CHAPTER XXV.
WATER CONSERVATION AND IRRIGATION.

A general survey of water conservation in Australia last appeared in Official Year Book No. 23.—1930 pp. 636–661. In view of the growing importance of this subject a comprehensive picture of current development is presented in the following special article which has been prepared by Mr. Ulrich Ellis, of Canberra. The co-operation of various Commonwealth and State Departments and other bodies connected with water conservation was sought and freely given, and valuable assistance was rendered by them, particularly in the direction of supplying basic information for incorporation in the article.

The statistics which in recent years have been contained in this chapter have been included in the article.

THE CONSERVATION AND USE OF WATER IN AUSTRALIA.

§ 1. Geographical and Climatic Factors.

1. **General.**—To appreciate the significance of the Australian water pattern it is necessary to relate the geographical configuration of the continent to climatic and other allied conditions. Chapter II. of this Year Book (page 27), deals with the physiography of Australia, and more detailed information is available in earlier issues. Therefore it is proposed to present in this article merely a simplified picture of the main geographical and climatic features.

2. **Topographical.**—Examining the continent from east to west, a narrow belt of coastal plain is found to extend along the eastern coast, bounded by the Great Dividing Range which extends from the far north of Queensland to the south-east of New South Wales, thence westward through Victoria. This mountain system is never more than 250 miles, and at one point only 27 miles from the coast. West of the range the country descends gradually until areas are reached, in the northern interior of South Australia, which are at or below sea level. Thence there is a gradual rise till the coastal mountains of Western Australia are reached, and the western shores are again flanked by a narrow coastal plain. The average elevation of the continent is approximately 900 feet but mountains in the Australian Alps (in the south-eastern highlands) rise to 7,300 feet. A predominant feature is the absence of high mountains over a large part of the continent.

3. **River Pattern.**—Most of the rivers are on the eastern coast, but owing to the proximity of their catchments to the sea, they are comparatively short. The longest river on the northern Coast is the Flinders (520 miles) which flows into the Gulf of Carpentaria, while the Burdekin, on the east coast of north Queensland, is 475 miles.

The Murray-Darling system drains one-seventh of the continent. The main Murray rises in the Australian Alps, and carries substantial quantities of water, especially in the winter and spring, through the semi-arid areas to the westward. Though its highland catchments experience a high average rainfall, exceeding 70 inches, and melting snows augment the streams, the volume is sometimes seriously affected by the variability of precipitation on the watersheds. Apart from the Murrumbidgee, which also rises on the southern highlands, and is snow fed, most of the other tributaries are irregular in flow, though sometimes contributing substantial quantities of flood waters. The Goulburn River in Victoria is fairly regular, and contributes large flows practically every year.

4. **Climate and Settlement.**—Australia is a continent 2,974,581 square miles in extent, in which climatic conditions range from the alpine to the tropical. Though average rainfall on the north coast of Queensland ranges up to 160 inches the annual average in a great part of the continent is less than 10 inches. It is estimated officially that 37.6 per cent. of the total area receives an average of less than 10 inches; 57.5 per cent. less than 15 inches; 68.4 per cent. less than 20 inches; 77.5 per cent. less than 25 inches; and 84.8 per cent. less than 30 inches per annum.

In terms of settlement these figures can be interpreted only if related to land use possibilities, soil conditions, incidence and variation of rainfall, temperature and evaporation, etc. For a fuller statement of climatic factors see § 2 "Climate and Meteorology of Australia" of Chapter II. of this Year Book (page 30).

A recent interpretation by Dr. A. E. V. Richardson, Chief Executive Officer of the Council for Scientific and Industrial Research, suggests these general conclusions :—

Thirty-four per cent. of the continent is of little value because the major portion of this area is true desert and uninhabitable, while the remainder is capable of carrying only sparse stock population.

Forty-two per cent. is likely to remain extensive sheep and cattle country for the most part, with only a sparse to moderate stock population.

Twenty-four per cent. receives a rainfall which is adequate for agriculture and intensive stock raising. A substantial part of this well-watered region is unsuited, however, by reason of rugged topography and barren soils, for the cultivation of crops.

Approximately one quarter of one per cent. may ultimately be regarded as suitable for irrigated culture, owing to the limited water resources of Australia.

Major population development has taken place in those areas in the east, south and south-west which have maximum water supplies derived under conditions favoring settlement; but there is ample evidence that in these and other areas possibilities exist for further expansion and population growth. Though considerable areas of Australia may be classed as dry it should be noted that most other continents face difficult settlement problems because large areas of land are too hot, too cold, too rugged, too wet, or too dry to support substantial population with reasonable living standards.

§ 2. Water Resources and their Utilization.

1. **Surface Supplies.**—Though river gaugings have been recorded over considerable periods in some parts of Australia, records elsewhere are intermittent, of short duration, or non-existent. Therefore, it is impossible at present to estimate, with any degree of reliability, the total average annual flow of Australian streams. The streams of the Murray-Darling system provide an estimated annual average of 12,000,000 acre feet from a catchment of 414,000 square miles. The average for the rivers of Northern Queensland has been computed at a figure approximately 18,000,000 acre feet. The coastal streams of northern New South Wales and southern Queensland have been assessed at about 10 or 12 million acre feet.

The extensive and reliable records of the Victorian State Rivers and Water Supply Commission estimate the aggregate flow of all rivers gauged in that State, including Murray tributaries, at 14,000,000 acre feet.

As great volumes of water do not flow through other areas, it is doubtful whether the total annual average flow of all Australian rivers would exceed 60,000,000 acre feet, a figure small in comparison with the flow of rivers in other continents.

For purposes of comparison the following estimates of mean annual discharge in other parts of the world are stated here in millions of acre feet: Nile, 72; Danube, 228; Amazon, 1,780; Volga, 148; Mississippi, 474; and the ten main rivers of the United States of America, 900 (in the aggregate).

2. **Irrigation.**—(i) *History.* The history of irrigation in Australia commenced in Victoria after the droughts of 1877 and 1881, when it became recognized that the northern plains could be developed only with water artificially supplied. Thereupon, the Government began the systematic regulation of north-flowing streams. George Chaffey and his brother (who were successful irrigationists in California) were invited to investigate the possibilities of the Murray River from Echuca to Renmark. The Chaffey brothers later established irrigation settlements at Mildura (Victoria) and Renmark (South Australia). Though their efforts were at first clouded with difficulty and misfortune, the possibilities of irrigated culture in these areas were proved beyond doubt.

The Irrigation Act passed by the Victorian Government in 1886 influenced the whole future of water development in Australia. This Act vested in the Government the right to use water in any stream, lake or swamp; provided that no riparian rights could be established which might prevent the use of water for irrigation; authorized the construction of Government works; and provided finance for irrigation trusts elected by the people to conduct local schemes. Similar legislation followed in other mainland States.

(ii) *Extent and Nature.* Fifty per cent. of Australia's irrigated acreage is now in Victoria, and about 68 per cent. is situated along the Murray and its tributaries (including the Murrumbidgee) in the three States of New South Wales, Victoria and South Australia. In these areas served by the Murray and its tributaries irrigation water is used extensively for vines, orchards, pastures, fodders, and for domestic and stock purposes.

Approximately fifty per cent. of Queensland's irrigated acreage is devoted to sugar cane. Western Australia's small irrigated acreage is confined to areas in the south-west where fodders and pastures are served. Irrigation schemes have not been developed in Tasmania or the Northern Territory.

With the expansion of markets for primary products after the 1914–18 War, the irrigated acreage has gradually extended and is now more than four times as large as in 1917. The following statistical statements illustrate the extent and nature of irrigated culture :—

IRRIGATION : AREA IRRIGATED.

Season.	N.S.W.	Victoria.	Q'land.	S. Aust.	W. Aust.	Tas.	A.C.T.	Australia
	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
1932–33 ..	*a*130,977	474,716	31,409	42,556	6,434	7,605	..	693,697
1933–34 ..	*a*131,772	435,324	29,363	42,898	7,640	9,194	..	656,191
1934–35 ..	*a*125,423	494,226	34,138	39,594	8,861	7,786	26	710,054
1935–36 ..	*a*138,016	495,835	44,283	42,672	11,396	8,987	123	741,312
1936–37 ..	*a*151,683	518,827	44,509	42,292	13,295	9,987	70	780,663
1937–38 ..	*a*170,719	590,112	49,154	44,250	14,284	8,428	6	876,953
1938–39 ..	*a*183,518	515,357	48,953	43,602	14,278	8,599	50	814,357
1939–40 ..	*d*326,875	517,903	55,153	44,470	15,443	8,656	263	968,763
1940–41 ..	*d*325,075	596,662	60,961	46,268	14,513	8,821	391	1,052,691
1941–42(*c*) ..	*d*354,762	602,074	(*b*)	45,757	15,060	6,975	48	(*b*)
1945–46 ..	*d*331,030	656,845	68,347	42,192	16,864	11,279	502	1,127,059
1946–47 ..	*d*544,775	708,590	79,030	46,145	17,947	9,326	743	1,406,556

(*a*) Excludes pasture and fallow lands. (*b*) Not available. (*c*) Details for years 1942–43 to 1944–45 are not available. (*d*) Includes pasture and fallow lands.

LAND UNDER IRRIGATED CULTURE : 1946–47.

Crop.	Area (Acres).							
	N.S.W.	Victoria.	Q'land.	S. Aust.	W. Aust.	Tas.	A.C.T.	Aust.
Cereals, Hay, etc.	140,333	135,073	15,022	1,127	..	240	486	292,281
Rice	32,096	..	..	..	..	..	..	32,096
Vegetables ..	15,884	14,594	16,441	5,527	4,308	..	147	56,901
Orchards ..	20,246	34,324	2,317	7,631	2,330	1,207	..	140,575
Vineyards ..	11,243	39,035		22,080	162	..	..	
Sugar Cane ..	..	..	40,558	..	..	..	..	40,558
Hops	..	..	..	..	..	1,153	..	1,153
Cotton ..	..	..	346	..	..	..	..	346
Other Crops ..	*ab* 58,515	(*b*) 9,138	(*c*) 3,573	468	713	535	25	72,967
Total Crops	278,317	232,164	78,257	36,833	7,513	3,135	658	636,877
Pastures ..	266,458	476,426	773	9,312	10,434	6,191	85	769,679
Total	544,775	708,590	79,030	46,145	17,947	9,326	743	1,406,556

(*a*) Includes lucerne for grazing and cutting, 27,994 acres. (*b*) Includes fallow land (*c*) Includes tobacco, 1,551 acres.

(iii) *Statistical Aspects.* It should be noted that the basis of recording statistics of water use differs in various States. Therefore, while every attempt has been made to present a uniform statistical picture, it has been difficult to ensure that statistics quoted as between States are strictly comparable in detail. Some steps have been taken by State authorities with a view to securing uniformity of statistical data, but until this objective has been achieved allowance should be made for this factor in this article.

(iv) *Irrigation Trends.* In the past, Government policy has concentrated largely on supplying cheap water to the semi-arid fringe between the ten and twenty inch rainfall isohyets. Now that the limits of water availability are more clearly known, new trends are appearing. Increased attention is being given, for example, to the improvement of irrigation techniques in established areas. Science is tending to seek maximum results from existing supplies, and it is even admitted in some areas that less water, more efficiently applied, will yield better results.

There is also a growing appreciation of the benefits and necessity of irrigation in humid and sub-humid areas with a flush annual rainfall. While the annual average might be comparatively high in such areas, the bulk of the rain may fall in a few months of the year. Consequently it is being increasingly recognized that irrigation, where possible, is an advantage to stabilize production (both as to quantity and quality) over the dry months, or to balance the varying precipitation between the good and lean years.

Similarly, irrigation is being used along the Murrumbidgee and Murray to stabilize the stock industries, especially on an "extensive" basis. Water is being provided for parts of existing holdings (say one acre in ten or more) in certain areas, thereby enabling the best portions of holdings to be devoted to irrigated pastures and fodders, thus supplementing natural rainfall and natural feed.

In line with the construction of barrages at the mouth of the Murray, consideration is being given in other parts of Australia to the provision of weirs which will prevent the entry of salt water, thereby enabling fresh water to be drawn direct from coastal streams for farm, domestic and industrial purposes, enabling the reclamation of flats and swamps now unsuitable for productive purposes owing to the presence of tidal salt, and safeguarding existing farms from periodical deluges by salt water through floods and ocean storms.

A significant trend is the growing appreciation of the benefits to be derived from the "marriage of electric power and water". Recent surveys indicate that while oil pumps and windmills are used extensively for pumping water, cheap electric power is being sought increasingly to aid pumping operations for stock, domestic and irrigation purposes. In the Inkerman-Home Hill area of North Queensland and in the Lockyer Valley in southern Queensland, electricity development policies have been specifically designed to assist and encourage irrigation. Special rates for power pumping are provided by the Clarence River County Council in northern New South Wales to permit farmers to pump water at night when normal power demands are low. This policy has had a particularly marked effect on the production of winter vegetables and tomatoes in the Coff's Harbour–Valla districts.

Finally, it can be said that an increase in the extent of spray irrigation has been recorded in recent years, aided by electric power and internal combustion engines.

(v) *Research.* Comprehensive programmes of research and investigation are being pursued by State water and agricultural authorities and the Commonwealth Scientific and Industrial Research Organization, often in collaboration. Special attention is being given to the following: High water tables due to the application of water to land where no natural drainage lines exist, or where drainage lines are too small to cope with extra water; presence of salt in semi-arid soils, resulting in surface accumulation; salinity of water, which makes it unsuitable for human beings, stock and plant life; adverse reactions of semi-arid soil types to increasing quantities of water which affect the sub-soil; increasing density of stock on irrigated pastures which leads to the spread of such diseases as foot rot and fluke in sheep, and mastitis and contagious abortion in cattle; and growth problems affecting plants and trees.

The Commonwealth Scientific and Industrial Research Organization maintains the following research stations :—Merbein (Victoria), horticultural problems, mainly vines, soils, watering and diseases ; Griffith (New South Wales), mainly citrus and vegetable problems ; Deniliquin (New South Wales), pastures ; Werribee (Victoria), stock diseases. These stations are in close contact with the settlers. Merbein Station was originally financed partly by the settlers, but funds are now contributed, in addition, by primary industry boards, co-operative companies and associations, with contributions from the New South Wales Water Conservation and Irrigation Commission as well. The Griffith Station is maintained by the Organization in co-operation with the New South Wales Water Conservation and Irrigation Commission.

The Soils Division of the Organization has made detailed surveys of more than a million acres since 1927, with less detailed reconnaissance surveys over many millions of acres. The Division works closely with State authorities. The keynote of soil investigations is relationship between soil and land use, and there is an increasing tendency to seek such surveys before irrigation districts are established.

It is of interest to note in passing that the Organization is also conducting experiments to test the possibility of " making rain " by stimulating precipitation of moisture from clouds through the introduction of such substances as dry ice.

An important step forward in agricultural development in Australia has been taken in the creation of the Irrigation Research and Extension Committee with head-quarters on the Murrumbidgee Irrigation Areas. The scheme aims to provide the best possible service to farmers. It is regarded as an experiment in organization and regional administration which may have far-reaching effects. The objectives are :—

(*a*) The provision, by the proper authorities, of administrative machinery for the continuation and development of the agricultural extension services to the farmers in the defined sub-region.

(*b*) Providing a mechanism for advising on the formulation, review, and adjustment of local agricultural policy and organization.

(*c*) Providing means whereby farmer opinion will have due weight in the consideration of regional agricultural administration and policy.

(*d*) The bringing about of a unified approach to sub-regional extension in all branches of agriculture.

(*e*) The research needs of the sub-region and the co-ordination of the agricultural research of the various rural institutions working therein.

(*f*) The achievement of a close liaison between research and extension.

(*g*) Conducting research in extension methods.

The Committee is representative of the State Department of Agriculture, the Commonwealth Scientific and Industrial Research Organization, the Rural Bank of New South Wales, the Soil Conservation Service of New South Wales and certain farmers' organizations (including Extension Groups). Finance is provided by these authorities on an agreed basis. Introduced in the present form in 1947, the scheme is to operate initially for a period of seven years.

3. **Preservation of Catchments.**—As water conservation commences on the catchments, it is becoming increasingly recognized that anything which interferes with catchment efficiency affects the quantity of water available for all purposes. Active steps are being taken to counteract soil erosion, to conserve soil generally, and to minimize effects of floods, overstocking, bush fires, and destruction of vegetative cover. All States and the Commonwealth have initiated forestry policies which provide for reafforestation and the preservation of catchments. In recent years efforts to counteract soil erosion have been intensified and there is some evidence of a more unified approach to catchment, water, forestry, and land use factors regarded as parts of a single problem.

The Victorian Parliament passed the Soil Conservation and Land Utilization Act in 1947 to establish an authority to control land on catchments, to determine whether such land shall be used for forestry, grazing or other purposes, and to delegate to other authorities (such as the Forestry Commission and the Soil Conservation Service) the responsibility of carrying out necessary works to maintain catchment efficiency. The Act had not been put into operation when this article went to press. In New South Wales a Conservation Department was established in 1944 under single Ministerial control, linking the Water Conservation and Irrigation Commission, the Soil Conservation Service (established in 1938) and the Forestry Commission. In Queensland the Bureau of Investigation has been established under the Land and Water Resources Act of 1943 designed to bring about the co-ordinated development of land and water resources. Other States are also giving attention to this problem.

4. **Hydro-electric Power.**—Australia's main coal deposits lie within the well-watered regions, but with accelerated industrialization, increased interest is being displayed in the development of hydro-electric power for rural electrification, for stabilizing interconnected systems, for contributing to metropolitan peak demands, and for general industrial and domestic purposes. On the mainland it is usual to allot water for irrigation purposes, combining this with hydro-electricity to whatever extent is possible. During summer, when irrigation is proceeding, there is ample discharge for power, but in the non-watering period the main objective is to store water.

