1

WATER AND VICTORIA'S ENVIRONMENT*

INTRODUCTION

Australia is a continent of generally low relief. Much of the country is flat and featureless, with the highest mountain (Mt Kosciusko) reaching an elevation of only 2,230 metres above sea level.

It is not surprising, then, that rainfall over most of the continent is low and extremely variable. Average annual rainfall varies from less than 100 mm in the north-east of South Australia, to over 3,000 mm near Innisfail in Queensland. Evaporation generally exceeds rainfall over most of the continent for most of the year, evaporation rates being significantly higher than in North America and Europe. As a result of the generally low rainfall and high evaporation, surface run-off is generally low. Moreover, it is unevenly distributed and exhibits a high degree of variability. These factors make it difficult and expensive to harness the water resources of the nation.

Victoria is the second smallest State of Australia, having a total area of 227,600 square kilometres or 2.96 per cent of the total land area of Australia. However, with its estimated population of 3,907,900 (December 1980) it has the second largest population of the States and is the most densely populated (17.2 persons per square kilometre against an Australian average of 1.9 persons per square kilometre).

By comparison with most of the rest of Australia, Victoria is in a better position with regard to rainfall and run-off. Average annual rainfall varies from 250 mm in the north-western corner of the State to over 1,400 mm in the ranges north-east of Melbourne. Nevertheless, rainfall and run-off are highly variable and unreliable. Conservation of the surface water resources of the State to provide secure supplies is therefore a formidable task requiring detailed study of the available resources and their variations over space and time.

The historical development of the available water resources to meet increasing demands of the first settlers follows closely upon the story of agricultural and urban settlement of Victoria. The early settlers of Melbourne drew their domestic water supplies directly from the Yarra River at a point upstream from the present Swanston Street bridge. At that point the water was generally fresh due to a rock barrier which prevented the salt water from flowing upstream at high tide.

The increase in Melbourne's population brought with it problems of supplying water of good quality. The Yarra River, through the spread of industries and settlement, had become polluted to the extent that typhoid fever and other water-borne diseases claimed a heavy toll on life.

Melbourne's water supply did not improve until an English engineer, James Blackburn, arrived in 1849, and set about developing an effective water supply system. His first attempt was the formation, with the help of four other citizens, of the Melbourne Water Company. It took over control of tanks that had been constructed by the Melbourne City Council near what is now the corner of Flinders Lane and Elizabeth Street. Under Blackburn's guidance, the scheme was made to operate efficiently. Water supplied by the Company from these tanks was filtered through charcoal and sand.

*This is the seventh in the series of special articles on Victoria's environment and man. Previous articles have appeared in Chapter 1 of the *Victorian Year Book* since 1976.

Soon after his arrival, Blackburn was elected to the post of City Surveyor and immediately set about investigating methods of providing Melbourne with a pure water supply. He proposed that the City's source of supply should be a distant, unpolluted source. In 1850, he was granted $600 to carry out a survey of the alternative means of supplying Melbourne with clean water.

Following his investigations, Blackburn recommended diverting part of the flow of the Plenty River into a large storage at Yan Yean. From there the water could gravitate to Melbourne. Following a Parliamentary Select Committee Inquiry, Blackburn's recommendation was accepted and work on the Yan Yean Reservoir and pipelines to Melbourne commenced in 1853. Four years later, on 31 December 1857, the reservoir was opened by Major-General Edward MacArthur, and the works are still in use today.

The discovery of gold in the late 1850s resulted in large numbers of persons migrating to the goldfields. The Victorian Government constructed water supply schemes to serve the areas of most need. Bendigo, Ballarat, and Geelong gained reticulated supplies in 1859, 1862, and 1865, respectively.

The Water Conservation Act of 1881 provided the first comprehensive legislation for the supply of water to country areas. The Act provided for the establishment of Waterworks Trusts: authorities independently responsible for the construction and management of water supply services in country areas. The most significant legislation, however, was introduced in 1886, when, following a Royal Commission on water supply led and inspired by Alfred Deakin, then the Victorian Minister of Water Supply, the Victorian Government introduced the Victorian Irrigation Act. This Act vested in the Crown the right to the use and control of water in any watercourse, lake, lagoon, swamp, or marsh in Victoria. It also provided for the establishment of Irrigation Trusts supported by funds advanced from the Victorian Government to meet the costs of constructing irrigation works.

An outline of the Authorities now responsible for water resource management is given on pages 14 to 18 of this chapter.

ENVIRONMENTAL ASPECTS OF WATERWAYS

The environmental aspects of waterways are concerned with both their physical and chemical characteristics and the flora and fauna which live in, on, or near them. To a large extent these factors interact in that, for example, the health of a waterway depends upon the plant and microbial life which assimilates and decays wastes. Similarly, the chemical nature (quality) of the water in a river, impoundment, or lakes determines the lower forms of flora and fauna which can survive, and thus determines the higher forms of life which depend upon them for food. The structure or physical nature of a waterway also governs the flora and fauna to be found therein, since many species of animals require clear water, pools, riffles, shallow margins, or sheltered water in the lee of obstructions.

Taking physical and chemical characteristics first, there are several important factors that should be considered.

Physical and chemical characteristics

Oxygen

All forms of animal life, aquatic as much as terrestrial, require oxygen. The oxygen content of water is primarily derived from the atmosphere, since the small quantity of oxygen generated by the photosynthetic activity of plant life forms part of the cycle of growth and decay found in any ecosystem and is destined to be consumed by those animals or microbes which live on the plants. Oxygen diffuses into the surface film of any water body and is thereafter mixed downwards by turbulence; hence the importance of shallows, rapids, or bends in a river, and of wind on lakes and reservoirs. The deeper the water, the slower is the transfer of oxygen downwards, so that man-made impoundments which are generally deeper than lakes tend more often to have a bottom layer low in or devoid of oxygen. Similarly, the de-snagging of rivers, and their deepening by dredging or artificial straightening often tends to produce oxygen contents lower than saturation (the content present at equilibrium with the atmosphere). Groundwater, because of its long separation from the atmosphere, frequently has very low oxygen content, so that streams or lakes which derive much of their input from this source also tend to contain little oxygen. There is a constant demand for oxygen, not only from respiring animal life, but also from the decay of organic matter, so that replenishment of oxygen from the atmosphere is essential.

The amount of oxygen which a water body can hold decreases with the rise in temperature, so that there are often natural changes in oxygen content due to diurnal or seasonal cycles of temperature. Diurnal cycles of plant growth also produce fluctuations in oxygen content of water.

