is a function of the local municipal council. Where the construction of water and sewerage schemes is beyond the financial capacity of a local government authority, or if it requires assistance to pay for water supplied from regional schemes, the Commission may make recommendations to the Minister for payment of a subsidy.

Irrigation

The Cressy-Longford Irrigation Scheme, officially opened in March 1974, was the first major irrigation project to be established in Tasmania. The source of supply is the tailrace of the Poatina hydro-electric power station from which up to 12 million cubic metres will be available to farmers both inside and outside the irrigation district. Some 9,000 hectares, half of which are watered by gravity, will eventually be irrigated. The scheme services about sixty-five farms within the irrigation district (mostly by the spray sprinkler system), while a further thirty farms on the fringes will benefit from augmented river flows.

The Cressy-Longford Scheme which is operated by the Rivers and Water Supply Commission, and a privately owned scheme at the Lawrenny estate at Ouse, are the only extensive irrigation works in Tasmania. A large portion of the 22,305 irrigated hectares in the State in 1975–76 were watered by private schemes pumping water from natural streams. Approximately 50 per cent of the area was sown and native pastures. Vegetables occupied about 30 per cent, with potatoes responding particularly well to irrigation.

Northern Territory

Information on climatic conditions will be found in the chapter Climate of Australia. A brief outline of contour and physical characteristics is in Chapter 27, Territories of Australia.

Administration

Under the Northern Territory *Control of Waters Ordinance* 1938, control of natural waters is vested in the Crown. Where a watercourse or lake forms a boundary of any land alienated by the Crown, the beds and banks are deemed to remain the property of the Crown (except in special cases). The diversion of water is prohibited except under prescribed conditions. The Ordinance requires that drilling for groundwater be carried out only by drillers who are registered under the Ordinance. Registered drillers are required to provide the Government with information on bores drilled, including the location, depth and size of bore, strata encountered and water produced. In particular areas, described as Water Control Districts, where stricter control is necessary, the construction or use of a well or water bore without a permit can be prohibited.

Under the *Water Supplies Development Ordinance* 1960, any landholder engaged in pastoral or agricultural production may seek information or advice from the Commissioner of Water Development who is appointed under the Ordinance. He may also apply for an advance towards the cost of work proposed to be carried out. The Ordinance also provides for a refund to the landholder of the cost of drilling an unsuccessful bore where the landholder has applied to the Commissioner for advice on its construction and has carried out all drilling operations in accordance with advice given.

The Water Division of the Department of Transport and Works carries out systematic stream gauging, the collection of data relating to the quantity and quality of surface and groundwater, the planning of water use for industrial, irrigation and town water supplies, and flood prevention and control. It also provides a general advisory service to the public on water resources and water conservation by providing information on the geology of the Territory, the prospects of obtaining groundwater, the possible location of bore sites, the method of drilling and equipping bores, stream flows, surveys of dam sites, the design of water supply schemes and reticulation lay-outs, and the chemical and bacteriological quality of water supplies. It is involved in water pollution studies and control, and carries out environmental assessments of water and related developments. The Division administers both of the ordinances described.

Underground water

For information on underground water resources in the Northern Territory *see* Year Book No. 55 and earlier issues, and the Australian Water Resources Council's publication, *Groundwater Resources of Australia,* 1972 and *Review of Australia's Water Resources,* 1975.

Of approximately 11,000 bores and wells registered in the Territory up to 30 June 1978, 52 per cent were for pastoral use, 13 per cent were investigation bores, 12 per cent served town and domestic supplies, 5 per cent were for crop use, 3 per cent were used on mining fields, and the remainder for various other uses.

Community water supplies

The largest water conservation projects in the Territory are the Darwin River Dam (259.0 million cubic metres) and the Manton Dam (15.7 million cubic metres) which both serve Darwin with a reticulated water supply. Groundwater from McMinns Lagoon area can be used to augment supply.

Most other towns and communities, including Alice Springs, Tennant Creek, Katherine and Nhulunbuy, are supplied from groundwater.

Investigations are continuing into groundwater supplies for the new township to be built in the Uranium Province, aboriginal communities and irrigation supplies in the Alice Springs District.