Hydro-electric possibilities are confined almost exclusively to the eastern coastline of the mainland and to Tasmania. In 1932 the Power Survey Sectional Committee of the Standards Association of Australia estimated water power resources to be 4,750,000 h.p. of which 3,500,000 was located in Tasmania. Authorities are now inclined to believe that mainland sources could contribute approximately 2,000,000 h.p., bringing the total to 5,500,000. Recent investigations concerning the potential use of the Snowy River may increase the estimate further. The Committee also estimated that the water power potential in Papua and New Guinea was approximately 20,000,000 h.p.

It has been estimated that in 1946–47, of a total of 2,184,226 k.w. generated by all Australian power stations, the quantity derived from water power was 277,557 k.w., representing 12.8 per cent. of the total. The total hydro-electricity generated in each State (and the percentage of hydro-power to total electric power in that area) was as follows :—New South Wales, 26,845 k.w. (2.7 per cent.); Victoria, 51,906 (8.9 per cent.); Queensland, 4,360 (2.2 per cent.); and Tasmania, 194,446 (100 per cent.)

Hydro-electricity is generated in all States except South Australia and Western Australia and in the Northern Territory. Water is the sole source of electric power in Tasmania, all other States depending largely on steam and oil.

5. **Sub-surface Supplies.**—(i) *General.* While a more or less complete general picture of the available and potential surface water resources exists much remains to be done with regard to the location and development of sub-surface supplies, although the extent and potentials of the artesian basins—particularly the Great Artesian Basin—have been fairly accurately determined. In view of the importance of sub-surface waters as the basis of settlement over large areas of Australia, it is necessary to devote particular attention to these resources.

The use of sub-artesian supplies is also extensive and more development is possible, but the shallower groundwater supplies, particularly along alluvium valleys and coastal sandbed areas, have not been investigated and developed in any degree, except in a few localities. Increasing efforts are being made to locate and develop sub-surface supplies and comprehensive hydrological surveys have been initiated in many parts of Australia for the purpose of locating, further developing and utilizing these waters.

A good deal of investigational work has been carried out and many data have been recorded in respect of artesian basins, and the decreasing flow therefrom; and this information is being progressively supplemented, as is also the information recorded in respect of sub-artesian supplies.

(ii) *Definitions.* The term "artesian" is applied when the water contained in an acquifer and tapped by a bore hole rises and flows under hydro-static pressure above ground level. When a water-bearing stratum is intersected by a bore hole, and the water rises above the level at which it is tapped but does not rise sufficiently high to flow naturally above surface level, it is termed "sub-artesian".

The term "ground water" is generally applied to shallower waters found in alluvium or sand beds not confined between impervious strata, and these waters usually do not rise in a bore hole above the level at which they are met.

(iii) *Artesian and Sub-Artesian Supplies.* Pressure water, variable in quantity and quality, either artesian or sub-artesian, is obtainable in many parts of Australia, the various artesian basins extending over approximately one-third of the continent.

The Great Artesian Basin, the most extensive in the world, underlies an area of approximately 550,000 square miles, comprising about 350,000 in Queensland, 76,000 in New South Wales, 100,000 in South Australia and 24,000 in the Northern Territory. Of the numerous defined major and minor water-bearing basins in Australia, the following are the principal :—

PRINCIPAL WATER-BEARING BASINS : AUSTRALIA.

Name.	State.	Geological Age.	Area.	Depth of Water.
			Square Miles.	Feet.
Great Artesian..	Queensland, New South Wales, South Australia and Northern Territory	Cretaceous-Jurassic..	550,000	Up to 7,000
Murray ..	Victoria, New South Wales, and South Australia	Miocene	107,000	100 to 900
Torrens ..	South Australia..	Recent Pleistocene ..	4,000	Up to 600
Coastal Plain ..	Western Australia	Recent Jurassic ..	10,000	200 to 2,500
Adelaide ..	South Australia..	Recent Oligocene ..	1,100	100 to 500
Gippsland ..	Victoria ..	Pleistocene-Oligocene	1,800	200 to 1,800
Port Phillip ..	Victoria ..	Pleistocene-Oligocene	300	Up to 600
Eucla.. ..	Western Australia, South Australia	Pliocene-Miocene ..	68,000	300 to 2,000
North-west ..	Western Australia	Tertiary Permian ..	40,000	400 to 4,000
Collie ..	Western Australia	Permian	500	..
Desert ..	Western Australia	Permian	130,000?	200 to 3,000

(iv) *Discharge and Number of Bores.* The first artesian bore within the Great Artesian Basin was completed in 1878 at Kallara Station, near Bourke in New South Wales. Since then more than 3,000 artesian bores, ranging in depth from 10 to 7,000 feet have been constructed within the Great Artesian Basin which extends over the three States of Queensland, New South Wales and South Australia and into the Northern Territory.

The present daily free discharge from all bores continuing to flow in Australia is in excess of 350 million gallons, of which more than 90 per cent. is probably lost by evaporation and seepage.

The number of sub-artesian bores and wells throughout Australia is more than 200,000.

(v) *Quality.* Artesian water is used primarily for stock watering purposes and its availability has enabled vast areas to be settled which otherwise would be unoccupied. Indeed it is said that its use has doubled the stock-carrying capacity of Queensland alone. In some areas artesian waters have chemical properties which make them unfit for use even by stock, and in even wider areas sub-artesian waters contain such high proportions of dissolved salts as to be quite useless.

Artesian water generally, particularly throughout the Great Artesian Basin, is good stock water, but unsuitable for plant life, even if it were available (which it is not) in sufficient quantity for irrigation. In certain areas sub-artesian waters are suitable for all uses including irrigation, while a considerable amount of irrigation is carried out in some districts from shallow ground water supplies.

(vi) *Diminution Problems.* In common with other countries possessing artesian supplies, Australia, particularly with regard to the Great Artesian Basin, has been faced with the problem of flow diminution. Hydrologists and engineers in close touch with the early discovery and development of artesian supplies soon recognized the fact that flows were diminishing as more bores were drilled, but wastage continued (and still continues in many cases) despite continued warnings.

In Queensland the total flow from artesian bores, which in 1914 reached a peak of approximately 355 million gallons a day, diminished to about 230 million gallons in 1945, although the number of bores had been increased by more than 800. Similar conditions have applied in New South Wales and South Australia, many bores having ceased to flow; and most of the older still-flowing bores now have only about 30 per cent. of their original flow remaining.

Although only a small proportion of the actual quantity of water stored in the Great Artesian Basin has been drawn off, much of the original pressure has been lost, the hydraulic gradient has been steepened, and most of the free flow has been lost for all time.

The Queensland Government appointed a Committee to investigate various aspects relating to the Great Artesian Basin, with particular reference to the problem of diminishing supply, and its first interim report was published in 1945. This report contends that less than one inch depth of water has been retrieved by all Queensland bores in the past fifty years, and as the water-bearing strata are hundreds of feet thick over a large area, this is a small fraction of the total storage. The Committee is now investigating the economic aspects.

It has been said that eventually all bores within the Great Artesian Basin would cease to flow naturally and that the water would have to be pumped to the surface for use. Investigations in both Queensland and New South Wales have refuted this impression. It is now considered that although many of the bores, particularly those located at higher surface levels, will ultimately cease to flow, many will not cease. They will assume a perpetually steady rate of flow, corresponding with the average intake of water from rainfall absorbed by the outcropping sandstones which form the intakes at or near the surface. These outcrops occur along the western slopes of the Great Dividing Range in Queensland and New South Wales and dip in a general south-westerly direction, with more or less continuity, and of variable thicknesses and depths, across the full width of the basin, to form the storage reservoir or acquifers from which the flows are derived.

The pressure which causes the water to flow from a bore penetrating an artesian acquifer, or rise in a bore penetrating a sub-artesian acquifer, is principally gravitational, although it is now considered that the "elastic factor" or "elasticity" of the sand-rock in which the water is stored also has an important bearing upon the pressure which causes water to flow. Flush flows from newly constructed artesian bores (or on re-opening of temporarily closed bores) are attributed to the elastic factor in the sand rocks. When the "elastic" effect has been more or less completely lost, flows tend to stabilize and become steady in conformity with the amount of intake and other hydraulic factors operating.

(vii) *Economic Aspects.* Investigations are now proceeding with regard to (*a*) wasteful methods of distribution of artesian water by open channels or "bore drains" which result in the loss by evaporation and seepage of most of the water, and (*b*) careless use of water.

Investigations in New South Wales into the possibility of distributing artesian water by pipe-line systems to eliminate most of the losses and wastage occurring when open channels are used, suggest that the capital and operational costs would be so high as to make them uneconomic for the pastoral industry.

Diminution in flows from artesian bores continues to be regarded as of serious consequence in some districts in the south-west of Queensland and north-west of New South Wales because of the difficulties and high cost of providing alternative stock and domestic water supplies when flows are no longer sufficient to meet requirements. Water authorities therefore suggest that it is imperative to eliminate wastage as much as possible and that the utmost use should be made of available supplies throughout the whole of the Great Artesian Basin.

The areas considered to be most seriously affected are those where sub-artesian supplies are not available, the terrain is unsuitable for surface water storage because of its poor run-off and other factors, and the depth to the artesian acquifer is so great as to make the construction of bores for pumping supplies practically prohibitive.

Fortunately the areas to which these conditions apply do not comprise a large proportion of the grazing areas of either New South Wales or Queensland, and by far the larger areas in both States will continue to meet the needs of the pastoral industries at costs not uneconomic, even if the water has to be pumped, supplemented by sub-artesian supplies, ground tanks, and other surface storage facilities.

It is significant that even in those areas where diminution of artesian flows has been most marked and flowing supplies have practically ceased, no land has gone out of use. Alternative means of watering stock, although perhaps at a higher cost, have always been found.

(viii) *Ground Water.* The development of shallow ground water supplies for industry, irrigation, stock and domestic purposes, is receiving considerable attention and can in future be depended upon for great expansion. Modern methods employed in several States for the development of such supplies contained in sands and gravel formations have recently produced encouraging results. These supplies are by no means inexhaustible and their development will require to be carefully watched, and possibly controlled, in order that the withdrawals do not exceed the capacities of the reservoirs, and the recharge thereof from rainfall.

Excessive pumping from ground water supplies in many parts of the United States has resulted in the serious depletion of supplies, necessitating strict control of further development and the artificial recharge of the water beds in order to maintain a reasonably stable water table.

Reference is made to the use of ground water on other pages, namely, Burdekin Delta (page 1126), Lockyer Valley (page 1126), and Eyre Peninsula (page 1131).

In passing, it should be noted that many urban supplies are drawn from artesian and sub-artesian sources in various parts of Australia, and that ground water has been developed for industrial as well as domestic purposes in recent years.

The most notable ground water scheme is that conducted by the Hunter District Water Board which supplies a population of 217,900 in the Newcastle area where substantial industries (coal, iron and steel, shipbuilding, etc.) exist. Water storages fed from surface sources are supplemented by ground water from the Tomago sandbeds near the mouth of the Hunter River. In an area of approximately 50 square miles, water-bearing sands (with an impervious bottom at about 60 feet) are charged with rainwater to within a few feet of the surface. The scheme consists of electric pumping units extracting the water by tube wells for delivery to spraying basins for aeration and elimination of gases. Secondary pumps deliver the water to the reticulation system. Each of fifteen pumping stations has an average capacity of a million gallons a day normally, but can deliver up to two million in favorable circumstances for short periods. Pumps and pipe lines are designed for a maximum delivery rate of 25 million gallons a day. Total quantity delivered since 1939, when the scheme was inaugurated, to the end of December, 1947, was 19,020 million gallons.

It is interesting to note that a number of water-bearing sandbeds of a similar nature have been located and examined by the Public Works Department at points along the north coast of New South Wales.

In southern districts of Sydney some industrial concerns obtain considerable supplies of ground water by means of shallow bores, and in both Perth and Adelaide surface resources are supplemented from artesian and sub-artesian sources.

(ix) *Windmills.* In the development of water resources—and especially underground water—windmills have played a substantial part. Without them millions of acres would remain undeveloped. Though it is impossible to obtain precise statistics an unofficial estimate assesses the number in use at approximately 250,000; and that the capital value of windmills now working, including pipes, pumps, tanks, troughs, etc. is in the vicinity of fifty million pounds.

The bulk of windmills are installed on farms and stations for watering live-stock, though they are also used for pumping town supplies and providing water for locomotives, irrigating vegetables, and for retrieving water for domestic use.

Large "direct-acting" windmills, measuring from 17 feet to 30 feet diameter of windwheel, predominate in the western districts of Queensland and New South Wales, in the northern areas of South Australia, in the Northern Territory, and in the Kimberley Division of Western Australia where large mobs of sheep and cattle are watered. The smaller, geared windmills, from 6 feet to 14 feet diameter, are used mainly on farms in coastal areas.

The smaller windmills are similar in general principle to American types, but the large "direct-acting" types appear to have been developed mainly in Australia. By "direct-acting" is meant that the windmills are not back-geared, and so there is one stroke of the pump to each revolution of the wind wheel The wind wheels of geared windmills revolve from 2.33 to 4 times according to size to give one pumping stroke. Small windmills revolve faster than large ones in the same wind velocity so that if they were not back-geared their pumping strokes would be so rapid that they would cause speedy deterioration of the pump parts and undue strains on working parts, etc.

The first windmills in Australia were made principally of wood and required greasing fairly frequently. Improved types have been introduced progressively as the result of experience. In recent years a large direct-acting windmill has been developed which is a fully enclosed, automatically oiled machine, made of steel and cast iron, which needs refilling with oil only once a year; and even then it is unnecessary to climb the tower as in earlier types, an oil pump being provided on the tower near the ground from which the oil is pumped into the crankcase.

6. **Industrial, Metropolitan and Country Town Supplies.**—Human consumption needs are the first objective of water conservation, and the growth and dispersion of communities must be related to the availability and use of water. The growth of large metropolitan populations, associated with the development of substantial secondary industries, has created water supply problems of considerable complexity. Changes in manufacturing processes, apart from the increase of population and industry, accentuate these problems. While manufacture a century ago was comparatively simple, the development of modern industries such as chemicals, paper manufacture, plastics and food processing, has increased the demand for water.

As an illustration, such factors as the increasing consumption of bottled and canned foodstuffs, the provision of amenities such as sewerage and even electric bath heaters, and the development of home gardens, are all reflected in the total demand. The growth of country towns, as well as the development of metropolitan areas, is consequently responsible for the adoption of long-term programmes in all parts of Australia designed to guarantee future supplies on an adequate scale. Details relating to urban water supply systems will be found in Chapter XIII.—"Local Government" of this Year Book (pp. 539–50).

§ 3. National and Interstate Aspects.

1. **Constitutional Phases.**—As the government of Australia is conducted under a Federal system, and as the Commonwealth Constitution makes special reference to water problems, both the Federal and the State Governments have an interest in the control and conservation of water. As main responsibility for control of water resources resides in the State governments, and as political boundaries sometimes intersect river valleys and catchments, co-operation between governments has been necessary to develop resources in certain cases.

Under the Constitution, the Commonwealth's trade and commerce power extends to navigation (including navigation on rivers), and Section 100 provides that "The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation."

The Commonwealth and the States of New South Wales, Victoria and South Australia entered into an agreement in 1914 for the control of the Murray River which serves the three States mentioned In 1947 the States of New South Wales and Queensland entered into an agreement for the control and development of the Dumaresq and other rivers which intersect the border of the two States.

In the Report on Irrigation, Water Conservation and Land Drainage presented to the Commonwealth Government by the Rural Reconstruction Commission in 1945 national aspects of water conservation and use were emphasized. The report recommended the adoption of an all-Australian plan, having the assent of the various governments, to obviate lack of co-ordination resulting in attempts to develop too many schemes simultaneously, thus stimulating production in excess of markets, and competing for available finance, materials and manpower. It also recommended that the Commonwealth should endeavour to promote interstate co-operation and co-ordinated development generally.

In 1946 a conference between the Commonwealth and States agreed to revive the Irrigation Production Advisory Committee, first established under the authority of the Australian Agricultural Council in 1938. Its main function is to consider the relation of irrigated production to available markets and to advise on the expansion of irrigated production from a national viewpoint. It succeeded the Murray River Advisory Committee established many years earlier. The Commonwealth and the States are represented on the Committee.

Specific examples of Commonwealth-State and interstate co-operation and approach are given in the following sections.

2. **Murray River Scheme.**—(i) *General.* The Murray River and its tributaries form the largest river system in Australia. The catchment is approximately 414,000 square miles or one-seventh of the area of the Australian continent, representing five-sixths of New South Wales, over one-half of Victoria, one-sixth of Queensland, and one-fortieth of South Australia. The Murray proper is 1,600 miles long. Its main tributaries are the Murrumbidgee (1,050 miles), the Darling (1,760 miles), and the Goulburn (280 miles). The average annual flow of each of the chief contributory streams is as follows :—Upper Murray, including the Mitta Mitta and Kiewa Rivers, 3,400,000 acre feet ; Murrumbidgee River, 2,600,000 acre feet ; Goulburn River, 2,250,000 acre feet ; Darling River, 2,150,000 acre feet ; and Ovens River, 1,200,000 acre feet.

(ii) *History of Control.* Discovered in 1824, the Murray played a substantial part in early pastoral settlement. Navigation was the predominant initial interest, permitting cheap transport of supplies and production. Irrigation settlements which developed after 1887 commenced a new era in the River's history. In 1914 the three State authorities whose territories were served by the River agreed that joint control was necessary, and the following year the Parliaments of the Commonwealth, New South Wales, Victoria and South Australia passed the River Murray Waters Act. This ratified the River Murray Agreement, provided for the construction of works, the allocation of the water between the three States, and the appointment of a Commission to implement the Agreement. The Commission comprises four Commissioners, representing the Commonwealth and the three States respectively. The Commonwealth representative presides.