Temperature

All natural heat input to Victorian rivers and lakes comes from the sun. Solar radiation penetrates the top few centimetres of water and the heat gained is mixed downwards by wind or turbulence (as with oxygen). Similarly, heat may be lost from water when air temperature is lower than water temperature, as at night or in the winter. Small bodies of water tend to show diurnal cycles and all waters undergo a seasonal cycle of temperature. The headwaters of streams, which derive much of their water input from springs or groundwater seepage, usually at high altitude, and often shaded from the sun, tend to have temperatures lower than ambient. As the stream flows to lower altitudes, widens, and loses vegetation cover, its temperature tends to follow the ambient air temperatures more closely. Streams in general show a smaller temperature range than lakes, but a more rapid variation.

Aquatic fauna are adapted to cool, shady conditions, so that removal of stream bank vegetation and the input of warm effluents is generally deleterious. On the other hand, sudden effluxes of cold water from the lower layers of dams can also do harm. Temperature in waterways is important because of its effect on the life cycles of animals. Many invertebrates and fish are "triggered" into activity by the spring rise in temperature, while salmonids spawn in winter, following the temperature gradient upstream. Temperature has such a profound effect on animal physiology that there is scarcely any animal activity — feeding, migration, reproduction, growth — which is not linked to it in some way. Since most aquatic fauna will have adapted to the natural regime of the rivers and lakes they inhabit, changes in the temperature pattern caused by man are generally harmful.

Turbidity

Turbidity is the content of suspended silt, clay, or other particles in water. High turbidity reduces light penetration, thus inhibiting the growth of free-floating algae and bottom-rooted plants. In the absence of plants which stabilise the bottom and dampen wave action and turbulence, the bottom deposits are more readily stirred up, worsening turbidity, and continuing the cycle.

High silt loads are also deleterious to animal life in that they smother smaller creatures and interfere with feeding, either by choking up filter-feeding mechanisms or simply by reducing visibility. A high suspended load also tends to change the physical structure of a waterway, often covering gravel beds and filling quiet pools, thereby removing important habitats for some animals. Turbidity is worsened by erosion and river bank collapse.

Structure of waterway

There are two types of water body: flowing and still (or rivers and lakes). Changes in stream bed geology or soil, and the presence of obstructions such as boulders or fallen trees, deflect the current flow and cause meandering by undercutting and scouring of one bank with deposition of scoured material further down. This gives to rivers their wide range of habitats from swift flowing riffles, rapids, or gravel beds to still pools, all offering shelter or feeding and breeding areas to various animals. The changes in rate of water flow over such areas is utilised by animals to secure either dispersal of eggs and larvae or their safe deposition. Furthermore, seasonal changes in flow frequently act as a stimulus for breeding or migration. When man dams, dredges, de-snags, or straightens rivers, this diversity of habitat may be lost and with it much of the animal life.

In the case of lakes, the effect of man is most seen in the differences between a natural lake and the reservoir behind a dam. Natural lakes in Australia generally have shallow margins which support growth of fringing reeds and absorb changes in volume with seasonal rains. The output from a natural lake is always at the surface, so that the temperature of the outflow tends to follow a normal seasonal pattern. Furthermore, the flora and fauna of a lake, while different from those in the river upstream and downstream, tend to graduate each way since there is usually no physical obstruction to movement.

By comparison, a man-made storage has margins which are likely to be very steep, since dams are usually built across valleys to maximise storage for a given dam size. There is a physical obstacle to upstream migration in the form of a dam wall, and water levels usually fluctuate as the reservoir is operated, inhibiting colonisation of the margins.

Downstream, the river must adjust to an unnatural pattern of releases (in terms of both volume and temperature) as the reservoir is drawn down, filled, or spilled. The results of this are seen in the disappearance of many native species, (e.g., Murray cod and Macquarie perch in some tributaries of the Murray River).

Chemical factors

The total dissolved chemicals in a water body are usually called Total Dissolved Solids (TDS). Most Australian waterways tend to have a much higher TDS than water bodies elsewhere, perhaps because of the generally low rainfall over the continent, but also because of differences in soil and rock formations. There is also a tendency for sodium to be more abundant than calcium or magnesium, and for chloride to be more abundant than bicarbonate. This is the reverse of the situation in most other countries. Surprisingly, for a continent whose soils are considered deficient in phosphorus, most Australian waterways have a higher phosphorus content than those of Europe or North America. This may be partly a reflection of the generally higher TDS, but since most river and lake phosphorus derives from phosphate absorbed onto soil particles, it may also reflect the tendency to high erosion rates in Australia.

Nitrogen compounds (such as nitrate and ammonia) occur in waterways, both as a result of the decay of organic matter, and from the activity of nitrogen fixing bacteria, which are extremely abundant in the soil around the roots of wattle trees. Despite this tendency to higher levels of both nitrogen and phosphorus, very few Australian waterways show symptoms of eutrophication. (This is a condition of massive growth of aquatic plants in response to high nitrogen and phosphorus inputs, leading to decay and de-oxygenation.) Eutrophication is usually found only where excessive man-made inputs occur, for example, from sewage effluent or fertiliser run-off.

Under natural conditions, a large proportion of the chemical input to rivers comes from rain both directly and indirectly, in the form of material washed off vegetation or leached from the soil. Another large part derives from vegetation debris such as leaves, which fall or are carried into waterways. Some animals feed directly on this debris, while others depend on its breakdown by microbes which both release the products of decay for algae growth or themselves form the prey of the smallest animals. There is, in general, a tendency for the TDS of a river to stabilise, during periods of steady flow, showing peaks at the beginning of floods or high run-off.

Aquatic life

Aquatic life, both plant and animal, is extremely resilient to increases in TDS, provided that the levels do not increase or decrease too rapidly. Freshwater animals begin to show stress if the TDS rises to such a level that the mechanisms for maintaining body fluids constant are strained beyond their capacity. This occurs at different concentrations for different animals, and while some larvae may be killed or damaged at TDS levels of one to two milligrams of salt per litre of water, many fish tolerate levels of a few thousand milligrams per litre and some animals are adapted to cope with movement from salt to fresh water. Because of these differences, a change in the TDS of river water (caused perhaps by an industrial effluent, or by de-vegetation of a catchment) will result in the replacement of some species of animals by others. This is not usually so drastic, of course, as the changes caused by the introduction of exotic species such as carp, trout, or water hyacinth.