Surface water measurement

The hydrological investigations required in the Northern Territory as part of the National Water Resources Assessment Program are being carried out by the Water Division. The program for the Northern Territory includes establishment of base streamgauging stations and pluviographs (automatic rainfall recorders). In particular areas of development where water supply or irrigation proposals require special or extra surface water data, supplementary gauging stations are built to obtain this information. Intensive studies are being undertaken in the Uranium Province and other mining areas collecting both quantitative and qualitative data for environmental and management purposes. The streamgauging network of the Division comprises gauging stations (base gauging and supplementary) and pluviographs. The Commonwealth Scientific and Industrial Research Organization also maintains streamflow and rainfall recording stations for the arid zone research project.

Irrigation for agricultural purposes in the Territory is not extensive, being confined to isolated locations near Darwin, Adelaide River, Coomalie Creek, Daly River, Katherine, Douglas River, Ti Tree and Alice Springs for the purpose of growing fruit, vegetables, fodder crops, pastures and some dairying. Some of this irrigation is carried out using bore water.

Both the Daly and Adelaide Rivers offer considerable potential for irrigation development with regulation of the rivers. Investigations have been conducted into possible dam sites and areas suitable for irrigation in these regions. There is an increasing demand for water resources assessment studies and assistance for relatively small irrigation projects.

Australian Capital Territory

The climate of the Australian Capital Territory is such that annual evaporation exceeds the annual rainfall of about 600 mm. Primary producers have therefore found it necessary to practise water conservation, and to irrigate from groundwater supplies during dry periods.

Surface water

Surface water storages supplying the Capital City (pop. about 214,000) and the city of Queanbeyan (pop. about 22,000) are located in the heavily timbered, mountainous, western part of the A.C.T. within the catchment of the Cotter River. At present three water storages—Corin Dam (75.5 mil. cubic metres), Bendora Dam (10.7 mil. cubic metres) and Cotter Dam (4.7 mil. cubic metres), serve the two cities and another storage, Googong Dam (124.5 mil. cubic metres) was recently completed on the Queanbeyan River to the east of the A.C.T. It is expected to be commissioned as an additional source of water supply early in 1979 following final commissioning of water treatment plant facilities.

Within the Molonglo–Queanbeyan River catchments, the Cotter and Queanbeyan Rivers provide approximately two-thirds of the surface water resources suitable for development for urban water supply for the A.C.T. with a potential for serving a population of approximately 400,000.

Groundwater

Groundwater in the A.C.T. and environs occurs mainly in fractures in crystalline rock such as granite and volcanic rocks; in folded and fractured slate; and rarely, in solution cavities in limestone. Alluvial aquifers of significance are restricted to the Lake George basin and small areas along mature sections of the Molonglo and Murrumbidgee Rivers. Groundwater has been used in the past by most primary producers to augment surface storage. Groundwater production bores in the A.C.T. have yields ranging between about 0.4 and 20 cubic metres per hour; 3 cubic metres per hour is about the average yield. However, many farm bores have fallen into disuse as a result of the Government's resumption of freehold land within the A.C.T., and because of the rapid expansion of urban growth. The Bureau of Mineral Resources has provided a bore-siting, groundwater-quality and yield-prediction service in the A.C.T. since the early 1950's and until 1978 maintained a network of 48 observation bores which were monitored regularly for up to 25 years. Emphasis has shifted recently from predicting groundwater levels for rural landholders, to trying to establish the groundwater resources that are available for augmenting surface water supplies for urban purposes. The Bureau assessed the feasibility of a groundwater supply for the new National Fitness Camp at Tidbinbilla and also supervised drilling and testing of production bores for the $500,000 camp. Data are now being collected on groundwater occurrences within the A.C.T. and environs for preparation by the Bureau of a 1:100,000 scale hydrogeologic map.

Many bores have been drilled in the Canberra area for determination of ground conditions for specific projects such as dam sites, sewer tunnels, deep foundations for large buildings; disposal of household and industrial wastes, including radioisotopes; monitoring hydrocarbons, pollution of groundwater or for feasibility studies for urban development. These bores are generally monitored for short periods only. Long-term monitoring of water infiltrating from refuse-disposal areas commenced in 1977.

Control of irrigation and farm water supplies is exercised by the Conservation and Agriculture Branch of the Department of the Capital Territory. The Bureau of Mineral Resources of the Department of National Development provides technical advice to landholders and drilling contractors on groundwater and, occasionally, on runoff.