(iii) *Terms of Agreement.* Under the Agreement construction works are carried out by the States (who are also responsible for maintenance) subject to the approval and direction of the Commission. The Agreement provides that the minimum quantity

of water to be allowed to pass for supply to South Australia in each year shall be sufficient to fill Lake Victoria storage once, and with the aid of water returned from Lake Victoria, to maintain certain specified flows in the lower river varying from 47,000 acre feet per month in the winter months to 134,000 acre feet per month in the four summer months of maximum demand—the total amounting to 1,254,000 acre feet over twelve months. These flows are to meet domestic and stock requirements in South Australia, losses of water in the locks, and evaporation losses other than in the lakes at the Murray mouth ; together with 603,000 acre feet per annum for diversion from the Murray for irrigation in South Australia. The flow at Albury is shared equally by New South Wales and Victoria, and each of these States has full control of its tributaries below Albury, subject in each case to the fulfilment of the South Australian allocation.

Under the original agreement the major works comprised two large storages—one on the Upper Murray above Albury (the Hume Dam) and the other at Lake Victoria in Victoria near the South Australian border. In addition, provision was made for a number of weirs and locks along the Murray and Murrumbidgee Rivers. In 1934 the Agreement was varied to provide for the construction of a diversion weir at Yarrawonga (145 miles downstream from the Hume Dam), and the provision of barrages at the mouth of the River to prevent the entry of salt water. The amendment also limited the original proposal for 26 weirs and locks on the Murray and 9 on the Murrumbidgee to 13 on the Murray and 2 on the Murrumbidgee. At the same time it was agreed that the Hume Dam should be completed to a capacity of 1,250,000 acre feet with provision for later increase to 2,000,000. As a result of the amendment, navigation is limited to a route of 600 miles, extending from the mouth to a point some 50 miles above Mildura.

(iv) *Cost.* All works authorized under the amended Agreement (except the enlargement of the Hume Dam to 2,000,000 acre feet) have been carried out at a total cost of £12,000,000, of which approximately half represents the cost of the Hume Dam. Expenditure has been shared equally by the Commonwealth and the three States.

(v) *Hume Dam.* The Hume Dam is situated just below the junction of the Murray and Mitta Mitta Rivers, 10 miles above Albury, forming a lake of 33,000 acres. The design comprises a mass concrete spillway and outlet works extending 1,000 feet and an earthen embankment 100 feet high extending for 4,000 feet across the river flats. The length of the total structure is approximately 1 mile. Ultimate plans include provision for hydro-electric generation, for which planning is now in hand. Attention is also being given to the completion of the dam to its designed capacity of 2,000,000 acre feet and also to the enlargement of the inlet channel to Lake Victoria, necessary to permit greater storage of periodic flood flows of short duration.

(vi) *Weirs and Locks.* Yarrawonga Diversion Weir was completed in 1939 to raise the river level so that water could be diverted by gravitation into main channels constructed on either side of the river. Between the Yarrawonga Weir and the Murray mouth, thirteen weirs and locks have been built. Two have been constructed on the Murrumbidgee—one between Hay and the Lachlan Junction ; and the other below the Lachlan Junction.

(vii) *Distributaries.* The Mulwala Canal, served by the Yarrawonga Weir, has an off-take capacity of 2,500 cubic feet per second, and will serve 1,500,000 acres of land in New South Wales. The Yarrawonga Channel, on the Victorian side, has an off-take capacity of 1,250 cubic feet per second, and is designed to serve 270,000 acres. Only a portion of both these areas will be irrigated.

(viii) *Lake Victoria.* Adjoining the river in New South Wales and 35 miles from the Murray-Darling Junction, Lake Victoria storage was completed in 1928 with a capacity of 551,700 acre feet and a surface area of 27,670 acres. The water is used by the South Australian settlements.

(ix) *Murray Mouth Barrages.* Five barrages across channels near the river mouth connecting Lake Alexandrina with the sea were completed in 1940 to prevent ingress of salt water to Lakes Alexandrina and Albert and to the lower river, thereby increasing the productivity of adjacent lands. The structures maintain a sufficiently high level for 50 miles up river to permit watering by gravitation of a considerable area of reclaimed river flats. The total distance across the barrages and intervening islands is 15 miles.

(x) *State Storages and Works.* In addition to the works carried out under the auspices of the Commission, the separate States have constructed thousands of miles of distribution channels and provided a number of storages on the tributaries, thereby contributing very materially to the large amount of irrigation development in the Murray Basin. The total capacities of such main storages are: New South Wales—Burrinjuck (Murrumbidgee), 771,640 acre feet; Wyangala (Lachlan), 304,000 acre feet; Victoria—Eildon (Goulburn), 306,000 acre feet; Waranga (Goulburn), 333,400 acre feet. No storages exist on the Murray in South Australia. More details of these and other State works on Murray tributaries will be found in the sections dealing with State systems.

(xi) *Extension of Agreement.* Towards the end of 1948 legislative action was taken to ratify an Agreement by the Commonwealth and the States of New South Wales, Victoria and South Australia to vary the original terms. The amended Agreement provides for the increase of the capacity of the Hume Dam from 1,250,000 to 2,000,000 acre feet, the widening of the inlet channel to Lake Victoria storage, and the production of hydro-electric power.

The States of New South Wales and Victoria have agreed to report annually on the condition of the catchment and to take any special action recommended by the Murray River Commission in regard thereto.

The parties have also agreed that the Commission shall have power to initiate proposals for the better conservation and regulation of the river and may have investigations and surveys made respecting additional water storage works which might be carried out by one or more of the contracting governments, subject to the Commission's control.

(xii) *Production.* Irrigated production in the River Murray basin is mainly in the form of wine, dried fruits, fresh fruits, dairy produce, wool, fat lambs, rice, vegetables, poultry, eggs and pigs. The value of production from these areas has been estimated at about £19,000,000 a year, apart from the value added by processing or manufacture. The Murray River Commission estimates that without irrigation the annual production of these areas would not have exceeded £2,000,000 a year.

(xiii) *Diversions.* The total estimated quantity of water diverted in 1947–48 for irrigation from the Murray and its tributaries (under the Murray River Agreement) was as follows (in acre feet): New South Wales (1,524,897); Victoria (1,807,194); South Australia (157,328); a total of 3,489,419 acre feet.

3. **New South Wales–Queensland Border Agreement.**—The Border Streams Agreement between New South Wales and Queensland, effective from 1st July, 1947, provides for the construction of works on portions of the valleys of the Barwon, McIntyre and Dumaresq Rivers, forming part of the boundary between the two States, on the basis of equal partnership in respect of works expenditure and use of water. The catchments (2,000 square miles) extend to the granite areas in the vicinity of Tenterfield (New South Wales) and Stanthorpe (Queensland), and elevation rises to 3,000 feet. Average rainfall is 30 inches. The catchments and the areas suitable for irrigation are approximately equal in each State. The scheme provides for a major dam on the Dumaresq, near Mingoola, 15 miles upstream from Texas, with a storage capacity of 120,000 acre feet, together with 12 weirs and 4 regulators, at an estimated cost of £1,140,000. Investigations suggest that 70,000 acres close to the storage are suitable for irrigation.

Climatic conditions are such that it is necessary to supplement rainfall from April to October by irrigation to stabilize and increase production. The capacity of the area to grow lucerne and tobacco under irrigation has already been demonstrated. Irrigation of cotton, root crops, cereals, and citrus fruit, and expansion of the fat stock industry, is being examined. A Commission to carry out the Agreement is being appointed.

4. **Snowy River Scheme.**—(i) *General.* Investigations have been carried out for many years to determine the best means of fully utilizing the waters of the Snowy River, which rises in the alpine area to the east of the Snowy Mountains in the south-eastern corner of Australia. The main stream rises in New South Wales on the slopes of Australia's highest mountain, Kosciusko (7,305 feet), and enters the sea below Orbost in Victoria.

Estimates made by the New South Wales Water Conservation and Irrigation Commission suggest that the average run-off of the Snowy catchment above Orbost is approximately 2,229,150 acre feet per year, based on records for the 35 years from 1907 to 1941. The average run-off above Jindabyne (2,900 feet elevation) accounted for 928,005 acre feet of the total. The average for the river as a whole was exceeded in thirteen of these years. In 1934 the phenomenal figure of 7,003,474 acre feet was recorded.

On this upper catchment of 680 square miles the rainfall varies from 22 inches at Jindabyne to 90 inches at Kosciusko. An important feature of the catchment is that snow falls in considerable quantities during the winter months and may persist for a many as eight months in some areas. The effect of the accumulation of snow in winter is to reduce the discharge of the river at that time and to increase it in summer, thereby maintaining a more uniform flow throughout the year.

(ii) *Diversion Proposals.* Observing that this substantial quantity of water is collected at elevations considerably higher than the courses of adjacent westerly flowing rivers, investigators have from time to time proposed the diversion of the waters of the Upper Snowy catchment to augment supplies for irrigation, stock and domestic purposes in inland areas. As early as 1884 the New South Wales Surveyor-General suggested diversion to the Murrumbidgee by means of an open channel from a point about five miles upstream from Jindabyne.

Various proposals have also been made for the utilization of Snowy water for the production of hydro-electricity, and investigations were made concerning a proposal to divert the water to Sydney to augment the metropolitan supply.

The Government of the Commonwealth and the State Governments of New South Wales and Victoria have certain legal rights in relation to the use of the Snowy. Under a long-standing agreement with New South Wales, the Commonwealth was granted rights in connexion with the development of the Snowy for hydro-electricity to provide for the needs of the Australian Capital Territory. Experience of deficient flow in the Murrumbidgee, which affected the output of hydro-electric power at Burrinjuck and threatened the stability and expansion of the Murrumbidgee Irrigation Areas, led the New South Wales Government to appoint a special investigating committee which reported in 1944 in favor of diversion to the Murrumbidgee.

The Victorian Government also has an interest in the river by virtue of the fact that the Snowy flows through Victoria to the sea.

Furthermore, the Victorian Government has expressed interest in the diversion of the Snowy to the Murray (which rises to the south of Mount Kosciusko) as a means of supplementing electricity supplies and increasing the water available for irrigation purposes along the Murray River.

Following discussions at the Premiers' Conference in 1946 investigations were initiated with a view to utilizing the highland water and power potentialities in the best national interest. During 1947 and 1948 joint investigations were carried out by a technical committee representative of the Commonwealth and the States of New South Wales

and Victoria. The members of the Committee had achieved a substantial measure of agreement concerning the works necessary to obtain a maximum quantity of electric power and water through the interlinking of highland and westerly flowing rivers, when this article went to press.

5. **Australian Pattern Summarized.**—From the foregoing it is obvious that water conservation and use has both a national and a local aspect. The following survey indicates the local pattern of water resources and the steps taken by State Governments to bring about their development. It will be seen that water policies in the various States 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 Areas. In Queensland, up to the present, the predominant emphasis has fallen on water for the stock industries (mainly underground sources), and the development of small irrigation schemes in sub-humid and humid areas, especially to stabilize sugar production.

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 appertains to hydro-electric generation almost exclusively. The Northern Territory is primarily concerned with stock supplies and the safeguarding of long stock routes.

§ 4. States and Territories.

1. **New South Wales.**—(i) *Rainfall.* Northern districts receive most of their rain in summer months, the southern districts in the colder months, but in neither case is the pattern so clearly defined as in various sections of other States. Over a large area rainfall is not seasonal, and wet as well as dry periods may be experienced during any portion of the year. Rainfall on the coast and coastal highlands is higher than inland, especially on the northern sectors where cyclonic storms may bring a substantial proportion of the year's rain in a few days. Over an area of 310,272 square miles, comprising New South Wales (309,433 square miles) and the Australian Capital Territory (939 square miles) 19.7 per cent. receives an annual average rainfall less than 10 inches; 43.2 per cent. less than 15 inches; 60.7 per cent. less than 20 inches; and 84 per cent. less than 30 inches. Areas receiving more than 30 inches represent 16 per cent. of the total area of which the 30 to 40 inch areas comprise 9.9 per cent.

(ii) *History.* A Royal Commission under Sir William Lyne in 1887 recommended a system of canals served from diversion weirs on the Murrumbidgee below Wagga. As a result, a water conservation and irrigation branch was attached to the Department of Mines and Agriculture, but except in respect of water for travelling stock in dry areas, little progress followed. Colonel F. J. Home, Chief Irrigation Engineer of the Punjab (India) reported in 1897 that only the Murray and Murrumbidgee could be relied on for regular flows. Mr. H. G. McKinney, who had assisted the Lyne Commission, recommended a major storage at Burrinjuck which was approved by Parliament in 1906 and completed in 1924. In 1910 an Irrigation Trust was established to control the Murrumbidgee Irrigation Areas, served from Burrinjuck, and this system operated until the creation of the Water Conservation and Irrigation Commission established under the provisions of the Irrigation Act of 1912.

(iii) *Administration.* Since 1916, when the Irrigation Act was amended, the Commission has consisted of three members including the responsible Minister (who is chairman) and two appointed Commissioners. The operations of the Commission cover water conservation, control of irrigation areas, establishment, operation and maintenance of works for domestic and stock water supply, and irrigation districts, flood control districts, sub-soil drainage districts, constitution of water trusts, the issue of licences for private irrigation, artesian and shallow boring, and a farm water supply scheme.

Under the Water Act 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 Crown. A system of licences also operates for the protection of private works of water conservation, irrigation, water supply, drainage, and prevention of inundation.

(iv) *Schemes summarized.* The bulk of irrigated land is along the Murray and its tributary the Murrumbidgee. Smaller areas are served by the Wyangala Dam on the Lachlan, another tributary. None of the other rivers are regulated by large head storages, though weirs and dams have been provided for town supplies, etc. in many places, and head storages have been commenced on the Macquarie, Namoi and Hunter Rivers. Substantial use is made of artesian and sub-artesian water in pastoral areas.

(v) *Storages.* The capacities of the main storages (in acre feet) are :—

Murray:—Half share of Hume Dam, weirs and locks to Wentworth (736,420); Stevens Weir, Edward River (7,165).

Murrumbidgee:—Burrinjuck Dam (771,640); Berembed Weir (10,000); Maude Weir (6,740); Redbank Weir (7,360).

Lachlan:—Wyangala Dam (303,900); Lake Cargelligo (29,435); Jemalong Weir (1,790).

Water from the Hume Dam is used for domestic and stock purposes, to provide bulk supplies for country towns, for the irrigation of vines, fruits and fodder in the Curlwaa and Coomealla areas, for domestic and stock supply and irrigation in the Berriquin and Wakool Districts, and for water trusts for domestic and stock purposes and/or irrigation.

The Wyangala Dam is 30 miles upstream from Cowra in the Central West. It has a catchment of 3,200 square miles. Water from the dam, supplemented by the unregulated flow of the Belubula River, provides for domestic and stock purposes along the full length of the river (over 700 miles) and also for irrigation by land holders operating licensed pumps. The towns of Cowra, Forbes, Condobolin, Hillston and Booligal are supplied. A balance storage at Lake Cargelligo conserves water during periods of high flow for release as required. Water from the Lachlan, diverted at Jemalong Weir, supplies the districts of Jemalong and Wyldes Plains, serving an area of 223,936 acres. Wyangala is now producing hydro-electric power. Proposals for future development include provision of a head storage at Belubula River, the construction of a balance storage of 108,000 acre feet at Ballyrogan (now in hand), and the constitution of domestic and stock water districts, or development by licensed diversions.

(vi) *Distributaries.* The approximate total length of channels (including main canals) in New South Wales is 2,597 miles. The approximate length of drains and escape channels is 903 miles, and approximate total length of pipe lines is 9 miles, making a grand total of 3,509 miles of channels and pipe lines, etc.

(vii) *Scheme Types Enumerated.* 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, and Flood Control and Irrigation Districts.

There are four Irrigation Areas: The Murrumbidgee Irrigation Areas consisting of 381,814 acres served with water through a channel system off-taking from the river at Berembed Weir; the Coomealla Irrigation Area of 35,450 acres, served by pumping from the Murray; the Curlwaa Irrigation Area of 10,550 acres, supplied from the Murray by pumping; and the Hay Irrigation Area of 6,806 acres, supplied with water pumped from the Murrumbidgee. All these areas are administered by the Commission, and details of the various schemes follow.

LAND UNDER IRRIGATED CULTURE: NEW SOUTH WALES, 1946–47.

(Acres).

Systems.	Total Area.	Area Irrigated.										
		Rice.	Other Cereals Grown for Grain.	Lucerne.	Other Fodder Crops.	Pastures.		Vineyards.	Orchards.	Vegetables.	Fallow and Miscellaneous.	Total.
						Sown.	Natural.					
Irrigation Areas—												
Murrumbidgee (within the Areas) ..	381,814	27,428	61,992	3,408	7,675	15,025	5,039	5,546	15,674	4,688	28,059	174,534
Lands adjacent thereto	(a)	398	220	(a)	210	(b) 2,830	7,170	..	..	47	200	11,075
Coomealla, Curlwaa and Hay ..	52,806	..	..	143	179	1,019	103	3,173	1,160	12	13	5,802
Total ..	434,620	27,826	62,212	3,551	8,064	18,874	12,312	8,719	16,834	4,747	28,272	191,411
Irrigation Districts—												
Benerembah ..	121,744	4,240	18,495	1,147	3,120	7,580	3,100	..	..	28	..	37,710
Tabbita	6,316	30	726	6	45	135	..	..	..	..	..	942
Wah Wah ..	567,760	..	5,540	478	..	1,952	150	..	..	..	..	8,120
Berriquin	629,853	..	22,925	10,053	2,304	45,325	10,128	..	..	115	1,649	92,499
Wakool	502,820	..	1,326	959	508	20,061	11,963	..	..	30	400	35,256
Jemalong and Wyldes Plains	223,936	..	4,890	1,847	2,286	1,365	11,086	..	..	..	..	21,474
Lowbidgee Flood Control District ..	367,090	..	..	..	..	..	107,037	..	..	..	..	107,037
Total ..	2,419,519	4,270	53,902	14,490	8,263	76,418	143,464	..	..	173	2,058	303,038
Irrigation Trusts ..	16,031	..	114	104	58	233	336	1,965	369	50	11	3,240
Licensed Diversions—												
To Irrigate ..	(a)	..	..	9,849	7,720	7,339	7,482	559	3,043	10,914	180	47,086
Grand Total ..	..	32,096	116,228	27,994	24,105	102,864	163,594	11,243	20,246	15,884	30,521	544,775

(a) Particulars not available. (b) Perennial pastures only.