No less important than the waterways are the areas adjacent to waterways — the wetlands and swamps—since these provide a habitat for water fowl as well as buffer zones for floods and droughts. The activities of man in draining such areas, in order to reduce flooding or to provide more agricultural land, further diminished the sparse bird habitat. Australia has the least number of species and individual water fowl in the world. About eight species are endemic to the southern region, while five species range over the continent.

This sparsity is a reflection of the aridity of the continent and the irregular nature of the rainfall. Numbers fluctuate greatly from year to year in response to the varying area of wetlands available for breeding and feeding, even though most species are nomadic and seek out fresh habitats when their own are dry. The gradual reduction of wet-lands by drainage and river regulation aggravates this natural stress. While the number of dams steadily increases (27 in the 1960s, compared with 111 natural lakes), these man-made water bodies are generally too steep-sided to provide suitable habitat. On the other hand, some irrigation works and farm dams could provide suitable habitat if protection were afforded for the birds. Formerly, the coastal swamps of Victoria were the most important habitat for southern Australian water fowl. However, these have largely been drained, and the Murray-Darling system now provides the principal breeding areas.

In the temperate northern hemisphere bird breeding is related to day length, but in Australia this role is assumed by rainfall, which governs the availability of both nesting sites and food. For example, some southern birds actually breed in late winter because of the seasonal regime of winter rainfall (while northern species breed in late summer). There tends to be much variation in the timing of breeding, depending on how permanent or transitory is the swamp or wetland which forms the usual home of a particular bird. If rainfall is inadequate, some birds do not breed at all.

The nesting sites of water fowl depend to some extent on their feeding behaviour. Most birds will feed on seed-heads, buds, or other plant parts, others dabble for benthic animals in mud or shallow water, some dive for food, while others filter surface water to trap the organisms swimming in it. A few are totally vegetarian and some entirely carnivorous, but most will vary their diet according to its availability. The most important animal prey are insects (beetles, water-boatmen, and aquatic fly larvae), some molluscs, and crustaceans. Four species feed only on grasslands away from water. Hence, nesting sites may be on swamp vegetation, stumps of trees, in holes in trees, or in the ground, under stones, or simply in open sites on land.

The freshwater fish fauna of Australia are poor in comparison with other continents. Long separation from major land masses has ensured that none of the "primary" freshwater groups have reached Australia from the northern hemisphere by natural means; this includes the Ostariophysi group, which forms the majority of the world's freshwater fishes. With only two possible exceptions, (the lung fish, *Meoceratodus,* and the barramundi, *Scleropages*), all of Australia's native freshwater fishes are "secondary" freshwater with very obvious marine connections.

There are only about 166 essentially freshwater species native to Australia. About 40 occur in Victoria, and only about 30 are restricted entirely to freshwater. However, while endemism is high at the species level, it is low at the family level, suggesting that the fauna are not of great age. In addition, Victoria now has ten introduced species. Trout are particularly well established and both species have proven successful introductions, with self-reproducing populations present in many streams.

Natural water conditions in streams are erratic, with levels fluctuating greatly in response to rainfall in the highlands. Native fish are closely adapted to such conditions. Perhaps the most striking adaptations are in the sexual cycles and breeding biology. For example, spawning of some fish is apparently triggered by a rise in river level or temperature. Many native species migrate during the breeding season, to spawn in areas sometimes remote from their normal habitat. Thus, both species of eel migrate to sea to breed and re-enter the river systems as "glass eels" while grayling, *Prototroctes maraena,* apparently undergo annual upstream migrations to spawn.

Of the 40 species referred to earlier, only 16 commonly exceed 10 centimetres in length and are considered of value as angling species. Of these, the fishes of the family

Percicthydae are probably regarded as the most important. Thus, there are a large number of native species of little or no angling value and little known to the general public. However, these species are of considerable interest and are an integral part of the stream ecosystem.

It has been suggested that approximately one-third of Australia's freshwater fish species are in danger of depletion, and that a number are already seriously threatened with extinction. In Victoria, three native species are principally threatened: grayling, *Prototroctes maraena*; Macquarie perch, *Macquaria australasica*; and trout cod, *Maccullochella macquariensis.* Furthermore, the abundance and distributions of cat fish, *Tandanus tandanus* and golden perch, *Plectroplites ambiguus* have been considerably reduced. Many *galaxias* spp. show a very patchy distribution; for example, dwarf galaxiid, *Galaxiella pusilla,* is restricted to a number of shallow backwaters and ditches which are very susceptible to habitat alteration by man.

Effects of man on water resources

One of the first actions of Europeans when colonising Australia was to remove timber from catchments watersheds, develop pasture, and commence heavy grazing. As a result, patterns of run-off have been changed, increasing the difference between maximum and minimum flows. Siltation rates were increased, adversely affecting those species not able to tolerate muddy conditions.

Man's increasing demand for water has further affected inland waters. Many natural lakes are now controlled by water storages. Numerous reservoirs have been constructed and artificial canals laid down for irrigation purposes. An increase in the total number of lentic waters has already been noted (construction of artificial waters has out-stripped the destruction of natural waters by drainage). There has also been a geographical redistribution of water bodies: there are now many large reservoirs in areas where natural lakes did not exist. This is particularly so in the highland regions of Victoria. The native fish fauna contains few species readily adaptable to this environment and such reservoirs are invariably dominated by introduced species such as trout. It is worth noting that fish of the family *Falaxudae*, which can adapt to these newly created environments, are particularly susceptible to displacement by introduced trout.

Downstream effects of impoundments are considerable. Because of varying demands on the water being stored, unnatural fluctuations in flow occur and temperature variations can be noticed for considerable distances downstream. If water from a thermally stratified reservoir is drawn out from lower levels, the effect is considerably greater. Impoundments thus may create a new environment downstream, often to the detriment of the native fauna. Fluctuating water levels may cause desiccation and death of fish eggs spawned near the surface or on marginal vegetation.

Impoundments also present a physical barrier to the migration of fish species. Up to 1981, there had been little attempt in Australia to evaluate the use of fish ladders to overcome this problem, but this matter is likely to receive more attention in the future (e.g., Mitchell River investigation).

The indiscriminate use of pesticides for agricultural purposes must be regarded as a potential danger to Victoria's aquatic fauna. The long-term effects of pesticides on the native fauna is not yet known.