(viii) *Murrumbidgee Irrigation Areas.* (a) *Description.* These areas comprise about a third of the State's irrigated acreage and received (in 1946–47) 346,064 acre feet of the total water allocated for stock, domestic supply and irrigation (1,013,711 acre feet). They are served by the Burrinjuck Dam (capacity 771,640 acre feet), 40 miles north-west of Canberra, on the Murrumbidgee. The catchment above the dam is 5,000 square miles. The river rises on the high plateau north of Mount Kosciusko where rainfall exceeds 60 inches. Flow for the irrigation districts is supplemented by unregulated flow below the dam from the Tumut River. The dam also provides town supplies for Gundagai, Wagga, Narrandera, Hay, Balranald, and for towns served by the South-West Tablelands scheme.

Domestic and stock water and water for irrigation is supplied for the Irrigation Districts of Tabbita, Benerembah and Wah Wah and the flood irrigation districts of Lowbidgee. Flood flows are relied on to serve the Lowbidgee district and water is not released from the dam for that purpose. For the other undertakings, however, water is stored during the winter and spring freshets, fed by melting snows, and is released during the September-April irrigation season. It passes along the river channel to Berembed Weir, 240 miles westward, where it is diverted to the main canal with an off-take capacity of 1,600 cubic feet per second. The main canal has been completed to beyond Griffith, 96½ miles from the off-take. Reticulation channels aggregate 840 miles and drainage channels 810 miles.

In addition 380 miles of supply channel run through adjacent irrigation districts in which the water supply is operated and maintained by the Commission, but land transactions are not under its control. The land on which the Murrumbidgee Irrigation Areas are situated originally comprised large sheep stations with a sparse population.

Population was 12,000 in 1923, 15,000 in 1929 and 20,000 at the 1947 Census. The population of the Yanco district (with Leeton as the centre) was then 9,000; and the population of the Mirrool Area (with Griffith at the centre) was 11,000.

(*b*) *Administration.* The Water Conservation and Irrigation Commission controls land transactions and water supplies for the Murrumbidgee Irrigation Areas, also the electricity supply undertaking. Other local government services, including town water supply, are provided by Shire Councils. Land is disposed of by the Commission under freehold or perpetual lease tenure or leased for short terms for grazing or cultivation. The area under occupation at 30th June, 1947 was 338,121 acres, including 45,951 held for short lease grazing, agriculture, etc.

(*c*) *Production.* Since the scheme was inaugurated in 1911 the value of total production has aggregated £39,000,000. During the year ended 30th June, 1947, production was valued at £3,169,100. Live-stock contributed £653,100, comprising sheep, £353,500; cattle, £32,000; pigs, £20,000; wool, £191,600; and dairy products, £56,000.

Rice (£803,200) and other crops (£202,000) contributed a total of £1,005,200. Horticulture accounted for £1,090,500, comprising almonds, apricots, citrus, drying grapes, table grapes, wine grapes, figs and olives, peaches and nectarines, pears, plums and prunes, quinces and apples. The greatest individual contributions were made by grapes, £283,800, peaches and nectarines, £202,800 and citrus, £278,200.

The total value of all vegetables was £379,000, including root crops, £157,100, tomatoes, £105,600, peas and beans, £64,000, cabbages, cauliflowers, onions and other products.

A total of £41,300 represented the value of miscellaneous products.

(*d*) *Rice.* Rice growing was initiated in 1924. Since then aggregate production has been 783,500 tons valued at £8,360,000. In 1946–47 the acreage sown was 31,989, and the quantity of water delivered was 198,340 acre feet. Water supplied for rice represents about one-half of the total delivered in the areas and a fifth of the water artificially supplied for irrigation in New South Wales. Before the war the rice crop was more than sufficient for Australian requirements. During and after the war the area planted was increased to the limit of water available. Rice has also been grown in the adjoining districts of Benerembah and Tabbita, while in 1945–46, 21,389 acre feet was used for 4,104 acres of rice in the Wakool Irrigation District on the Murray, representing nearly half the water delivered. No rice was grown at Wakool for the 1946–47 season.

(*e*) *Co-operation.* Co-operation is a prominent feature in the Murrumbidgee Areas. Co-operative organizations in the Mirrool section handle 300,000 bushels of fruit per year (compared with 54,600 in 1927–28). Aggregate sales turnover of the Leeton cannery in the past five years was over £1,000,000. Settlers and government agencies co-operate extensively in all matters relating to irrigation practice.

(ix) *Other Irrigation Areas.* The Curlwaa, Coomealla and Hay Irrigation Areas follow the same administrative pattern as the Murrumbidgee Areas—that is, land transactions are administered by the Water Conservation and Irrigation Commission which also is responsible for operation and maintenance of works to supply water at rates determined by the Commission.

Curlwaa Area, on the Murray near Wentworth, consists of 10,550 acres of which 2,143 acres comprised irrigated holdings at 30th June, 1947. Production consists of dried vine fruits, deciduous fruits and fodder crops of a total estimated value of £113,872.

Coomealla Area, 9 miles upstream from Curlwaa, comprises 35,450 acres of which 3,419 acres are occupied in the developed portion. Other land in the undeveloped part is leased for grazing. Production consists of vines, citrus and lucerne of an estimated value of £214,266. Vines account for 2,465 acres, citrus 240, and lucerne 29. Works are now under construction to provide 100 new farms for ex-servicemen.

Hay Area, on the lower Murrumbidgee, consists of 6,806 acres, of which 1,028 acres are occupied as irrigated holdings. Annual production, valued at £18,775, comprises dairy products, fat lambs, sheep, wool and fodders.

(x) *Irrigation Districts.* These Districts are set up under the Water Act for (*a*) domestic and stock water supply and (*b*) irrigation. They differ from water trusts as the cost of the works is not required to be repaid over a period, but annual charges are made by the State for water supplied to landholders The following districts or provisional districts have been constituted :—

Irrigation District.	Area of Land Benefited.
	Acres.
Murray River—	
Wakool District (completed)	502,698
Berriquin Provisional District (almost complete)	625,494
Deniboota Provisional District (in progress)	303,064
Denimein Provisional District*	140,850
Jernargo Provisional District* (domestic and stock supply only)	130,850
Barramein Provisional District* (domestic and stock supply only)	88,651
Murrumbidgee River (completed)—	
Benerembah District	121,555
Tabbita	5,631
Wah Wah Provisional District	549,099
Lachlan River—	
Jemalong District (completed)	171,608
Wyldes Plains District (completed)	52,328
Total	2,691,828

* Works not yet commenced.

Since the completion of the Hume Dam several such districts have been established along the Murray to utilize the New South Wales share of the storage. Water is not available for the whole of the five million acres adjacent to the Murray in New South Wales, and therefore 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 (one acre in ten or twelve, etc.) will be irrigated, but additional water, when available, may be obtained by landholders. "Water right" means right to such a quantity annually of water, 12 inches deep, as will cover an area of one acre.

Water to serve Berriquin and Wakool Districts is diverted through a main canal which will be 100 miles long when completed. At 30th June, 1947, 75½ miles had been constructed to those districts and a further length was under construction in the Deniboota District. Off-take capacity is 5,000 acre feet per day. Ultimately the water will serve Deniboota and other districts for which works have yet to be constructed.

Wakool, with 340 miles of channel, contains 215 holdings and it is expected that the area developed by irrigation will comprise about one acre in 13 of the total area. The total area irrigated in 1946–47 was 35,256 acres and water supplied was 38,270 acre feet. Crops comprised fodders, pastures, cereals and vegetables, but sheep raising is the main industry.

Considerable subdivision has occurred within the Berriquin District and it is expected that the proportion of total area to be developed for irrigation will be considerably higher than in the case of Wakool. Total irrigated acreage was 92,499. Sheep and wheat growing are main industries. The fat lamb industry is well developed and expanding. Dairying is making headway, and a butter factory has been established at Finley.

In the Benerembah, Tabbita and Wah Wah Districts, supplied from the channels of the Murrumbidgee Irrigation Areas, the quantity of water supplied during the 1946–47 season for irrigation was 76,639 acre feet, and the area irrigated was 46,772 acres, including rice and other cereals, pastures and fodder crops. The estimated value of production, included in the amount (viz., £3,169,000) for the Murrumbidgee Irrigation Area, was £396,500, including wool, live-stock, wheat and oats and rice.

For the same season 25,987 acre feet of water was supplied from the Lachlan River to irrigate a total area of 21,474 acres within the Jemalong and Wyldes Plains Districts. The total estimated value of production was £521,000, including wool and lambs £415,000, calves and pigs £33,000, wheat, oats and other crops £32,000 and lucerne £41,000.

(xi) *Water Trust Districts.* The Water Act provides for the constitution of Trust Districts for domestic and stock water and irrigation and empowers the Commission to construct, acquire or utilize 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. The following water trusts—other than irrigation—have been constituted; the area in acres of each district is shown in parenthesis:—Murray River: Tuppal Creek (78,080), Bullatale Creek (68,320), Little Merran Creek (157,440), Poon Boon (32,985), Minnie Bend Flood Prevention (2,190); Murrumbidgee River: Yanko, Colombo and Billabong Creeks (1,001,210); Lachlan River: Torriganny, Muggabah and Merrimajeel Creeks (170,240), Condobolin West Weir (4,480), Marrowie Creek (295,040), Ulonga (71,655), Micabil Weir (11,500); Miscellaneous: Algudgerie Creek (9,760), Nidgery Creek (46,880), Great Anabranch of Darling River (995,200), Collarenebri Water Supply (88), making in all a total area of 2,945,068 acres.

Thirteen of these trusts have been formed for the provision of water for domestic and stock purposes, one for a town supply and one for flood prevention.

(xii) *Irrigation Trusts.* These trusts are established under the same Act and are administered by trustees in a similar way. The following are the Trust Districts (area in acres is shown in parenthesis):—Hunter River: Blairmore (511½); Murray River: Bama (3,446), Goodnight (1,364), Bungunyah–Koraleigh (1,785), Glenview (2,750½), Bringan (4,933); Darling River: Pomona (1,241½), making in all a total area of 16,031½ acres.

(xiii) *Flood Control and Irrigation.* The Lowbidgee Provisional Flood Control and Irrigation District (367,090 acres) was constituted in 1945, being the first of its kind. Its purpose is to provide flood irrigation for 140,000 acres on the lower Murrumbidgee by water diverted from the Maude and Redbank Weirs. There are 47 holdings. Another district (Medgun near Moree in the North-West) is being developed on similar lines.

(xiv) *Underground Water.* Extensive use is made of artesian, sub-artesian, and shallow underground water. Eighty thousand square miles in the north and western portions are covered by the Great Artesian Basin. Eighty Bore Water Trusts and twelve Artesian Wells Districts have been constituted. The Bore Trusts are administered in the same way as Water Trusts, but in Artesian Wells Districts settlers maintain the drains. Bore Trusts and Artesian Districts cover nearly five million acres and water is distributed through 3,285 miles of open earth drains. The number of artesian bores giving a flowing or pumping supply at 30th June, 1947 was 876, and the estimated total daily flow from the 546 flowing bores was 65,849,000 gallons. The deepest bore is Boronga No. 2 (4,570 feet) which also has the greatest flow, namely, 1,115,360 gallons per day. Of the total number of bores sunk, 221 have been installed by the Government in connexion with public watering places. The estimated flow of all bores in 1914–15 was 99,350,419 gallons per day for 372 bores. In 1946–47 the flow had decreased to 65,849,000 gallons for 546 bores, confirming the similar experience of Queensland.

(xv) *Shallow Bores.* Since 1912 the Government has assisted settlers in shallow boring operations for which repayments are required over a period. To 30th June, 1947, the total constructed by the Commission's plants was 3,980 and their average depth was 293 feet.

(xvi) *Licences and Permits.* During recent years the numbers of licences and permits issued to individuals to draw water from rivers and lakes for irrigation has increased substantially, especially along the coastal streams in sub-humid districts where the value of supplementary irrigation is becoming more recognized as a means of stabilizing production in lean months. There has also been a considerable increase along the Murrumbidgee and Lachlan.

(xvii) *Farm Water Supplies.* The Farm Water Supplies Act was passed in 1946. Technical advice and assistance, and financial assistance is made available to aid individual farmers and groups of farmers to provide and improve water supplies for domestic, stock and irrigation purposes by means of wells, bores, excavated tanks, weirs or dams.

(xviii) *Future Programme.* The future programme envisages expenditure of £30,000,000 over the next 15 years to provide eighteen dams and storages, eight diversion weirs, flood mitigation and river protection works in various parts of the State. Construction has been commenced on head storages at Keepit on the Namoi, Glenbawn on the Hunter, Burrendong on the Macquarie, and a balance storage at Ballyrogan on the Lachlan. The Hunter River development concerns an exceptionally fertile coastal valley, forming the hinterland to Newcastle, where the annual rainfall is not heavy and variations from month to month are considerable. This is the first coastal scheme initiated in New South Wales. Total estimated storage of all proposed new storages is 5,500,000 acre feet.

(xix) *Hydro-electricity.* The Nymboida hydro-electric scheme was opened in 1924 with an initial capacity of 800 k.w. to supply Grafton, South Grafton, and Ulmarra over a transmission line of 31 miles. The Nymboida power station is situated on a tributary of the Clarence River in Northern New South Wales and now has a capacity of 5,600 k.w. The station now operates in conjunction with a diesel station at Lismore and an associated transmission network to provide supply throughout the north-eastern area from Kyogle in the north to Kempsey in the south, a distance of some 200 miles north and south. In 1946 the system was inter-connected with the Department of Railways system based on Newcastle. The Nymboida system is controlled by the Clarence River County Council.

The Bega Valley scheme was opened in 1944 to supply an area of 2,700 square miles extending from Bermagui to Eden. The power is derived from the waters of Rutherford Creek, a tributary of the Bemboka River, and the capacity of the present installation is 500 k.w. Two 750 k.w. generating units are to be installed in conjunction with a further development on George's Creek, another tributary of the same river, and a comprehensive programme of rural electrification has been initiated. This system is controlled by the Bega Valley County Council.

Wyangala Dam power station was brought into operation in 1947. This station, with an installed capacity of 7,200 k.w., utilizes the irrigation waters released from the dam to generate electricity, and in addition is designed to provide an essential stabilizing feature in the transmission system between Burrinjuck and Lithgow, to which the station is interconnected. The output of the station at any time is dependent on the release of water for irrigation purposes.

Major hydro-electric developments which are being investigated by the New South Wales Government are the developments on the Clarence River at the Gorge, and the development of the Shoalhaven River for irrigation, water supply and hydro-electric purposes.

The Clarence Gorge scheme, situated 140 miles from Brisbane and 240 miles from Newcastle, embraces not only hydro-electric development, but also may offer considerable benefits by reason of the flood mitigation effects of a large dam built at this location. It has been suggested that a dam 200 feet high would impound some two million acre feet and might enable the production of as much as 75,000 k.w. The Queensland Government is also interested in the proposal from the aspect of obtaining additional energy to assist the Brisbane Metropolitan System and to extend rural services to south-eastern Queensland.

The Commonwealth and States agreed in 1945 on hydro-electric development at the Hume Dam. This proposal is associated with the intention to increase the capacity of this dam to two million acre feet. An initial installation of two 21,000 k.w. water turbine generators has been proposed.

2. **Victoria.**—(i) *Rainfall.* While the annual average rainfall of Victoria is 24 inches, it ranges from 10 inches in the far north-west to over 70 inches in southern and eastern districts. Of the State's area of 87,884 square miles 22.4 per cent. has an average below 15 inches and 37.6 per cent. receives less than 20 inches. Over 40 inches is received by 10.4 per cent. of the State. There is also a substantial year to year variation. For example, the average in 1889 was 32.77 inches; in 1902, 18.55; in 1914, 14.66; in 1917, 30.77; and in 1927, 18.56. Victoria is fortunate, however, in having (in common with New South Wales) access to the high rainfall and the snows of the lofty south-east highlands in which rises the Murray River.

(ii) *Administration.* As indicated earlier, practical steps were taken to organize Victoria's resources before the turn of the century but the passage of the Water Act in 1905 marked the commencement of sustained progress. The State Rivers and Water Supply Commission established by this Act is vested with the control of all irrigation, rural domestic and stock supplies, town water supplies and flood protection and drainage undertakings outside the Metropolitan area, with the exception of the irrigation area operated by the First Mildura Irrigation Trust and the town water supplies operated by locally-constituted Waterworks Trusts or Local Governing Bodies.

The operations of the First Mildura Irrigation Trust and the various Waterworks Trusts and Local Governing Bodies, as well as the various Sewerage Authorities which control sewerage undertakings in country towns, are also subject to general supervision by the Commission.

(iii) *General.* Since 1902, when a great drought emphasized the need for a concerted attack on water problems, the total capacity of water storages has increased from 172,000 to 1,969,970 acre feet (including Victoria's share of the Hume Dam). By means of channels, bores, etc. one-fourth of the State is artificially supplied for stock and domestic purposes. Large areas, which would be largely unproductive without water, are now contributing to the State's wealth. The area actually irrigated has increased from 110,000 acres in 1906 to 708,000 acres in 1947, and irrigation channels command 2,000,000 acres.

The Commission controls 35 large reservoirs and 225 subsidiary storages. Irrigation channels extend 4,404 miles; domestic and stock channels, 8,390 miles and drainage and flood protection channels, 2,144 miles, a total of 14,938 miles. In addition the Commission controls 1,120 miles of piping, comprising 258 miles of mains and 862 miles of reticulation. Farm holdings served with water total 39,383. Urban districts supplied by the Commission's channels and pipelines contain 134,460 persons in 127 towns, and a further 132 towns with a total population of 313,190 persons are supplied by Trusts under the supervision of the Commission.