In addition to the factors mentioned above, Victoria's inland waters have been changed by the introduction of fish species from overseas. The effects of introductions are mainly biological, although common carp, *Cyprinus carpio*, does cause physical disturbance to the habitat. Much contention exists as to what effect introduced fish have had on native species and most evidence is purely circumstantial. However, it is increasingly apparent that in certain circumstances introduced species have a marked deleterious effect on native fish.

The status of Victoria's native fish is by no means secure. As man's need for water increases, more and more waterways will be modified from their natural state. Effective management of Victoria's inland waters to conserve the native fauna must be based on detailed research. At present, knowledge of even the basic biology of many species is inadequate.

WATER RESOURCES

Climate

Rainfall (and snow) determine the total of the water resource, with available resources, either as surface water or groundwater, influenced by such factors as temperature, evaporation, transpiration, and infiltration.

The Great Dividing Range, which runs east-west across Victoria and varies in elevation from 500 metres to some 1,800 metres, is the major determinant of Victoria's climate. Rainfall varies generally with elevation, but the southern slopes receive more rain than the northern slopes.

With the exception of East Gippsland, Victoria receives more rain in winter than in summer. The annual rainfall ranges from 250 mm in the drier Mallee region to more than 1,400 mm in the Central Highlands. The Victorian average annual rainfall is 650 mm.

All areas of Victoria occasionally experience very heavy rains, monthly rainfalls as much as three times the recorded monthly average having been recorded. Such rains are usually the result of thunderstorms and affect relatively small areas.

The average annual number of wet days (0.2 mm or more in 24 hours) is 150 on the West Coast and West Gippsland, and exceeds 200 over the Otway Ranges. The number decreases to average 100 days in the northern areas of Victoria or at a distance of 160 kilometres from the coast.

Although snow has been recorded in most parts of Victoria (with the exception of the Mallee, Wimmera, north, and lower north), it is usually confined to the Great Dividing Range and the alpine massif. Falls occur during winter and early spring, with the average season lasting from 3 to 5 months in the alpine areas.

Surface water

Measurement

Victoria is relatively well endowed with stream flow information. Daily river levels were noted on the Murray River at Echuca and Mildura as early as 1865. These stations were established to provide information for river transport services. The first known gauge in Victoria specifically for recording stream flows was installed at Malmsbury Reservoir in 1875 and a second was installed on the Goulburn River at Murchison in 1881. The number of gauging stations has increased greatly over the years.

Early records are based on daily read gauges and the reliability of the data varies considerably depending on the diligence of the gauge reader. In particular, peak flows during floods may not have been recorded. Not only is this information important in assessing the potential flooding problems in an area, but as flood flows account for a high proportion of annual flow in many Victorian streams, it may also result in a poor assessment of the total volume of flow.

Daily read gauges at all key stations have now been replaced by continuous automatic level recorders that require servicing only at either weekly or monthly intervals.

Water resources

There is a virtually constant quantity of water in the world, in the frozen, liquid, and gaseous states. Sea water accounts for 97 per cent of the surface water. Of the remaining 3 per cent, most is in the form of ice in the polar regions and only some 1 per cent is actually available for use by man. Thus, the quantity of fresh water available at any time for land-based vegetation, animals, and man is a very small percentage of the world total.

The use of fresh water does not destroy the water itself but converts it into an unusable form by vaporisation or by adulteration with dissolved or suspended matter. It is converted back to a usable form by the processes of nature aided to a very small but increasingly significant degree by artificial processes (wastewater treatment, desalination, etc.).

The predominant natural process for the renewal of fresh water supplies is distillation — evaporation and transpiration powered by solar energy, followed by condensation in the atmosphere and precipitation of almost pure water in the form of rain or snow. Of the precipitated water, some is lost almost immediately by evaporation, some soaks into the ground and may be transpired by vegetation or may seep slowly to bodies of groundwater that eventually emerge as springs, and some runs off the surface of the land to collect in creeks and rivers discharging to land-locked lakes or the sea. Thus, the world's water is ceaselessly circulating through the hydrologic cycle. So long as man is dependent primarily on the hydrologic cycle for the continual renewal of fresh water supplies, his real interest lies in the rate at which the cycle operates rather than in the total volume of fresh water accessible at a given time.

Average annual rainfall over Victoria as a whole is about 650 mm. The area of the State is 227,600 square kilometres. Total precipitation is therefore about 148 million megalitres. However, only about 20 million megalitres appears in the average annual flow of Victorian rivers.

In the foreseeable future, Victoria will continue to depend mainly on surface water resources to meet increasing water demands, but these resources are unevenly distributed in both space and time. Their distribution in space can be conveniently described by considering Victoria as divided into four segments, by an east-west line along the Great Dividing Range and a north-south line through Melbourne. The north-west segment contains 40 per cent of Victoria's area; the other three segments contain 20 per cent each. Surface water resources, represented by average annual river flow, are heavily concentrated in the eastern segments, each accounting for about 40 per cent of the total. The western segments account for only 20 per cent of the total flow, with only 3 per cent in the north-west segment.

Quality of stream flow also deteriorates from east to west. Waters of the eastern rivers mostly contain less than 100 milligrams per litre of total dissolved solids. In the western rivers the figure is generally above 500 milligrams per litre except near their sources, and increases downstream to figures in excess of 1,500 milligrams per litre.

River flows in Victoria exhibit a marked seasonal pattern and marked variability in annual flow. Over Victoria as a whole, about 60 per cent of average annual flow is accounted for in the four months July to October, inclusive. In western streams this percentage approaches 75 per cent. Everywhere, flows typically recede in the summer and autumn, at the time of year when water requirements for most uses are at a peak.

Annual flow in wet years is commonly more than twice the annual average and in dry years commonly less than half the average. Dry years and wet years succeed one another almost at random, but runs of dry years inevitably occur from time to time. Even on a relatively reliable stream such as the Ovens River at Wangaratta, there have been five occasions in the past 80 years when the total flow over two successive years has been less than the average one year flow, and two occasions when the total flow over three successive years was only one and a half times the average one year flow.

A general assessment of the water resources of Victoria on a regional basis is given in the table on page 9. Figure 1 in the illustrations facing page 20 shows the river basins, based on a national identification of drainage divisions.

Groundwater

Any realistic assessment of Victoria's groundwater resources must take account of groundwater quality, and the fact that the resource consists of a large, though finite, store of water whose existence is dependent on recharge from infiltrating rainwater.

Aggregate figures of the groundwater resources of Victoria are presented in the table on page 9. It will be appreciated that these figures will be refined in the future, and that they are not directly relevant to the individual user, who is concerned with the occurrence and quality of water within a relatively small area.

All basins have a considerable potential for development with the exception of Western Port Basin, where for much of the basin the one-time optimal reserve is exhausted.

VICTORIA—SUMMARY OF WATER RESOURCES

River basins	Adopted drainage area (square kilometres) (a)	Average annual discharge (surface water x 1,000 megalitres) — Fresh and marginal water	Average annual discharge (surface water x 1,000 megalitres) — Brackish and saline water
II. SOUTH-EAST COAST DRAINAGE DIVISION			
21. East Gippsland	6,040	600	—
22. Snowy River	15,799	(b) 2,396	—
23. Tambo River	4,170	370	—
24. Mitchell River	5,646	1,034	—
25. Thomson River	5,905	1,200	—
26. La Trobe River	4,662	995	—
27. South Gippsland	6,786	1,268	—
28. Bunyip	4,118	550	—
29. Yarra River	4,066	1,193	—
30. Maribyrnong River	1,450	106	2
31. Werribee River	1,994	119	—
32. Moorabool River	2,176	100	2
33. Barwon River	3,626	179	110
34. Lake Corangamite	4,222	15	203
35. Otway Coast	3,963	829	—
36. Hopkins River	9,946	30	415
37. Portland Coast	4,144	98	287
38. Glenelg River	12,380	210	612
39. Millicent Coast	41,577	155	266
IV. MURRAY-DARLING DRAINAGE DIVISION			
1. Upper Murray River	15,281	(c) 3,590	—
2. Kiewa River	2,046	723	—
3. Ovens River	7,848	1,676	—
4. Broken River	7,330	325	—
5. Goulburn River	16,835	3,187	—
6. Campaspe River	4,014	264	—
7. Loddon River	15,359	291	—
8. Avoca River	11,992	40	41
14. Mallee	52,033	—	—
15. Wimmera-Avon Rivers and Murray River system	23,388	218	16
Total	298,796	21,761	1,954

(a) This figure includes areas of some catchments which are shared with other States.
(b) Transfer from Snowy River to Division IV. Amounts to 1,130,000 megalitres.
(c) Includes 580,000 megalitres from the Snowy River Basin (Division II) part of total diversion into Division IV from that basin of 1,130,000 megalitres.

VICTORIA—ESTIMATED POSSIBLE ANNUAL YIELDS OF MAJOR GROUNDWATER BASINS

Basins	Aquifer systems	Estimated annual recharge ($m^3 \times 10^6$)	Total dissolved solids — From recharge (milligrams per litre)			Total dissolved solids — Total (milligrams per litre)				
			< 1,000	1,000 to 3,000	3,000 to 7,000	< 1,000	1,000 to 3,000	3,000 to 7,000	7,000 to 14,000	> 14,000
Gippsland	Unconsolidated	19.27	12.45	6.82	—	52.92	15.44	—	—	—
	Sedimentary	403.96	191.04	212.92	—	275.58	261.07	—	—	—
	Total	423.23	203.49	219.74	—	328.5	276.51	—	—	—
Murray	Unconsolidated	46.9	31.5	—	—	1,409	753	1,266	633	2,528
	Sedimentary	51	20	21	10	711	804	598	296	1,408
	Total	97.9	51.5	21	10	2,120	1,557	1,864	929	3,936
Otway	Unconsolidated	8.6	6	2.6	—	79	79	15	—	—
	Sedimentary	404	354	53	16	859	395	138.08	—	—
	Total	412.6	360	55.6	16	938	474	153.08	—	—
Port Phillip	Unconsolidated	11.66	11.4	0.2	0.2	41	69	49	—	—
	Sedimentary	31.6	21.2	8.4	—	74.2	23.7	59	—	—
	Total	43.26	32.6	8.6	0.2	115.2	92.7	108	—	—
Western Port	Unconsolidated	10.6	10.6	—	—	—	(a)	(a)	—	—
	Sedimentary	7.56	1.5	6.06	—	—	(a)	(a)	—	—
	Total	18.16	12.1	6.06	—	—	(a)	(a)	—	—
Fractured rocks		236	97	111	28	430	242	245	—	—

(a) Not determined.

WATER QUALITY

Salinity

Salinity, as a factor affecting the utilisation of land and water resources, is now widely recognised. While this chapter is concerned only with salinity in Victoria, salinity is a phenomenon of some importance in many other parts of the world, notable instances being in southern and western United States, Russia, the Middle East, and on the Indian sub-continent. Salinity of agricultural soil and inland waters is not just a modern phenomenon. It was almost certainly known in ancient civilisations based on irrigated agriculture, and its onset would have contributed to the decline of some of these systems. In Australia, geological and historical evidence indicates that salinity is something of an ancient and natural phenomenon, and at times, even in the areas of present concern, may have been much greater than at present.

In terms of classical measurements, salinity of water is defined as: "The total (dissolved) solids in water after all carbonates have been converted to oxides, all bromide and iodide have been replaced by chloride and all organic matter has been oxidised". In practice, less rigorous, simpler, and quicker estimations of salinity are often used.

Because of the excellent relationship between chloride and salinity in sea water, simple measurements of chloride have been used to estimate the total soluble salts of inland waters. However, this may involve considerable uncertainty, and in recent years, major reliance has been placed on the measurement of the electrical conductivity (EC) of water to indicate its content of dissolved salts. The EC is usually standardised to that at a defined temperature (normally 25°C).

There are approximately 500 locations on streams in Victoria at which salinity is measured regularly with EC metres. Typically, the measurements are made at monthly intervals, but measurements may be made weekly, daily, etc. in locations of special significance. Often, the EC measurements are supported by detailed laboratory analyses of the individual components of the dissolved material. Some 300 of these stations receive more detailed analyses as part of the National Water Resources Assessment Program.

Water salinity is consistently lowest in the north-east of Victoria (Basin 1: Upper Murray) with very low salinity water at all times in many streams. The zone of consistently low salinity water tends to spread westwards along the Great Dividing Range, covering the higher parts of basins west to the Goulburn Basin (5) in the north, and La Trobe Basin (26) in the south. The waters of the Tambo Basin (23) appear anomalous in being slightly more saline than those on either side. Most stream systems become more saline as they flow away from the Great Dividing Range toward the sea in the south, or towards the Murray River in the north.