To 30th June, 1947, the total capital expenditure on irrigation, rural water supply, country town water supply, and flood protection and drainage works amounted to £34,000,000, one-half of which is in respect of irrigation.

The total capital liability in respect of irrigation, rural water supply, flood protection and drainage is £23,500,000, all of which is borne by the State, and for country town water supplies the total capital liability is £6,900,000, of which £4,300,000 is borne by the State and the balance by the ratepayers in the various towns.

(iv) *Production.* The influence of irrigation on Victorian production is illustrated by the following estimates prepared by the Commission of the value of production from irrigated areas:—1905–6, £500,000; 1925–26, £5,000,000; 1945–46, £12,000,000. A classification of 1945–46 production (gross values on the farm) follows:—Farm Products—Cereal, Hay and Grass Seeds (£700,000), Dried Vine Fruits (£2,400,000); Horticultural—Citrus (£700,000), Deciduous Fruits (£1,300,000), Vegetables (£1,000,000); Livestock—Dairying (£3,200,000), Other Cattle (£250,000), Pigs (£300,000), Sheep, Lambs and Wool (£1,600,000), Poultry (£500,000), Miscellaneous (£50,000); Total £12,000,000.

Although the area irrigated is less than 2 per cent. of the State, it yields approximately 16 per cent. of Victoria's rural production. The following table indicates the crops under irrigated culture, and the total land irrigated :—

LAND UNDER IRRIGATION CULTURE: VICTORIA, 1946-47.

(Acres.)

System.	Area of Districts.	Area Irrigated, including Lands adjoining a District.									
		Cereals.	Lucerne.	Other Fodder Crops.	Pastures. Sown.	Pastures. Natural.	Vineyards.	Orchards.	Market Gardens.	Fallow and Miscellaneous.	Total.
Goulburn	1,253,118	46,478	34,669	7,294	191,068	34,477	462	20,912	5,569	4,115	345,044
Murray—											
Torrumbarry Weir ..	370,856	15,252	12,588	3,914	83,447	69,285	4,562	2,241	1,635	3,075	195,999
Yarrawonga Weir ..	269,334	15,070	3,294	708	7,383	3,539	31	1,785	518	2	32,330
By Pumping ..	45,180	117	288	137	109	145	20,363	1,075	210	68	22,512
Total	685,370	30,439	16,170	4,759	90,939	72,969	24,956	5,101	2,363	3,145	250,841
Loddon and other Northern Systems ..	(a)19,725	2,157	973	254	3,057	1,306	67	4,690	1,602	1,009	15,115
Southern Systems ..	69,278	108	3,782	522	27,050	1,122	..	545	3,246	503	36,878
Mildura and Private Diversions	(b)44,000	4,081	14,106	4,828	14,708	4,183	13,550	3,076	1,814	366	60,712
Grand Total ..	2,071,491	83,263	69,700	17,657	326,822	114,057	39,035	34,324	14,594	9,138	708,590

(a) Area of Campaspe District only. (b) Area of First Mildura Trust District only.

(v) *Main Irrigation Systems.* (a) *General.* The capacities of total storages (1946-47) are shown below in acre feet.

Goulburn System—Eildon Weir, 306,000 ; Goulburn Weir, 20,700 ; Waranga Basin, 333,400 ; *Murray-Loddon System*—Half share of River Murray Commission storages including Hume, Yarrawonga, Torrumbarry, Euston, Mildura and Wentworth, 736,420 ; Kow Swamp, Laanecoorie, Kerang-North and West Lakes, Lake Boga and Lake Cullulleraine, 148,210 ; total, 884,630. *Wimmera-Mallee*—206,480 ; *Maffra-Sale*—104,540 ; *Coliban*—58,850 ; *Werribee*—34,900 ; *Bellarine Peninsula*—10,800 ; *Mornington Peninsula*—5,800 ; *Otway*—1,080 ; *Miscellaneous*—2,790 ; *Total*—1,969,970.

(b) *Goulburn.* The Eildon and Waranga Reservoirs, on the Goulburn River, supply half the irrigated acreage, and form the largest system in Victoria. Annual rainfall in the valley is only 18 inches and the annual discharge has varied from 567,000 acre feet in a drought year to 6,202,171 acre feet in a particularly wet season. Total regulated supply is 960,100 acre feet, comprising 660,100 held in storages and 300,000 divertible direct from the river.

Water from Eildon Reservoir flows down the Goulburn for 150 miles to the Goulburn Weir, which raises the summer level of the river about 45 feet to 408 feet above sea level, where water is diverted to two main channels. The eastern main channel conveys water to four irrigation districts surrounding Shepparton and the western main channel fills Waranga Basin in addition to supplying the eastern portion of the Rodney Irrigation District.

Waranga has been formed on the site of a natural swamp by the construction of an earthen embankment 4½ miles long, creating a reservoir covering 23 square miles to an average depth of 31 feet. Two main outlet channels issue from this reservoir, one serving

the western part of the Rodney district; while the other serves districts as far west as Boort, and continuing to Beulah East, about 230 miles by channel from Waranga Basin or some 400 miles from Eildon, supplements the Wimmera-Mallee system.

Districts served comprise 202,400 acres east of the Goulburn; 608,350 acres between the Goulburn and Campaspe; 445,100 acres between the Campaspe and Loddon Rivers; and 79,900 acres west of the Loddon—a total of 1,335,750 acres. Main channels of the system have a total length of 213 miles and in addition there are 2,344 miles of distributaries, a total of 2,557 miles for the whole system.

The development of the fruit-canning industries in the Goulburn Valley is an index of the results of irrigation policy. Annual production from the Shepparton, Kyabram and Mooroopna canneries, together with that of city canneries—from Goulburn Valley fruit—aggregates 55,000,000 tins. This represents 70 per cent. of Australia's total production of canned peaches, pears and apricots. Other main products of the Goulburn districts are fat lambs, fodders, wine and table grapes and dairy products.

(c) *Murray River.* The waters of the River Murray are used to supply an area of more than 500,000 acres between Yarrawonga and Merbein, and channels totalling 1,450 miles are in service. The districts between Yarrawonga and Swan Hill, excepting Tresco, are supplied by gravitation and those down the river (Red Cliffs, Merbein, Nyah and Mildura) are supplied by pumping.

The Murray Valley Irrigation District, supplied from Yarrawonga, will serve 400,000 acres when completed. At 30th June, 1946, 220 miles of main and distributary channels were completed and supplied 98,000 acres west of Yarrawonga.

The gravitation system based on Torrumbarry Weir (52 miles downstream from Echuca) serves an area of 415,500 acres with 846 miles of supply channels. The weir raises the level of the river some 16 feet and enables water to be diverted throughout the year. A lock enables the passage of small river craft. The weir comprises an original design evolved by Mr. J. S. Dethridge, comprising a series of steel trestles running on a concrete foundation and provided with wooden drop bars to keep the river up to diverting level. In flood times the bars are removed and the trestles are drawn out of the stream.

Red Cliffs Irrigation District comprises 31,000 acres. At present 11,300 acres are irrigated. This ranks first in importance among Victoria's pumping schemes. A system of main and distributary channels commands every holding in the district. The total length of channels is 125 miles, of which 115 have been lined with concrete for more efficient distribution. Effective drainage is provided by 85 miles of sub-surface drains and 5 miles of open drains. The district, originally for soldier settlement, has been subdivided into 700 blocks. The area planted comprises 11,000 acres of vines and citrus. The first harvest (1924) returned 570 tons of dried fruit in addition to table grapes. The average harvest is now 18,000 tons of raisins, currants and sultanas as well as large quantities of grapes for dessert and distillation.

Merbein Irrigation District comprises 10,350 acres and contains 436 holdings averaging 24 acres each. The main and distributory channels have a length of 54 miles, and most are lined with concrete. A reticulated pipe system supplies the town of Merbein, and the pumps also supply the Yelta Waterworks District of 51,200 acres.

Nyah Irrigation District is supplied with water diverted from the Murray by a high-lift pumping plant. Total length of channels, nearly all of which are lined with concrete, is 34 miles. They serve 3,800 acres in 220 holdings devoted mainly to orchards and vineyards.

(*d*) *Mildura.* The First Mildura Irrigation Trust—which is the only Irrigation Trust operating in Victoria—controls an area of 44,000 acres, of which 12,755 acres are irrigated. This area irrigated includes 11,320 acres of vines, 600 acres of citrus trees and small areas of apricots, peaches, prunes, figs, almonds, olives, lucerne and other fodders. The irrigation water is pumped from the River Murray and distributed through 168 miles of channels, approximately half of which are concrete lined to reduce seepage. Effective drainage is provided by 100 miles of sub-surface pipe drains which vary in size from 4 inches to 36 inches. The depths of the drains vary from 4 feet 6 inches—the minimum necessary to ensure satisfactory drainage of the root systems of the plants—to obtain the required grade. The present steam-driven pumping plants, which have a combined capacity of 200 cubic feet per second, include some plant installed by the Chaffey Brothers in 1890, but steps are now being taken to replace this with new units. The area produces approximately 15,000 tons of raisins, currants and sultanas each year.

(*e*) *Wimmera-Mallee System.* The Wimmera–Mallee scheme is regarded as the most extensive domestic and stock supply system in the world. The main supply is drawn from five reservoirs at the foot of the Grampians mountains with a capacity of 206,480 acre feet. Supplementary water is drawn from the Goulburn channels and the Loddon River. The system serves an area of 11,000 square miles or nearly one-eighth of the State which is largely devoted to wheat and pastoral industries. Without the artificial supply of water, development would be meagre.

Once a year, in the winter or spring, a volume of 90,000 acre feet of water is distributed through 6,600 miles of open channel and some 3,000 miles of farm channels. It is the responsibility of farmers to provide storages sufficient in size to meet their stock and domestic requirements for the ensuing year. At least 16,000 tanks are served. In addition forty-five towns with a total population of 40,000 obtain their water from the system. A total population of 80,000 depends upon the scheme. In the vicinity of Horsham and Murtoa, near the main storages, 3,000 acres are irrigated for soft fruits and pastures, but the limited water resources available will not permit any extension of irrigation.

The northern part of the system is affected by sand drifting into the channels, and in 1945, which was a year of extremely dry weather conditions, the effects of the drought were accentuated by unwise farming methods and overgrazing and it became necessary for the Commission to remove 12,000,000 cubic yards of sand from the channels.

Water distribution, sand removal, and other costs of this water supply system over the past 10 years have averaged £233,000 per annum, which represents 8d. per acre of the area of lands actually supplied with water. The cost of removing sand drift from the channels, which is included in this figure, has averaged £119,200, ranging from £70,000 to £323,000. This represents 4d. per acre per annum, which is 50 per cent. of the total maintenance costs of the whole system.

It is considered that a substantial reduction of the maintenance costs of this system could be obtained by better farming methods, particularly the cessation of the practice of burning stubble after harvesting, the elimination of overgrazing and improvements in fallowing methods. Efforts in this direction, including the use of recently given compulsory powers to prohibit the fallowing of land or burning of stubble within three chains of channels in light sandy country, have already resulted in marked savings in maintenance costs—the cost of sand drift removal for 1947 being reduced to £90,000.

(vi) *Farm Water Supplies.* The Farm Water Supplies and Drainage Advances Act (1944) is designed to give farmers an opportunity of establishing or improving domestic and stock water supplies on their farms. Advances are made by the Board of Land and Works in approved cases to farmers who cannot finance works to supply water to their

farms. Water may be obtained from underground sources, from catchment and gully dams by diversion from existing streams and channels, by storage of sufficient water to meet a year's requirements and by installation of windmills or hydraulic rams. Advances are repayable over a period not exceeding ten years. The amount advanced may not exceed seven-eighths of the total cost of construction.

The Farm Water Supplies Branch has been set up by the State Rivers and Water Supply Commission to administer the Act and advise farmers even if finance is not required. A comprehensive booklet entitled "Farm Water Supplies for Domestic and Stock Purposes" has been issued concerning the scheme. It contains general advice on farm water supplies and plans of typical structures and layouts.

(vii) *Underground Resources.* A comprehensive survey of the underground water resources of Victoria has been commenced. It will compile records of bores in the Mallee, Wimmera and Glenelg regions, and provide a detailed description of the Murray Artesian Basin. Investigations have also been made into the underground water resources of local areas such as Orbost Flats, Llowalong Estate on the Avon River and at Bacchus Marsh where a number of observation bores have been installed.

The Murray Artesian Basin underlies an area of 107,250 square miles, of which 26,808 square miles are in Victoria, 28,269 square miles in South Australia and 52,173 square miles in New South Wales. The quality of the water varies in different parts of the basin. Over 300 bores exist in this State, with an average daily flow of 3,000,000 gallons. Bores range in depth from 50 to 3,000 feet.

(viii) *Future Programme.* Victoria has now reached the stage when the demand for water is far greater than the supply, and a programme which envisages an expenditure of £25,000,000 has been launched. This includes the Rocklands storage on the Glenelg River (264,000 acre feet) and the Cairn-Curran Reservoir on the Loddon (120,000 acre feet). Investigations have also reached an advanced stage concerning a proposed enlargement of the Eildon Reservoir on the Goulburn from 306,000 to 2,350,000 acre feet by the building of a large earthen embankment 250 feet high and 3,300 feet long at an estimated cost of £9,600,000. This would be Australia's greatest storage.

(ix) *Hydro-Electricity.* The Kiewa project in the Australian Alps is the largest single hydro-electric development in Australia. The Kiewa River is a tributary of the Murray. In 1937 approval was given by the Victorian Parliament for a scheme comprising four power stations with a total installed capacity of 117,000 k.w. Owing, however, to war-time shortage of material and labour, completion of this scheme has been much delayed. No. 3 station with an installed capacity of 24,000 k.w. began operating in 1944. Work is now in progress on No. 4. Since 1937, further investigation of the water-power resources of the area, particularly in the upper levels, has revealed the practicability of a large-scale extension of the scheme, with an increase in total installed capacity to 289,000 k.w. Proposals for such an enlargement are the subject of a report dated 21st November, 1947, which was submitted to the Victorian Government by the State Electricity Commission of Victoria. Basic both to the 1937 project and to the new proposals for a larger scheme are the storages at Pretty Valley and Rocky Valley on the Bogong High Plains. In the 1937 project these storages were to have been 95,000 acre feet and 13,000 acre feet respectively. Under the later proposals they are likely to be very substantially enlarged.

The Sugarloaf–Rubicon scheme was completed in 1928 and comprises five stations with an installed capacity of 26,500 k.w. Sugarloaf station on the Goulburn River is situated at Eildon Weir, which impounds 300,000 acre feet and serves extensive irrigation, domestic and stock districts. Power is generated at Sugarloaf during the summer months, when water is being released for irrigation, or when storage is full at other times. The four associated mountain stream stations on the Rubicon and Royston Rivers generate maximum power in the winter and spring, when water flow is at its greatest.

3. Queensland.—(i) *Rainfall.* The area of Queensland is 670,500 square miles. More than half the State (359,000 square miles) is in the tropics. Average rainfall varies from 5 inches in the south-west corner to falls exceeding 160 inches on the north-east coast, where the highest precipitation in Australia is recorded Every part of Queensland receives the greater proportion of its rainfall in the six hottest months. Variability increases in proportion to the distance from the coast.

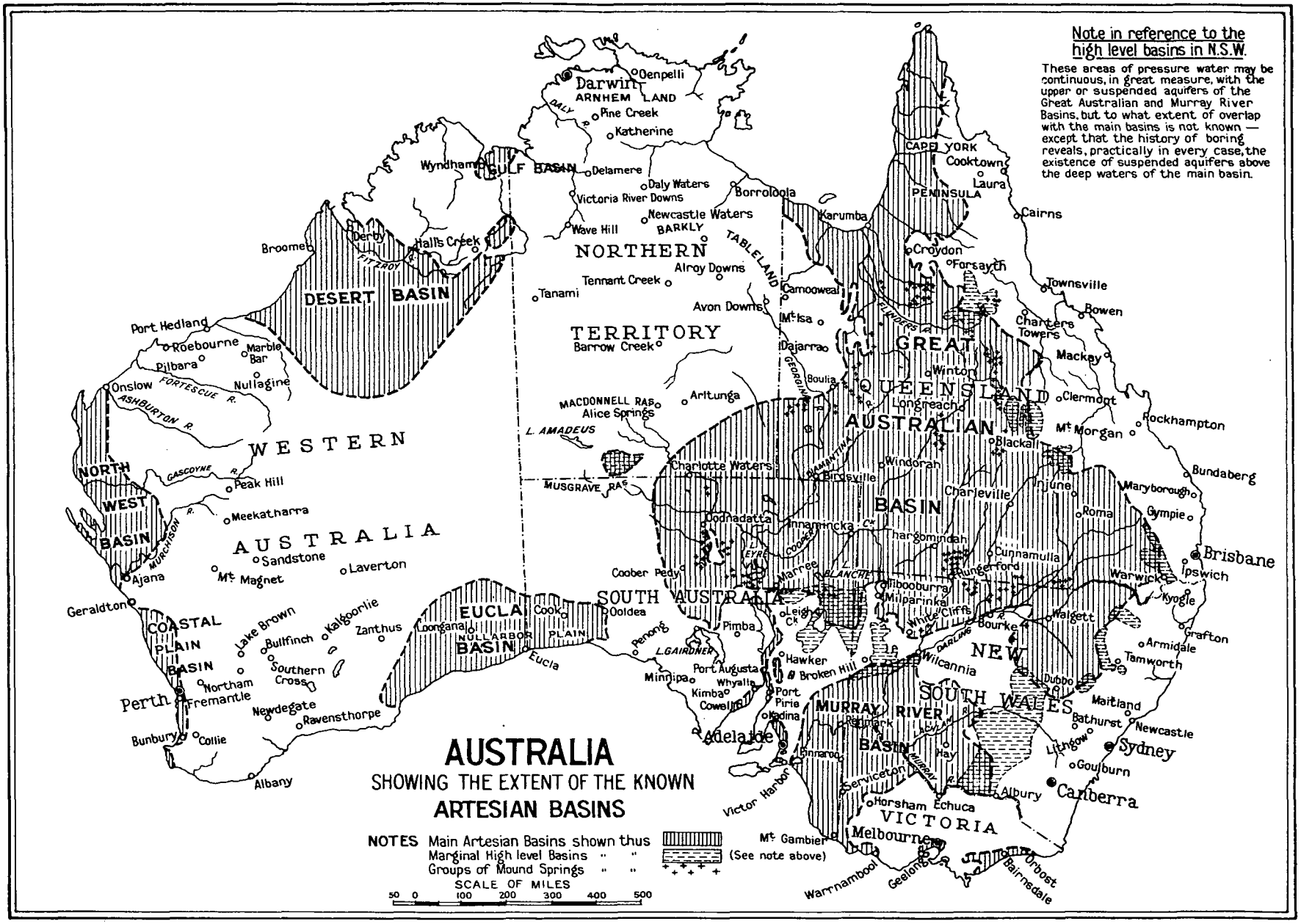
Areas which receive an annual average rainfall of less than 10 inches approximate 13 per cent. of the State; while 27.4 per cent. receives less than 15 inches; 47.1 per cent. less than 20 inches; and 65.9 per cent. less than 25 inches. Of the remaining 34.1 per cent. receiving 25 or more inches, 22.5 per cent. receives 30 or more inches.