Salinity appears to increase noticeably to the west of Melbourne. Pockets of relatively lower salinity waters in the west of Victoria occur in areas of higher rainfall (Otway Ranges, the Grampians, and around Ballarat). However, these waters degrade to medium or even extremely high salinity as they flow north or south out on to the adjacent drier plains.

The salinity of waters may affect their usefulness through the impact of the total soluble salts, or through individual components of these salts or through combinations of these components of the salts. Chloride may exert a toxic effect on some plants. Leaf wetting irrigation of some fruit trees may be harmful if chloride exceeds 100 milligrams per litre.

The waters supplied to the Victorian irrigation areas are quite satisfactory in terms of salt-sensitivity of irrigated crops, provided certain precautions are taken as above. However, serious problems may arise where impermeable soils or impeded soil drainage and rising water tables cause salts to accumulate in the plant root zones. In such situations, soil drainage must be provided to remove excess soil water and salts.

Apart from diversion of water into the irrigation areas, most streams of any significance in Victoria have diversions for private or public purposes. Even in the cases of the more saline streams, some use of the water has been made for irrigation. This may be achieved by carefully limiting the irrigations between leaching rains. The World Health Organisation provides guidance on the acceptable concentrations of total soluble salts in domestic water.

Other problems of domestic supplies may also be associated with high salinities, e.g., hardness, corrosion of metals. It is clear that the major problems in obtaining domestic supplies from streams will arise in the west of Victoria. In extreme cases, reliance must be placed on the use of rainwater tanks, water softening equipment, or groundwater sources where these are available. However, at times most streams will provide water of suitable quality for domestic use. The limit of acceptability of water for stock purposes varies with species, conditioning, etc., and account should be taken of other factors such as dissolved magnesium in the water.

The primary sources of stream salinity are from the weathering of rocks, and by aeolian transport from the sea which is a repository for soluble rock weathering products. Other intermediate sources and sinks include residual sea salts in sediments, groundwater, lake precipitates, and the atmosphere.

The geological history of an area may have a strong influence on the salinity of the local soils, groundwater, and streams. For example, a long and intimate association existed between the geological strata of north-western Victoria, and saline marine waters during the period of the ancient Murravian Gulf incursion. The salts left behind when the marine waters receded probably account for a significant part of the salts which now enter the Murray River and other rivers in this region.

There have been major and extensive changes in Australian land-use since European settlement. The most important have been the replacement of native vegetation (particularly deeper rooting evergreen trees) with shallow rooted perennial and annual pasture species to provide grazing for introduced livestock, and the development of irrigated agriculture and horticulture. Both these changes tend to disturb the previous equilibrium which would have existed.

The transition to shallower rooted plants causes less of the applied rainfall to return to the atmosphere as vapour after its evaporation from the soil surface or passage through the plants (evapotranspiration). Thus, more of the total water will appear as run-off and as water penetrating into the groundwater reservoir. These additions to the groundwater will tend both to bring free groundwater nearer to the soil surface, and to increase the hydraulic pressure head available to force flows of this water to the soil surface at low points or into the streams of the catchment. Since this groundwater is often charged with dissolved salts accumulated from rainfall, rock weathering, or directly from old marine sources, salinisation of areas of surface soil (dry land salting) and increases in stream salinity will occur. Such problems occur widely in Victoria.

Phosphorus

In recent years, phosphorus has been widely recognised as an important indicator of water quality, because of its association with the process of eutrophication or "enrichment" of surface waters. The element phosphorus is found naturally in rocks and soils, and as a consequence, is found generally in low concentrations in the waters of Victoria's streams. Phosphorus is an essential nutrient for the growth of plants and animals and, because Australian soils are typically low in phosphorus, phosphorus-containing fertilisers such as superphosphate are commonly added to agricultural soils to improve the growth of pasture and crop plants, and so enhance the profitability of agricultural activities.

The soil particles usually absorb the phosphorus and limit its movement, but it is inevitable that some fertiliser phosphorus will enter streams, particularly when run-off passes over fertilised land, and erodes the soil particles. The extent to which this occurs is likely to be affected by the fertiliser application rate, soil type, amount of run-off, and the degree of erosion.

Phosphorus in foods is only partly retained in the body, and hence it is found in significant quantities in human and animal wastes. Human excreta yields about 0.5 kilogram of phosphorus per capita per annum.

Domestic wastewaters may also contain phosphorus derived from additives used to improve the performance of detergents especially in hard waters. Phosphorus is also present in industrial wastes and in urban surface run-off. Thus, major point sources of phosphorus entering streams are likely to be discharges from sewage collection systems, unless "phosphorus stripping" of the effluent is employed, and for intensive animal based industries such as feed lots, sale yards, and piggeries.

Concern about the eutrophication of streams, lakes, and water storages arises because of undesirable side-effects which usually develop as increased quantities of phosphorus and/or nitrogen are added to them. These side-effects include an increase in algal growth and the growth of submersed and emergent aquatic macrophytes, which often reach weed proportions; a reduction in dissolved oxygen due to the decay of plant material, with a resultant impairment of the fish life; taints in the water and the blocking of supply system filters; impaired aesthetic quality; and a risk to stock from the production of toxins by certain algae.

Nitrogen

After phosphorus, nitrogen is commonly held to be the essential nutrient most likely to stimulate plant growth in surface waters, and so has the potential to bring about eutrophication. In particular, nitrogen has an essential role in the structure of protein material. When present in excess, certain forms of nitrogen in water supplies may have toxic effects on aquatic life and on humans.

Nitrogen has as its ultimate source the pool of gaseous nitrogen which comprises about four-fifths of the volume of the earth's atmosphere. In waters, nitrogen may be present in five major forms: dissolved molecular nitrogen; organic nitrogen compounds, such as proteins, amino acids, and simpler compounds derived from organic decay; ammonia, derived as an end product of the degradation of proteins and other nitrogenous organic matter, as an animal excretion product, and as a product of microbial reduction of nitrite; nitrite, usually present in clean waters in only minute concentrations derived from the microbial oxidation of ammonia or the reduction of nitrate; and nitrate, which may be taken up by plants, or reduced to nitrate or nitrogen gas during microbial denitrification.

These major forms of nitrogen are, for the most part, readily inter-convertible by appropriate micro-organisms under suitable micro-environmental conditions. This interconnection of nitrogen forms and microbial processes is usually called the *nitrogen cycle.* The process of biological reduction of nitrogen gas for eventual incorporation in cellular proteins is called *nitrogen fixation* and may be carried out by free-living organisms in the water (e.g., blue-green algae) or symbiotic bacteria associated with certain terrestrial plants such as pasture legumes and leguminous trees and shrubs. The major sources of nitrogen compounds in fresh water are by derivation from fixation in the terrestrial catchment, or from nitrogenous waste.

Suspended solids and turbidity

Both these characteristics adversely affect the quality of stream waters for several uses, and may indicate undesirable conditions in the stream catchment. Typically, higher values of both parameters suggest catchment soil erosion and the loss of this valuable resource. Although soil erosion may be quite severe in small parts of catchments and along stream courses, the suspended solids and turbidity values commonly found in Victorian streams are low by overseas standards.

In addition to eroded soil particles, suspended particles may derive from plankton (algae, etc.) and organic or inorganic detritus.Turbidity is a measure of light scattering in the water, and hence is sensitive to the presence of very fine suspended particles. In some instances at least, higher turbidities are probably indicative of algal blooms or detritus, rather than soil erosion. This could be particularly so for streams which receive concentrated nutrients in drainage water.

High concentrations of suspended matter are biologically undesirable (causing reduced light penetration, smothering, abrasion). European experience suggests that suspended solids concentrations less than 80 micrograms per litre are acceptable for freshwater fisheries. Such values should be applied with caution in the Australian setting.

Drinking water, at the point of consumption, should have a turbidity of less than 25 Nephelometric Turbidity Units (NTU), and ideally, less than 5 NTU. Obviously, domestic supplies in several parts of Victoria need treatment (settling, coagulation, filtering, etc.) prior to consumption to meet these criteria.

Human pathogens

There are numerous diseases of man, and in particular those caused by intestinal pathogenic organisms, which may be transmitted, either exclusively in water, or for which water is a major route for spread. The list includes various forms of dysentery, diarrhoea and enteritis, cholera, typhoid and other fevers, leptospirosis, infectious hepatitis, and poliomyelitis. The causative organisms may be bacteria, protozoa, or viruses. Consequently, microbiological examination is a major aspect in establishing the quality of a water for domestic consumption.

The greatest risk of producing fresh cases of disease associated with water arises when the water has been recently contaminated with sewage, or bird or animal excrement.

Transmission of the disease from water to humans occurs primarily through direct exposure to the contaminated water by drinking or possibly by swimming, and indirect exposure through contaminated food processing water or associated wash waters.

Complex and only partly understood relationships exist between the sources of the pathogens, the survival and transport of the pathogens, and the re-infection of man or animals.

WATER UTILISATION

An earlier section in this chapter relating to surface water resources (see pages 7 and 8) has noted that the long-term average annual flow of all Victoria's rivers has been estimated as 20 million megalitres. These surface water resources are unevenly distributed in both space and time. The spatial distribution of surface water resources is illustrated diagrammatically in Figure 2 in the illustrations facing page 20.

Victoria has always been conscious of the importance of water to the development of the State, and has followed a policy of developing its water resources which has resulted in the present high level of utilisation. Total water storage capacity in Victoria was approximately 10 million megalitres in 1980 and this will increase to 15.5 million megalitres following the completion of storages currently under construction. This is equivalent to 77.5 per cent of the estimated long-term average annual stream-flow of all rivers. The location of storages is shown in Figure 3 in the illustrations facing page 20.

A recent survey has indicated that the total volume of water consumed for domestic, industrial, stock, and agricultural purposes is currently approximately 5 million megalitres per annum, or 25 per cent of the total average annual river flow. Some 81 per cent of present water consumption is used for irrigation, mainly in the northern half of Victoria, 15 per cent is used for domestic and industrial purposes through public water supply schemes, while the remaining 4 per cent is used for domestic and stock water supplies. Water resources are also committed to non-consumptive uses such as hydro-electric power generation, environmental requirements, and for recreational purposes.

In attempting to determine the amount and location of water resources that may still be developed, two factors must be considered: water quality and potential for development.

With respect to water quality, salinity is probably the most significant single factor (see page 10). Water quality generally decreases as one moves from the Highlands in the eastern part of Victoria to the plains of the Western District. Many of the watercourses in the Western District have high salinities which make them unsuitable for most purposes. As a result there is little potential for development of the water resources of most of the western district of Victoria. The potential for development of a stream also depends upon the availability of suitably located storage sites. A preliminary survey has been carried out over the whole of Victoria to identify possible storage sites. Obviously development of the lower reaches of a river system is unlikely to be practicable as the topography would not generally be suitable for construction of major storages.

From the above considerations it has been estimated that the practicable limit of diversions that could be secured is in the order of 8 million megalitres per annum. Additional storages would be constructed to meet this figure. This represents an increase of some 60 per cent of the present consumption of 5 million megalitres per annum. The only significant water resources still capable of development are restricted primarily to the East Gippsland region and this could have a marked influence on future development of Victoria.

WATER RESOURCE MANAGEMENT

Historical

Water resource management in Victoria had its genesis in the Irrigation Act of 1886.

Legislation to this time had led to the development of small and generally insecure irrigation schemes. Parliamentary debates of the time indicate three views. First, if schemes were to be developed without administrative difficulties or litigation, it was necessary that the "supreme power and responsibility in connection with the care and custody of water, and in certain cases, in the construction and management of works, can be vested nowhere else than in the State itself". Second, the rights of the State would be ineffective "unless we (the Parliament) are absolutely sure that they cannot be interfered with by the existence of any such thing as riparian rights". Third, the progress of irrigation development would be hindered by lengthy and costly litigation unless the rights of individuals and the State were properly defined. The 1886 Act set the scene for an integrated programme of water resources development and was an important stage in the development of governmental control over water distribution.

The thrust of governmental policy then was to encourage the setting up of local trusts to develop and manage rural water supply systems. Government financial assistance for their establishment had been provided since 1883 with the initial expectation that the investment would be financially profitable. However, the trusts failed, for various reasons. A major reason was the lack of headworks storages to ensure continuity of supply in dry years. But an equally important reason was the shortage, at that time, of skills and experience, at the local level, in the management and utilisation of water resources.

The Water Act of 1905 established a central body, the State Rivers and Water Supply Commission, to take over from the trusts in a bid for integrated, orderly development and management of rural water supply. Of the irrigation trusts, only the First Mildura Irrigation Trust was not abolished. The Water Act of 1905 is significant because it brought together for the first time the matters of water resource management seen by the Parliament of the day as being necessary if Victoria's resources were to be developed and managed in a planned and co-ordinated way.