(ii) *Administration.* The first comprehensive Water Act in Queensland was the Rights in Water and Water Conservation and Utilization Act of 1926. The Irrigation Act of 1922 made special provision for development of irrigation projects. From 1922 to 1931 these acts were administered by a Commissioner of Irrigation and Water Supply. but in 1931 the Land Administration Board was appointed to act as the Commissioner, and this continued until the Irrigation and Water Supply Commission Act of 1946 was proclaimed in 1947. Under this Act, the Corporation of the Commissioner of Irrigation and Water Supply was reconstituted. The Commissioner is responsible for carrying out the provisions of the Irrigation Acts 1922 to 1934 and the Water Acts 1926 to 1942. He is also responsible for investigations and planned development of water resources under the Land and Water Resources Development Acts 1943 to 1946.

(iii) *General.* Queensland's predominant interest in the past has been water for stock and domestic purposes in its great pastoral areas which contain half the Commonwealth's cattle, a fifth of the sheep and a third of the horses. More than half the State's rural production is derived from cattle and sheep. The cattle are spread throughout the State, but most thickly along the wet eastern coastline. The sheep are mainly pastured on the inland areas which form part of the Great Artesian Basin. Most of the dairy cattle are south of the Tropic of Capricorn along the moist coastlands and on the Darling Downs. Consequently, great interest has been concentrated on the stabilization of water supplies in the pastoral areas and the provision of water along stock routes for travelling stock. More recently, the development of irrigated pastures on the eastern seaboard for fattening stock adjacent to meatworks and markets has become an important aspect in the utilization of water resources.

The State's agricultural crops differ from those of other States in that a large proportion are tropical. Sugar is the greatest individual crop, representing in 1946–47 about 40 per cent. of total agricultural production. Approximately 11 per cent. of the sugar cane acreage is irrigated and represents more than half the irrigated acreage of Queensland.

(iv) *Control.* Following the lead given by the Victorian Water Act of 1905, the Rights in Water Act of 1910 abolished the old common law riparian rights and vested in the Crown the right to the use and flow and control of the water in watercourses, lakes and springs which flow through or past or form part of the land of two or more occupiers. This principle has passed unchanged into the current Acts. Artesian, sub-artesian and any other subterranean waters are also vested in the Crown. The Acts also provide that the bed and banks of any watercourse or lake forming the boundary wholly or in part of any alienated land shall remain the property of the Crown. Except for the general right of persons to use water for domestic and ordinary use and for watering stock. no person, except under licence, may divert or appropriate any water from a watercourse, lake or spring. In addition, riparian owners may use water for a garden connected with a dwelling, but must obtain the Commissioner's consent to construct any works required.



This map was re-drawn from that published in the Report of the Fifth Interstate Conference on Artesian Water, Sydney, 1928.

(v) *Great Artesian Basin.* (*a*) *General.* Western lands beyond the 22 inch rainfall belt are predominantly pastoral. Westerly-flowing rivers and interior streams do not generally lend themselves to large surface storage, but use of relatively shallow underground water on the river plains and small surface storages, wherever possible, is of great importance. In areas where artesian, sub-artesian, or surface water is not readily available excavated storage tanks up to 30,000 cubic yards capacity have been provided.

By far the most important factor in the development of the western pastoral areas of Queensland has been the Great Artesian Basin. This basin covers an area of some 350,000 square miles in Queensland and extends into New South Wales, South Australia and the Northern Territory. The supplies of this basin were first tapped by bores in 1884, and in 1946–47 some 2,071 bores were operating and represent a total of 3,145,054 feet of drilling.

If sub-artesian bores are added, total bores registered in the Basin would exceed 10,500 and the footage drilled about six million feet. Artesian water is usually distributed from the bores by small "delver" channels for the use of stock, and, on an average, 10,000 gallons per day are needed to serve one mile of channel or drain. Owing to evaporation and soakage, less than 5 per cent. of the water at the bore head is actually available for use by stock.

The falling off in the supplies from the bores of the Great Artesian Basin has been very noticeable since 1914, and in 1939 a Special Committee was appointed to enquire into the geology and hydrology of the Basin and the methods of utilization of its resources. A first progress report has been issued by this Committee. (*See* page 1103.)

(*b*) *Bore Areas.* The constitution of Bore Water Areas was inaugurated in 1913 to aid pastoral settlement in districts where large flows were available at costs beyond individual capacity and to conserve artesian supplies. Loans are made for acquisition of existing, or drilling of new, bores. The total number of areas is 67 and the length of drains served is 3,042 miles. At present, 20 of these areas are still under local Bore Area Boards and the balance are administered by the Commissioner. Water facilities such as bores, excavated and storage tanks, windmills and troughing, are also subsidized by the Government to make water available on dry stages of stock routes.

Additional information on underground sources in dry areas outside the artesian basin was obtained during the war when it became necessary to provide water along the new Mount Isa (Queensland) to Tennant Creek (Northern Territory) strategic highway, 403 miles long, of which 200 miles passed through country previously regarded as waterless. Twenty-two bores which were put down and equipped with pumping plant now deliver from 100 to 3,600 gallons per hour.

(vi) *Irrigation.* With the exception of the Dawson Valley Scheme, orthodox irrigation projects served by a channel system have not so far been constructed. Supplies for irrigation are pumped from streams or from natural underground storages. Most of this has been by private farmers operating under licence, and irrigation as a means of stabilizing production is receiving more and more attention, because even in the areas of high rainfall most of the precipitation is received from January to March. More than half the Queensland irrigators use internal combustion engines, but wherever it is available electricity is the more popular medium. The largest areas using electricity for pumping are in the Townsville–Burdekin areas and the south coast (near Brisbane). In the south-east, where the main crops are vegetables and fodders, spray lines are largely used, but in the northern districts growing sugar cane and maize, furrow irrigation is predominant.

Of the total area irrigated in the year ended 31st March, 1947 (79,030 acres), irrigated sugar lands accounted for 40,558 acres, of which 8,343 acres were located in the Maryborough district of Southern Queensland and 29,689 acres in the Townsville district of North Queensland.

The following table shows for each division of the State the area and principal crops irrigated for the year ended 31st March, 1947.

IRRIGATED AREAS: QUEENSLAND, YEAR ENDED 31st MARCH, 1947.

Division.	No. of Irrigators.	Total Area Irrigated.	Principal Crops Irrigated.						Irrigated Pastures.
			Vegetables.	Fruit.	Sugar Cane.	Tobacco.	Cotton.	Other Crops.	
		Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Southern Queensland ..	2,592	38,649	12,287	1,653	8,345	761	129	14,831	643
Central Queensland ..	258	3,016	702	152	6	1	179	1,904	72
Northern Queensland ..	1,172	37,365	3,452	512	32,207	789	38	309	58
Whole State ..	4,022	79,030	16,441	2,317	40,558	1,551	346	17,044	773

Growth of irrigation is illustrated by the following figures:—the total area of land irrigated in 1906 was 9,922 acres; in 1916, 10,886 acres; in 1926, 24,250 acres; in 1936–37, 44,509 acres; and in 1940–41, 60,961 acres.

Queensland irrigation practice bears little comparison with the pattern of southern States and it is interesting therefore to mention briefly the more important developments in tropical and sub-humid areas.

(vii) *Lockyer Valley.* West of Brisbane and within 50 miles of that metropolitan market is the Lockyer Valley, which is portion of the Brisbane River Basin. It is actually an extensive flood plain where heavy black alluvial soil thickly overlies gravels and sands carrying considerable quantities of water suitable for irrigation. Although the rainfall averages 30 inches the year to year variation is considerable, and irrigation is necessary for continued fodder production. Recent surveys suggest that some 60,000 acres of good irrigable land are available. At present, 9,000 acres are irrigated by 464 well pumps and 6,000 acres by pumping from open water in the Lockyer Creek and its tributaries. Over 60 per cent. of the farmers operate electric pumps for irrigation purposes and a special policy designed to encourage electrified irrigation is pursued by the City Electric Light Company which serves the Valley. The Irrigation and Water Supply Commission has also constructed a number of small weirs on Lockyer Creek with a total storage capacity of 1,370 acre feet. These also tend to augment and conserve underground supplies. Though the Valley contains less than 5 per cent. of the State's cultivated area, it produces a third of Queensland's potatoes, practically all its onions, a fifth of the lucerne hay, a quarter of the green fodder (excluding oats), a quarter of the pumpkins, a tenth of the maize, and contributes a substantial quantity of dairy products. To study local problems an Irrigation Research Station has recently been established at Gatton Agricultural College.

(viii) *Burdekin River.* This large northern river joins the sea between Townsville and Bowen. Heavy floods are experienced in summer, but the flow decreases substantially in winter. In the Delta area the annual rainfall is about 41 inches, but the major part falls in the months December to March. Consequently, sugar growers and other farmers have tapped the underground water resources of the Delta to obtain supplies of water in the dry periods. Sugar is the main irrigated crop, but citrus, pineapples and vegetables are also irrigated. Irrigated acreage is 30,000 acres, and approximately 1,000 acre feet are drawn daily from underground sources.

The Home Hill–Inkerman irrigation areas are served by an electricity scheme unique in Australia. The electricity scheme was originally established by the irrigation authorities in 1921, transferred to the Inkerman Irrigation Board in 1933, and is now controlled by the Townsville Regional Electricity Board. The load demand at Home Hill is basically a demand for irrigation. The load totals 3,000 k.w. between 7 a.m. and

7 p.m., when the farmers are irrigating and this occurs for 110 to 290 days per year. Since all irrigation in the district is on the furrows system, unrestricted hours of electricity supply are being considered. Water is pumped from shallow wells by electric pumping units. In the Ayr district individual plants, including windmills, are extensively used.

The following table illustrates the relationship between electricity and water in the Home Hill-Inkerman area in years exhibiting wide variations in rainfall.

Year.	Rainfall.	Area Watered.	Total power sold for Irrigation.	Water Pumped per Acre.	Days of Watering.
	Inches.	Acres.	Units.	Acre Feet.	No.
1934-35..	10.21	6,405	3,710,000	2.47	290
1935-36..	56.84	6,117	2,740,000	1.91	213
1937-38..	21.59	6,793	3,735,000	2.35	266
1945-46..	35.00	6,158	2,715,678	1.87	237

The Burdekin River Trust was established in 1940 to safeguard the sugar areas of the Delta from erosion and floods. A farm established by military authorities during the war has recently been converted into an Irrigation Research Station to study the development of pastures under tropical conditions.

A major multi-purpose scheme, involving irrigation, flood control and electric power, is being investigated with a view to assisting the stabilization of the meat industry through provision of adequate irrigated pastures for fattening purposes. Aerial and ground surveys suggest that 400,000 acres might be irrigated from a head storage 99 miles from the mouth. A long range development programme, based on the possibility of storing 4,000,000 acre feet, is being examined.

(ix) *Dawson Scheme.* This scheme, south-west of Rockhampton, aimed at an extensive development of the resources of the Dawson River. The scheme, as originally proposed, consisted of a large dam at Nathan's Gorge (capacity 2,500,000 acre feet) and a diversion weir and other works to distribute water to some 70,000 acres. However, the large dam was not built and irrigation is practised at Theodore only. This area is served by two timber weirs with a combined capacity of 11,000 acre feet. Water is pumped from the weir at Theodore and supplies 2,000 acres through 28 miles of earth channels. Pastures, vegetables, cotton, agricultural produce and dairy products represent the main production. A cheese factory has been established at Theodore and, with the increase in dairying based on irrigated lucerne, the future of the scheme seems much more secure that it did a few years ago. Many of the earlier mistakes are being corrected and the development of permanent pastures as part of a programme to stabilize fat stock production will be an important factor in its growth.

(x) *Tobacco.* Tobacco crops are irrigated almost to the extent of available water in the Texas and Inglewood areas of southern Queensland, and, to a smaller extent, at Mareeba in North Queensland. It is proposed to construct weirs in the Inglewood area. Also, proposals for a dam at Walsh River (10,000 acre feet capacity) to irrigate 3,000 acres of tobacco and 2,000 acres of alternative crops are being examined.

(xi) *Bureau of Investigation.* Under the land and Water Resources Development Act of 1943, the Commissioner of Irrigation and Water Supply was directed to prepare comprehensive plans for the development of the water resources of the State. Also, a Bureau of Investigation has been established under the Act for the co-ordinated investigation of land and water resource development.

The Bureau consists of representatives from the authorities controlling water resources, lands and agriculture and the chairman is the Co-ordinator General of Public Works.

Preliminary reports issued by the Bureau suggest the feasibility of storing considerable quantities of water in the eastern part of the State. However, prospects for storing large quantities in the western areas are not promising. The Bureau considers, as a result of investigations, that a major feature of large-scale irrigation works will be pasture development. Surveys have been carried out to determine possibilities of using underground and surface supplies in a number of river valleys, including the Condamine, Callide and Burnett Rivers.

(xii) *Channel Country.* Extensive investigations of the "Channel Country" fed by the western inland rivers in the south-west corner are being carried out. This country has an extraordinary topography, being intersected by deep and irregular flood channels through which millions of gallons of flood waters pass. The stabilization of water supplies would permit the depasturing of thousands of cattle travelling to coastal markets from the Barkly Tablelands. Therefore, the possibility of developing storages to create artificial floods when most needed for pasture and water purposes is being closely investigated.

(xiii) *Bradfield Scheme.* The late Dr. J. J. C. Bradfield hoped to overcome natural climatic disabilities of the Lake Eyre Basin (South Australia) and Western Queensland by diversion of North Queensland rivers to the inland slopes. His schemes were based to some extent on the theories of Mr. E. T. Quayle, a meteorologist who contended, *inter alia*, that evaporation from new water surfaces aggregating 20,000 square miles would provide an additional annual rainfall of 4 inches over 500,000 square miles. The scheme has been closely examined by the Chief Engineer of the Stanley River Works Board (Mr. W. Nimmo) in the light of information gained during and since the war in the form of military contour maps produced from aerial surveys, ground surveys and extended records of rainfall and stream flow. His report to the Queensland Government in 1947 contends that portions of the scheme are physically impracticable, and that, for example, the major dam proposed by Dr. Bradfield at Hell's Gate on the Burdekin River could not be built to the height of 400 feet as he suggested, the practicable limit being 300 feet. Even if it could be built to 400 feet the surface level would be insufficient to permit a reasonable diversion to the Flinders. The report considers that water might be diverted from a smaller part of the Burdekin catchment through a conduit 200 miles long, half being by tunnel with a small gradient and lined with concrete. The cost of this modified scheme would be approximately £100,000,000 compared with £40,000,000 mentioned by Bradfield. In addition, the Nimmo report indicated that half the available flow of the Tully River has already been hypothecated for hydro-electricity, while the whole is likely to be used ultimately for this purpose. Furthermore, the Queensland Government is considering a large storage on the Burdekin for coastal use. A description of the Bradfield Plan appears in the eight Report of the Rural Reconstruction Commission on Irrigation, Water Conservation and Land Drainage (1945).

(xiv) *Hydro-Electricity.* High seasonal rainfall, variability and small catchments combine against the exploitation of water resources for hydro-electric generation, but the Queensland Government has planned development among the streams of the Cairns-Ingham area. The Barron Falls scheme came into operation in 1935, utilizing a head of 410 feet 14 miles north-west of Cairns. Present installed capacity comprises three 2,000 h.p. water turbines. The district receives supply by means of a 22,000 volt transmission network. Average rainfall varies from 80 inches to 150 inches along the ranges of the catchment to less than 35 in the western portion. There is an extreme variation from year to year, resulting in great fluctuation of stream flow which, at Kuranda, has varied from a maximum of 117,000 cusecs in 1911 to a minimum of 30 in 1915. As the river is not sufficiently entrenched to provide good dam sites, no large storages have been provided. During periods of low water flow electricity demands are supplemented by fuel plant.

As the result of an investigation in 1944 it is also proposed to develop the Tully River at Tully Falls, 80 miles south of Cairns and 120 miles north-west of Townsville. Initial development provides for a small dam and generating station of about 17,000 k.w. capacity, while ultimate capacity, using full storage, will be about 45,000 k.w. The Tully has characteristics similar to the Barron.

Other northern schemes which have been investigated include Freshwater Creek (3,500 k.w.); North Johnstone and Russell Rivers (30,000 k.w.); and South Johnstone River (25,000 k.w.). Development will be determined by future demands.

A small hydro-electric scheme is installed on the Mossman River, 5 miles from Mossman, North Queensland. Utilizing a head of 200 feet, two 120 h.p. water turbine sets are installed. Further development is not possible owing to lack of water storage to cope with dry periods.

The Somerset Dam, a few miles above the confluence of the Brisbane and Stanley Rivers (in South Queensland), is almost complete. Storage capacity will be 724,000 acre feet. The estimated cost, £2,000,000, is being shared between the Government and the cities of Brisbane and Ipswich. The dam is designed for flood mitigation and to stabilize the Ipswich and Metropolitan water requirements. Plans provide for a 3,000 k.w. hydro-electric plant using a head of 80 feet.

4. **South Australia.**—(i) *Rainfall.* South Australia has an area of 380,000 square miles of which 312,000 have an arid climate, 53,000 a semi-arid climate, and the remaining 15,000 (or 4 per cent.) a sub-humid or humid climate. Annual average rainfall varies from under 5 inches in Lake Eyre Basin to 46 inches in the Mount Lofty Ranges skirting Adelaide, and 96 per cent. of the State receives less than 20 inches. Evaporation losses range from 36 to over 100 inches. In the lower northern and mid-northern agricultural areas evaporation averages 60 inches or nearly four times the normal rainfall. At Cook, in the far west, evaporation is eighteen times the average rainfall. Metropolitan water storage losses due to evaporation in 1943–44 were calculated to be 1,239 million gallons in comparison with a metropolitan consumption of 8,841 million gallons.

(ii) *Administration.* Water supplies, other than irrigation works, are under the control of the Engineering and Water Supply Department which administers the Waterworks Act governing the supply of water through mains in water districts for townships and farm lands. The Water Conservation Act provides for the construction of storages in non-reticulated areas and authorizes the Minister to "divert and impound the water from any streams or springs or alter their courses, and take water therefrom, or any other waters as may be found in, under or on any land entered upon for the purpose of supplying water to the inhabitants of any water district".

(iii) *General.* Early steps were taken to vest all running streams, springs and "soaks" in the Crown. Since the Water Conservation Act was passed in 1886 more than 550 dams, tanks and "rainsheds" have been built or acquired by the State, in addition to 460 wells and 340 bores, at a total cost of £1,185,841. The rainsheds comprise timber frameworks roofed with galvanized iron to catch precipitation which is delivered to storage tanks. Rainshed catchments vary from a few hundred square feet to four acres, discharging water into tanks ranging in capacity from 2,000 to 500,000 gallons. Over most of the State extraordinary precautions are taken to counteract evaporation. Pipelines in preference to open channels are used to reduce seepage and evaporation. Meters are attached to practically all services to check usage by individual consumers.

(iv) *Irrigation.* In South Australia irrigation is almost exclusively confined to the Murray Valley. Except for that held in various lock pools, no water from the Murray is stored in South Australia. Water is either pumped on to the land or gravitated from the river. The upper Murray of South Australia and the Mildura area of Victoria formed the cradle of Australian irrigation. South Australian irrigation commenced with an agreement between the Government and the Chaffey Brothers (*see* page 1097) in 1887 whereby 250,000 acres at Renmark were made available for irrigation settlement. The Department of Lands administers an area of 27,663 acres of high irrigable land, together with 9,365 acres of reclaimed swamp and 162,545 acres of non-irrigable land in the irrigation

areas. In addition the Renmark Irrigation Trust controls 20,557 acres, of which 8,340 are irrigated. Water used for irrigation in 1946 in the area controlled by the Department of Lands was 115,328 acre feet compared with 88,638 in 1926. In the Renmark area water used for irrigation in 1946–47 was 25,780 acre feet. The production of the upper Murray areas is almost exclusively fruit and vines. Principal crops are sultanas, currants, lexias, apricots, peaches, nectarines, pears and figs (mainly for dried fruit), wine grapes, and citrus fruits. Before irrigation, these semi-arid lands were of little productive value. The following table shows the acreage devoted to various crops in the government-controlled and Renmark Irrigation Trust areas on the upper Murray, and the government-controlled Reclaimed Swamp Districts near the mouth of the Murray :—

IRRIGATED AREAS : SOUTH AUSTRALIA, 1946-47.

ORCHARD LAND.

Name of Area.	Vine Fruits.	Tree Fruits.	Citrus Fruits.	Lucerne.	Total.
	Acres.	Acres.	Acres.	Acres.	Acres.
Berri	5,603	539	902	45	7,089
Cadell	645	90	70	60	865
Waikerie	2,015	326	890	61	3,292
Cobdogla	3,820	99	151	33	4,103
Moorook	403	74	126	15	618
Kingston	297	72	163	1	533
Chaffey	770	24	7	..	801
Mypolonga	36	323	409	..	768
Renmark	7,195	600	545	..	8,340
Total	20,784	2,147	3,263	215	26,409

RECLAIMED SWAMP LAND.

Name of Area.	Lucerne.	Other Fodders.	Total.
	Acres.	Acres.	Acres.
Monteith	..	917	917
Mypolonga	100	1,140	1,240
Wall	16	470	486
Burdett	2	90	92
Mobilong	49	403	452
Long Flat	..	240	240
Neeta	14	420	434
Pompoota	9	345	354
Cowirra	30	518	548
Jervois	94	3,391	3,485
Total	314	7,934	8,248

Total population of the upper Murray Irrigation Areas in South Australia is approximately 17,000 and 1,500 persons are settled on the reclaimed areas. The latter figure does not include the population of adjacent towns outside the area, but closely associated therewith.

The expenditure incurred by the Government in purchase of land, reclamation of swamps, preparation of irrigable lands for fruit growing, and purchase of pumping plants for drainage and water supply is approximately £4,250,000. A new irrigation development has been commenced at Loxton on the Murray, 180 miles from Adelaide, where it

is anticipated that about 7,000 acres will be developed for planting of trees and vines for War Service Land Settlement. Water will be pumped from the Murray into open concrete channels and thence reticulated on to the blocks through pipelines. This land has previously been used for cereals and grazing.

Renmark Irrigation Trust is administered by a local board of management consisting of seven members. This area differs from other South Australian irrigation areas in that the land is freehold instead of leasehold, self-contained and self-controlled. Every settler is entitled to vote for the election of Trust members. The Trust maintains 80 miles of channel for the reticulation of 8,250 acres.

(v) *Underground Water.* The occupied portion of South Australia is, on the whole, well endowed with underground water. The extent of the several artesian basins is tolerably well known. There are also considerable areas, notably in the south-east of the State, in which ground water occurs. Quality varies widely, but a great deal is at least useful for watering stock, the major use to which it is put. Apart from numerous boreholes and wells tapping underground water for farms, stations and towns, two notable basins are being developed on Eyre Peninsula—one at Flinders (Streaky Bay) and the other at Uley-Wanilla, near Port Lincoln. Leigh Creek coalfield, some 350 miles north of Adelaide, derives its supply from a borehole at Sliding Rock mine, the water being pumped through a pipeline 25 miles long.

The deepest portion of the Great Artesian Basin (in the north-east) is not extensively developed because development costs are large in proportion to the carrying capacity of the arid land. Deep boreholes have been drilled by the Government, however, to provide watering places along stock routes, and pastoralists rely largely on supplies in suspended basins at shallower depths.

There has been no regular measurement of flows from artesian bores, as in New South Wales and Queensland, but evidence of diminution exists. While the main intake areas for the Great Artesian and Murray Basins lie outside South Australia, there are considerable accessions within the State, and chemical contents of water of western origin are known to differ from those in the east. In South Australia absorption takes place in the channels of intermittent streams in times of flood, such streams being the Finke, Stevenson, Hamilton, Alberga and Arckaringa.

The minor intake areas of the Murray Basin are of the same character. The use of the waters of this basin is essential to settlement in the south-east, especially for farms, but also for township supplies for Mount Gambier, Naracoorte, Bordertown and Pinnaroo. In 1946–47 the ground water overlying the artesian water of the Murray Basin had been tapped by 121 boreholes drilled for new and prospective settlers. The maximum depth of these holes is 235 feet and the minimum 71 feet. Average tested yield is 14,808 gallons per day.

Pastoralists, farmers, market gardeners and others have been assisted with expert advice on drilling, for which the Government maintains about 15 drills. A large area within the Murray River Basin has been examined critically to ascertain the extent of land which could be used for lucerne and an examination of a large part of Kangaroo Island is being made to facilitate settlement.

The results of comprehensive surveys of underground supplies undertaken by geologists of the South Australian Government have been published in the State's geological survey bulletins in recent years.

(vi) *Farm Water Schemes.* While the Department of Mines and the Engineering and Water Supply Department give assistance to individual farmers in the provision of supplies from underground sources, a great part of the farming areas derive water supply under pressure from the extensive distribution systems connected to various reservoirs or the Murray River.

(vii) *Country Water Supply Schemes.* Areas extending for a distance of 90 miles north of Adelaide are supplied from the Warren and Barossa Reservoirs in the Barossa Ranges. The principal towns served are Gawler, Angaston, Nuriootpa, Kapunda, Eudunda, Freeling, Hamley Bridge, Riverton and Saddleworth.

Agricultural towns and areas further north are supplied from Beetaloo, Bundaleer and Baroota Reservoirs, with a connexion to the Warren system, the principal towns served being Port Pirie, Crystal Brook, Gladstone, Balaklava, Snowtown, Wallaroo, Moonta and Kadina.

The Morgan–Whyalla pipe line now provides an assured supply for the industrial town of Whyalla, also for Port Augusta, and generally augments the supplies to the northern areas.

Eyre Peninsula has, up to the present, been supplied from the Tod River Reservoir (9,167 acre feet) and three small reservoirs near the Franklin Harbour District. Tod River is the most important source of supply and water is pumped from this reservoir through 2½ miles of rising main to a service reservoir, the pumping lift being approximately 500 feet. From this service reservoir it gravitates for a distance of 240 miles in a northerly direction to Ceduna and the Port of Thevenard. Water from Tod River Reservoir is also used to supply Port Lincoln by gravitation, this town being 17 miles to the south. The principal towns served are Port Lincoln and Ceduna (Tod River system) and Cowell (Yeldulknie system). The demands of Eyre Peninsula have increased to such an extent in recent years that further sources of supply are necessary, and with this end in view a water-bearing area known as the Uley-Wanilla Basin is being developed. Boreholes are being sunk on this basin at selected points, pumping units installed and new mains and service reservoirs constructed. In addition to providing more water for the Tod River and Yeldulknie systems many miles of new mains are to be laid to serve areas hitherto without a distributed water supply.

Many other water supply schemes have been constructed in various parts of the State. These include pumping from the River Murray; supplies from sub-surface sources at Streaky Bay (Eyre Peninsula), Bordertown and Naracoorte and at other localities, including the recently established Leigh Creek coalfield; reservoirs to supply Victor Harbor, Strathalbyn and other southern districts; and a supply to Mount Gambier from the Blue Lake. More than 4,000,000 acres of country lands are provided with a reticulated supply.

(viii) *Morgan-Whyalla Pipeline.* The installation of a blast furnace at Whyalla and the extension of smelting activities of the Broken Hill Pty. Co. Ltd., combined with fears that existing supplies would be insufficient to prevent disaster to the agriculturalists of the north, led to the commencement of the pipeline in 1940. The work was completed in 1944 at a cost of £2,750,000 just in time to avert the threatened calamity. The total length of the pipeline, which brings water from the Murray at Morgan, is 223 miles. Water is pumped through 57 miles of 30 inch steel main to a summit storage at Hanson, 1,558 feet higher than Morgan; then gravitated through 166 miles of 26 inch to 21 inch pipe to Whyalla on the western shores of Spencer Gulf. Pipeline capacity is 2,150 million gallons per annum which can be boosted to 2,400 million. A power line from Adelaide, 119 miles distant, supplies the electricity for pumping. Under an agreement between the South Australian Government and the Commonwealth, an amount not exceeding 3,000,000 gallons in any week or 150 million gallons per year is to be made available at Port Augusta, this now being mainly required for railway purposes, including dwellings, workshops and locomotives. An agreement with the Broken Hill Pty. Co. Ltd. provides for a supply of not more than 3,000,000 gallons of water at Whyalla in any given period of 24 hours, for which the company pays a minimum of £40,000 a year irrespective of the amount used up to 343 million gallons. Above that figure payments are based on actual consumption.

(ix) *South-Eastern Drainage.* Nature has played an ironic prank in the south-east of South Australia where it has been necessary to construct costly drainage schemes to dispose of surplus water. The area comprises a series of valleys or flats separated by low ranges parallel to the coastline which prevent natural drainage. The highest "range" is approximately 50 feet above the adjacent flat and the most easterly flat, some 50 miles from the coast, is 200 feet above sea level. The ranges are generally of poor soil or stony but the flats are fertile.

The Millicent Drainage System was completed in 1885, when 100,000 acres were reclaimed by 100 miles of drains at a cost of £150,000, which was included in the land allotment prices.

The South Eastern Drainage Area System, which is controlled by the South Eastern Drainage Board, comprises drains constructed by the Government at national cost, plus those undertaken by the Government in co-operation with the landholders. There are approximately 500 miles of drains, costing £720,000, of which the landholders are required to contribute £125,000. A scheme for the complete drainage and settlement of 400,000 acres in the western sector is under consideration.

(x) *Summary.* Water conservation and distribution works in South Australia have cost £20,000,000 (exclusive of river control and irrigation works on the River Murray which are dealt with elsewhere). A summary of statistical information concerning country supplies in 1946-47 follows :—Length of water mains, 5,400 miles ; approximate population served, 220,000 ; area served, approximately 4,000,000 acres ; and total capital cost, £13,688,324.

5. **Western Australia.**—(i) *Rainfall.* More than half Western Australia's area of 975,920 square miles receives an annual average rainfall of less than 10 inches and 87.2 per cent. receives less than 20 inches. Only 5.4 per cent. has an annual average above 30 inches, the bulk of which is associated with the low coastal ranges of the south-west. There are few rivers which run all the year, and underground supplies are generally regarded as poor, except in the artesian basins. Evaporation is high and records show that in the wheat belt (with an average annual rainfall of 10 to 20 inches) the average dam will lose annually between six and seven feet depth of water by evaporation. High evaporation rates, therefore, make special safeguards necessary, as for example, at Wicherina reservoir (105,000,000 gallons capacity) near Geraldton, where the storage has been roofed over an area of seventeen acres to prevent the loss of 40 million gallons annually. Eighty per cent. of the State's rainfall comes in five months, even in areas of adequate rainfall. Main irrigation areas in the south-west have an annual average of 40 inches. The bulk falls in May to September (inclusive). In December to March (inclusive) the annual average over a period of years has been half an inch per month.

(ii) *Administration.* Irrigation districts are administered under the Rights in Water and Irrigation Act of 1914-45 and the Government is advised by an Irrigation Commission representing the local irrigationists and government technical and financial branches. The Goldfields Water Supply is administered by a branch of the Public Works Water Supply Department and its responsibilities include control of water from this scheme for agricultural purposes. The metropolitan water supply is controlled by a separate department under the control of the Minister for Water Supply, Sewerage and Drainage. Under the Water Boards Act (1904) seventeen towns are administered by local water boards and nineteen are under direct Ministerial control. The Minister also controls three District Farming Schemes. Water rights over water flowing in streams and water courses is vested in the Crown unless specifically appropriated for irrigation purposes under the irrigation legislation.

(iii) *Irrigation.* The main irrigation areas are along the south-west railway line between Waroona (70 miles from Perth) and Dardanup (116 miles from Perth). The total area irrigated in 1946-47 was 17,947 acres and the total water allocated was 54,956 acre feet. In 1946-47 the total acre waterings (i.e. the number of acres watered multiplied by the average number of waterings) was 71,104 and the number of holdings 438.

In 1917 a concrete gravity dam with a capacity of 1,840 acre feet was built on the Harvey River to irrigate a district of 2,928 acres designed mainly for citrus culture. As the orchards proved a failure, the water was devoted to pastures and the demand soon exceeded supply. Accordingly, the reservoir was enlarged to 8,300 acre feet and Harvey District No. 2 was established. At the same time the Waroona District of 10,325 acres was constituted, and served from the Drakesbrook reservoir (1,855 acre feet). The Collie River District (28,762 acres) was also established, served by a reservoir of 27,800 acre feet.

To meet the demand for more frequent waterings, a dam has been constructed at Samson's Brook (6,540 acre feet) and the Stirling Dam was completed in 1947 with a capacity of 44,344 acre feet. The latter is the second largest storage in Western Australia and is regarded as the highest earth dam in Australia, the total height of the wall being 148 feet above stream level.

The following table, which shows acre waterings supplied to crops during each season 1935–36 to 1946–47, illustrates the growth of these irrigation schemes.

IRRIGATION, WESTERN AUSTRALIA: ACRE WATERINGS.

Year.	Pasture.	Fodder.	Potatoes.	Vegetables.	Orchard.	Flax and Broom Millet, etc.	All Crops.
1935–36	18,049	2,177	2,339	613	891	..	24,069
1936–37	24,067	1,528	3,305	986	1,025	2	30,913
1937–38	25,606	1,575	2,394	904	1,102	..	31,581
1938–39	31,049	934	3,142	692	922	..	36,739
1939–40	35,774	747	5,330	980	928	..	43,759
1940–41	30,731	839	3,352	444	940	18	36,324
1941–42	40,625	961	2,811	1,259	879	8	46,543
1942–43	35,552	931	2,565	1,687	789	..	41,524
1943–44	53,389	434	2,787	2,386	1,134	40	60,170
1944–45	50,748	453	5,363	2,543	1,107	66	60,280
1945–46	57,707	995	4,269	2,915	1,176	209	67,271
1946–47	61,948	547	4,304	3,209	1,096	..	71,104

(iv) *Goldfields Scheme.* Western Australia has one of Australia's most spectacular water supply schemes. A substantial population gathered in the Kalgoorlie-Coolgardie goldfields after the discovery of gold in 1892. As the area is 400 miles from the coast and has an annual rainfall ranging from 4 to 9 inches, the Government spent £400,000 in providing water by boring, well-sinking and distillation. The goldfields were not connected with the coast by rail at that time and many difficulties arose in bringing water from a distance. Consequently a scheme propounded by the Engineer-in-Chief (Mr. C. Y. O'Connor) was adopted to provide a storage at Mundaring on the Helena River, 26 miles from Perth, from which water could be pumped through a pipeline to the goldfields. The job was commenced in 1898 and completed in 1903. Mundaring reservoir has a capacity of 4,650 million gallons and a catchment of 569 square miles. The water now passes through 430 miles of steel main, mostly of 30 inch diameter, aided by eight pumping stations, involving a total net lift of 1,280 feet.

Hundreds of miles of branch mains and pipes have been laid to mining districts, towns and farming districts, the most important being the Norseman extension of 101 miles. The system serves 34 towns and water is reticulated to 970,000 acres of farming lands. Total length of mains is 1,757 miles and the population served is 50,000. Total quantity of water pumped from Mundaring in 1946–47 was 2,225 million gallons. Total cost of system to the end of 1946–47 was £6,281,291.

(v) *Rock Catchments.* An interesting feature of the State's conservation system is found in the Barbalin, Narembeen and Kondinin District Farming Land Schemes in the wheat belt, where extensive granite outcrops have been used as catchments. The rain is caught at the foot of the rocks, and pumped to tanks from which the water is reticulated to farms. The Barbalin system comprises Barbalin Reservoir (41,000,000 gallons); Waddouring Reservoir (21,750,000 gallons) and Knungagin (7,750,000 gallons), the catchment areas being 272 acres, 160 acres and 87 acres respectively. Over 300 farms are supplied comprising 340,000 acres. Total mileage of pipes is 329, and these serve a number of small towns also. This scheme is now connected with the Goldfields pipeline to supplement supply in dry times. The Narembeen reservoir has a capacity of 9,500,000 gallons based on a catchment of 119 acres. It serves 86 farms totalling 88,000 acres. The Kondinin reservoir has a capacity of 9,500,000 gallons based on a catchment of 70 acres. The scheme supplies 38 farms totalling 40,000 acres.

(vi) *South-west Scheme.* The Commonwealth Government has agreed to assist a scheme to extend water for agricultural areas and towns in the south-west of Western Australia, which will be administered by the State Government. It is estimated that the scheme will cost £4,300,000 of which the Commonwealth will contribute £2,150,000. The scheme provides for raising the height of the Mundaring Weir and the Wellington Dam and increasing the capacity of pumping stations on the Goldfields pipeline to permit water diversions from that source. Twenty-three towns and over 4,000,000 acres of agricultural country will benefit.

(vii) *Underground Water.* Individual farmers, orchardists, market gardeners and others derive water from wells or windmills wherever available, and, where power is available, pumps and motors are used to tap such supplies. The Department of Public Works has twelve boring plants which are lent out to farmers to facilitate boring operations to an average depth of 150 feet. The Department also contracts with private firms to bore for communal farm supplies. Records are kept of all bores sunk (including exploratory bores) together with details concerning the strata encountered, and the quality and quantity of water obtained. These are made available to anyone who wishes to bore on his own account in the same locality.

During the past 53 years 296 artesian and sub-artesian bores have been sunk, mostly for private purposes. No bores may be sunk without a government licence. The most complete operation records exist in relation to bores in and around Perth which augment metropolitan supplies in the summer months. When these bores are brought into service at the beginning of each season (usually about the end of October), the pressures are sufficient to maintain the flow, but by February the pressures have to be boosted to maintain flow. The bores are usually closed down by the end of March, and from then the pressures gradually rise to the normal static maximum as no draw takes place for six to seven months, confirming the conclusions of the Queensland Artesian Investigation Committee.

The total depth of all recorded bores in Western Australia is 242,333 feet; daily flow is 80,418,500 gallons; and the average depth at which water is struck is 819 feet. Maximum depth of any bore is 3,325 feet and minimum 39 feet.

(viii) *Ord River Scheme.* The Ord River in the north-west of Western Australia traverses a tropical area served with monsoonal rains of irregular incidence and quantity, varying from 20 inches in the south to 30 in the north. The hottest months (December to March) are also months of highest rainfall. Communications and population are sparse. The Western Australian Government is considering a proposal to build a dam to conserve 2,000,000 acre feet of water, equipped with hydro-electric plant, which might supply irrigation water for an area of 100,000 acres if investigations show that the climate and soil conditions are suitable for vegetables, tropical fruits and rice. However, the economic production of these and other crops, as well as the possible use of such irrigation areas for interim fattening of cattle, is being examined at the Kimberley Research Station on the Ord River.

6. **Tasmania.**—(i) *Rainfall.* The area of Tasmania is 26,215 square miles. Mainly mountainous and in the temperate latitudes, the State has a high and comparatively regular rainfall. Of the total area, 56.5 per cent. receives an annual average exceeding 40 inches; 76.9 per cent. receives more than 30 inches; 11.4 per cent. receives between 25 and 30 inches; and 11.0 per cent. between 20 and 25 inches. Maximum rainfall in the Lake Margaret district has been known to exceed 175 inches (in 1924), and many mountainous areas receive over 100 inches.

(ii) *General.* Owing to its fortunate rainfall position, scarcity of water is not a serious problem in normal seasons. Conservation of water for hydro-electric generation is the predominant interest, and conservation for domestic and industrial purposes is more important than irrigation.

(iii) *Administration.* The State does not own all natural waters as in Victoria, and consequently the subject of water rights is a difficult one. The Mines Department has power to grant certain rights for mining operations, and the Hydro-Electric Commission must approve the abstraction of water from any stream or lake of potential value for power generation. There is no machinery other than the Courts for deciding the issue in cases where municipal councils or private individuals propose to divert water for town supplies or irrigation from streams in which neither of these two authorities is interested. The only exceptions are a few municipal and industrial undertakings which have statutory rights, such as the Hobart Corporation, two paper manufacturers and a company producing paint ingredients.

(iv) *Irrigation.* There are no State irrigation projects and none are envisaged in the near future. All systems operating are privately owned and, with one exception (at Bushy Park), are single farm units. At Bushy Park a small system serves a group of properties. The larger proportion of the area under irrigation is watered by gravitational systems and the remainder concerns areas devoted to vegetables and served by municipal water supplies. Irrigation, as practised in Tasmania, was applied in 1946–47 to 9,326 acres devoted to: hops (1,153 acres); fruit (1,207 acres); pastures (6,191 acres); cereals, hay, etc. (240 acres) and other crops (535 acres).

(v) *Underground Water.* There is only one known flowing bore—at Speyrton, which yields 1,690 gallons per hour. Underground water is of poor quality and a small quantity exists over an area in the Midlands which has been exploited to a limited extent only by bores and windmills. Geological conditions do not appear to favor the utilization of ground water except on a minor scale.

(vi) *Farm Supply Schemes.* Conservation of water on farms is not practised to the same extent as on the mainland, probably because running streams and good rainfall are on a more generous scale. Provision of artificial storages (apart from house tanks) is rare.

(vii) *Industrial.* Three principal industrial schemes have been installed privately. The Australian Newsprint Mills pump approximately 6,000,000 gallons a day from the Derwent River at Lawaitta for the Boyer mills where it is coagulated and filtered. Associated Paper Mills pump several million gallons a day from Emu River at Burnie, and Titan Products Pty. Ltd. reticulate water from Chasm Creek to their factory at Weybridge. Potential sources capable of greater development without storage exist on the Derwent, South Esk, Huon, Lake Mersey and Forth Rivers. There is also a great reserve of untapped permanent streams in the western half of the State, at present largely unsettled. Diversion to the eastern side of the watersheds is regarded as practicable.

(viii) *Hydro-Electricity.* (*a*) *General.* Tasmania's hydro-electric potential has been estimated at 3,500,000 h.p., making the State the major contributor to the Australian total. Installed capacity at the end of 1947 was 184,000 k.w. or approximately two-thirds of the Australian total of 265,400 k.w.

Tasmania depends entirely on water for power development, and its rich mineral and timber resources have contributed substantially to such development. When the Launceston City Council commenced the construction of a 75 h.p. station at Duck Reach on the Esk River in 1895, Tasmania pioneered the generation of water power for Australia. The undertaking was taken over by the Hydro-Electric Commission in 1944, when its capacity had been increased to 3,500 h.p.

The Commission now provides most of Tasmania's power requirements from three schemes—the Waddamana, Tarraleah and Shannon. The Mount Lyell Mining and Railway Co. Ltd. also operates a 10,000 k.w. plant at Lake Margaret to serve copper mines, and this station is interconnected with the Commission's network. Small stations operated by tin mining companies have a total capacity of 2,000 k.w.

(*b*) *Waddamana.* This scheme was completed in 1916 with an original capacity of 10,000 h.p., since increased to 66,000 h.p. Waddamana B was completed in 1944 with a capacity of 33,400 h.p. and since that date the total has been increased to 50,000 h.p. A further 16,700 h.p. plant is being installed. When this is installed, the total capacity of Waddamana will be 132,700 h.p. The scheme was commenced by the Hydro-electric Power and Metallurgical Co., formed to generate power from the Great Lake to treat complex ores by an electrolytic method, but was taken over by the Government when the company faced financial difficulties.

(*c*) *Shannon.* To meet the terms of a contract with the Electrolytic Zinc Co. of Australasia Ltd. in 1919, the Government decided to enlarge the Great Lake scheme by the construction of a dam at the outlet of the lake, 3,380 feet above sea level, to conserve the water on a catchment of 150 square miles, with a rainfall ranging up to 60 inches. The dam is situated at the source of the River Shannon. A canal, five miles long, to divert water from the River Ouse to the Great Lake, was completed in 1923 and the catchment increased by the addition of the run-off from 100 square miles of rugged country to the westward with a rainfall up to 80 inches. This canal was partially relined with concrete in 1943. Water from the Great Lake, representing a flow of 610 cusecs or 350 million gallons a day, passes down the Shannon River to the Shannon Power Station by pipeline and canal, where 14,500 h.p. is generated before the water passes into the Waddamana canal and power station. A second canal is under construction to provide water for operation of the additional plant being installed at Waddamana. Transmission lines connect the stations with Burnie, Launceston and Hobart.

(*d*) *Tarraleah.* This development is situated on the Nive River, and served by water from the River Derwent at Lake St. Clair and Clark Dam. The dam will ultimately have a hydro-electric installation. The system was completed in 1938 and now has a total capacity of 105,000 h.p. The water from Lake St. Clair flows down the Derwent to Butler's Gorge, where a 200 feet concrete dam will impound 243,000 acre feet of water. At the foot of the dam a power station is being built to produce an average of 12,000 h.p.

(*e*) *Lake Margaret.* On Mount Sedgwick, on the west coast, 2,168 feet above sea level, is the site of two stations with a combined capacity of 12,000 h.p. They are operated by the Mount Lyell Mining and Railway Co. Ltd. whose copper smelting works are 5 miles distant. The average rainfall on the catchment is 147 inches.

(*f*) *Future Programme.* The Hydro-Electric Commission is carrying out investigations to develop an additional 100,000 h.p. to meet increasing demands. Coupled with this is a long range development programme concerned with the provision of 500,000 h.p. in the next twenty years. The authorities consider the most economical development will be in the high catchment areas of the Derwent, Nive and Ouse Rivers. Within the next three years the Clark Dam will be completed to provide an additional 34,000 h.p. at an estimated cost of £2,000,000.

(g) *Summary.* The following table represents the development of Tasmania's hydro-electric power resources at the end of 1947 :—

HYDRO-ELECTRIC POWER RESOURCES : TASMANIA, 1947.

Name.	Installed Capacity.	Ultimate Capacity.	Average Flow per Year.
	K.W.	K.W.	Acre Feet.
Waddamana	85,000	97,000	430,000
Shannon	10,500	10,500	400,000
Tarraleah	75,000	90,000	634,000
Clark Dam	Nil	12,000	634,000
Launceston	2,000	2,000	211,000
Lake Margaret	10,000	10,000	56,000

7. **Northern Territory.**—(i) *Rainfall.* The Northern Territory (523,620 square miles) is located in the North-West Monsoon–South-East Trade Wind Belt and consequently has a pronounced summer incidence of rainfall. In northern sections approximately 85 per cent. of the annual precipitation occurs during the four months, December to March. It is not unusual for up to six of the coldest months to be quite rainless. In the south the seasonal variation is less marked and during winter months southern depressions not infrequently bring beneficial rains. Rainfall varies from 60 inches at Darwin to below 5 inches in the south-east corner. Over the total area, 26.6 per cent. receives an average annual rainfall of over 25 inches per annum ; 16.3 per cent. receives between 15 and 25 inches ; 57.1 per cent. receives below 15 inches.

The north to south variation in mean yearly temperature is not very pronounced, ranging from 85 degrees at Darwin to a little over 70 at Alice Springs. Moreover, this difference is largely accounted for by the difference in topography, Alice Springs being some 2,000 feet above sea level. Seasonal and diurnal variations are much more marked, being much greater in the south than the north. While Alice Springs experiences fairly severe frosts in the winter months, summer temperatures of up to 115 and even 120 degrees may occur in the desert to the south-east of the Territory. Darwin, on the other hand, is frost free and rarely registers temperatures over 100 degrees. In a large part of the Territory evaporation rates are high.

(ii) *Rivers.* The main topographical features are the Arnhem Land Plateau in the north-east, the Barkly Tableland in the east, and the MacDonnell Ranges rising out of a central peneplain in the south. About half the territory south of the 15 inch isohyet drains internally. In southern parts the rivers are really storm channels, and when they flow their waters are lost in the near-desert soils. In the north the coastal rivers flow continuously throughout the year, though their flow is markedly seasonal.

(iii) *Irrigation.* There are no large-scale water conservation projects in the Territory with the exception of the Manton Dam (80,350 acre feet) which serves Darwin with a reticulated supply. Irrigation has therefore assumed no current importance. Small agricultural activity exists in the higher rainfall areas near the coast, the rainfall being supplemented by small-scale irrigation only. Peanuts are grown under natural rainfall conditions north of Katherine. Market gardens and citrus orchards exist on a more intensive scale near Alice Springs, being dependent on small-scale irrigation practices.

The Katherine River appears to offer large-scale irrigation potentialities on the levee soils below the township. The river passes through a gorge some miles upstream under conditions apparently suitable for dam construction. No geological or drilling investigations have yet been made, but the Commonwealth Scientific and Industrial Research Organization is investigating the potentialities of the soil for agricultural production.

(iv) *Underground Water.* Artesian water is found mainly in the south-east where the Great Artesian Basin enters the Territory. Pastoral (beef) production accounts for over 90 per cent. of the Territory's income, and the marked seasonal conditions affect the

industry's economy. During the wet summer season there is adequate water, but during the winter most natural watering points disappear, and pastures dry. Bores supplement the permanent watering points which are mainly along river frontages. The cattle industry is concentrated in the area in which the feed retains an appreciable nutritive value during the winter despite the dry conditions. This area is not in the wetter coastal regions, but in the inland belt of 15 to 25 inch rainfall and to the north of Alice Springs. Lack of bores is a limiting factor in the industry's economy, as cattle are able to thrive only within certain distances of reliable water.

In 1947 some 602 bores were recorded, comprising 339 put down by pastoralists, 106 established by the Government on stock routes, 12 leased by the Government to pastoralists, 2 maintained by the Postmaster-General's Department, and 143 put down north of Birdum by the military services during the war.

Complete records are not available concerning these bores. Stock route bores range in depth from 37 to 640 feet, and the total hourly capacity of the 106 bores concerned is approximately 136,615 gallons per hour. Statistics for the 143 service bores put down during the war show that depths range from 40 to 374 feet, and that total hourly capacity approximates 150,530 gallons per hour.

(v) *Control.* Under the Control of Waters Ordinance (1938) of the Northern Territory natural waters are 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) and diversion of water is prohibited except under conditions prescribed.

8. **Papua and New Guinea.**—(i) *Rainfall.* When all localities (32 stations) where gauges are kept are taken into consideration, the average annual rainfall, over periods varying from two to ten years, is about 159.21 inches. This figure includes both inland and coastal stations. Mean annual rainfall for the inland stations, which average 786 feet in height, is 134.77 inches and for coastal stations, 83.66 inches.

(ii) *General.* For a general description of these territories see Chapter X.—"The Territories of Australia", pages 345, 346 and 353 of this Year Book. Irrigation has not been developed on any organized basis owing to the availability of high rainfall and the nature of agricultural development. The main water conservation interest in New Guinea at present is the hydro-electric potential.

Those portions of New Guinea administered by Australia are well served with large rivers deriving their water from heavy tropical rains and high mountains which rise to 13,000 feet. Complete data concerning water resources are not available, but it is known that the opportunities for production of hydro-electric power are extensive. Some authorities estimate that 20,000,000 h.p. could be generated. Present investigations have been limited to those areas where a demand for power is likely to arise. New Guinea has a substantial native population and few major industries.

Explorations over the southern portion, known as Papua, have resulted in the collection of much information concerning water resources. The largest stream is the Fly River, at least 500 miles long, which is situated in the western division. Its large tributaries extend to the northern boundary of the Territory rising among lofty mountain ranges. Records show that at a point above the tidal influence, where the river is 600 yards wide and 40 feet deep, the stream travels at a rate of 3½ miles per hour and discharges 105,200,000 gallons per minute.

All the principal rivers flow from the main range in a southerly direction. Most of them carry a large volume from a great height over relatively short distances. They have a total catchment of about 50,000 square miles having an elevation between 2,000 and 13,000 feet.

(iii) *Hydro-Electricity.* The Government Geologist has estimated that if only 50 per cent. of the annual rainfall were utilized through a height of only 500 feet a total of 8,500,000 h.p. would be produced.

The Bulolo River, which delivers 400 to 500 cusecs at a point 2,600 feet above sea level, is being harnessed by a gold mining company for 20,000 h.p., but total power produced in New Guinea in 1945–46 was 10,000 h.p.

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