The Commission's early initiatives were first directed at the consolidation and rehabilitation of the water supply systems previously operated by the Trusts and then at the development particularly after the two World Wars of new irrigation enterprises which were associated with government sponsored rural closer settlement schemes. Concurrent with these projects the Commission constructed, and has continued to this day to construct, major projects directed at the conservation of water resources and distribution of water supplies according to need. Figure 4 in the illustrations facing page 20 indicates these major works.

There are two very early provisions of the Water Act that require special mention for they are the foundation on which the general legislative scheme is developed. These state that the right to the use and flow, and to the control of the water at any time in any river, creek, stream, or watercourse and in any lake, lagoon, swamp, or marsh shall vest in the Crown and that the bed and banks of any river or stream, creek, or watercourse or any lake which forms part of the boundary of an allotment shall be and remain the property of the Crown.

The Melbourne and Metropolitan Board of Works is responsible for providing water supply, sewerage, and main drainage services to the Melbourne metropolitan area. The Royal Commission of 1889 into Melbourne's sewerage system prompted the establishment of the Board which was constituted by an Act of the Victorian Parliament in 1890 and began operation in July 1891. The Board was initially constituted to assume responsibility for Melbourne's water supply and to establish a sewerage system to serve the Melbourne metropolitan area. The Board now, in addition to the above responsibilities, is also responsible for main drainage, flood protection, the maintenance and improvement of metropolitan rivers and watercourses, town planning, and metropolitan parks.

The *Water Resources Act* 1975 established a Ministry of Water Resources and Water Supply for the purpose of ensuring the most efficient utilisation of the water resources of Victoria. The Act laid down duties for the Minister administering this Act and others defined in the Act as "to determine the means by which the water resources of Victoria can be conserved, developed and utilised to the best advantage of the people in Victoria to promote the extension of sewerage and drainage services and to ensure as far as practicable that adequate water is provided for the conservation of the flora and fauna of Victoria". The Act also established a Water Resources Council of eleven members to investigate and advise the Minister generally on matters pertaining to the water resources of Victoria or to water supply, drainage, or sewerage throughout the State, referred to it by the Minister.

In addition to the above authorities, there is a range of local authorities which have responsibilities for the provision of services to specific areas of Victoria.

Irrigation

Irrigation is by far the greatest use of water in Victoria. The State Rivers and Water Supply Commission controls most of the irrigation areas within Victoria. Within its ten Irrigation Districts, a total area of some 803,000 hectares is classified as suitable for irrigation, while 48,000 persons within Victoria rely directly on irrigation for their livelihood. The major irrigation districts are shown in Figure 5 in the illustrations facing page 20.

The First Mildura Irrigation Trust is the only autonomous Irrigation Trust still operating within Victoria. This Trust has an interesting history, having been established in 1886 by George and William Chaffey under a special agreement established by Her Most Gracious Majesty Queen Victoria. The Trust currently provides water for irrigation purposes to an area of some 8,000 hectares comprising mainly vineyards and orchards.

In addition to the above irrigation districts, a further area of 84,556 hectares is irrigated by private irrigation schemes. Most of these schemes are operated by individual landowners who pump water directly from watercourses under the provisions of licences or permits issued by the State Rivers and Water Supply Commission.

Domestic and stock supplies

Apart from the irrigation districts discussed above, there are a number of systems throughout Victoria which provide water to rural properties for domestic and stock watering purposes. The largest of these is the Wimmera-Mallee domestic and stock supply system which is operated by the State Rivers and Water Supply Commission. The Wimmera and Mallee regions of Victoria have low average annual rainfalls ranging from 450 mm in the south, to 300 mm in the north. Development of these regions which have no reliable surface water resources, is completely dependent upon the availability of stock and domestic water supplies.

Minor conservation works were initiated by individual landowners in the 1850s, and these works were subsequently extended first by local shire councils, and then after 1905 by the State Rivers and Water Supply Commission. The system now comprises some 9,660 kilometres of State Rivers and Water Supply Commission channels, and 6,440 kilometres of farm channels which serve an area of 28,489 square kilometres. Sixty townships and some 20,500 farm storages receive domestic and stock water supplies through the system. Major storages supplying the system now have a total design capacity of 762,680 megalitres. The major domestic and stock water supply schemes are shown in Figure 5 in the illustrations facing page 20.

Urban water supplies

Public water supplies to urban communities are under the control of the Melbourne and Metropolitan Board of Works, the State Rivers and Water Supply Commission, and Waterworks Trusts constituted under the provisions of the *Water Act* 1958 or other specific statutes. The area supplied by the Melbourne and Metropolitan Board of Works and the major components of the water supply system are shown in Figure 6 in the illustrations facing page 20. Total average annual consumption of water within the Melbourne metropolitan area is currently 420,000 megalitres. This represents some 57 per cent of domestic water consumption and about 8.5 per cent of all water used within Victoria.

The State Rivers and Water Supply Commission is responsible for the operation of domestic water supply schemes serving the Mornington Peninsula, Bellarine Peninsula, Coliban region, and Otway region, as well as numerous townships within irrigation and domestic and stock supply districts throughout Victoria. Current annual consumption of all these areas is approximately 60,000 megalitres.

Waterworks Trusts are autonomous bodies established under the provisions of the Water Act, and operating under the general supervision of the State Rivers and Water Supply Commission. Trusts are responsible for the provision of water supplies for domestic purposes to specified areas and for the day to day operation of the supply system.

Wastewater treatment and disposal

The responsibility for the provision of sewerage facilities to serve urban communities within Victoria lies with the Melbourne and Metropolitan Board of Works within the Melbourne metropolitan area, and with local Sewerage Authorities in all other areas. The Board operates an extensive sewerage system which was first designed in the 1880s to serve a population of 1 million persons. Like all other systems in Victoria it is designed as a "separate" system, the sanitary sewers carrying wastewater being completely separate from the stormwater drains.

One of the most interesting features of the system is the Board's farm at Werribee. The Werribee Farm commenced operation in 1897 and until recently treated 90 per cent of Melbourne's wastewater. The farm covers an area of approximately 10,800 hectares and currently treats an average of 200,000 megalitres of wastewater per year. Of this, approximately 50 per cent is treated in lagoons, 30 per cent is treated by grass filtration during the winter period, and the remaining 20 per cent by land irrigation. Approximately 80 per cent of the sewage used for irrigation is applied without primary treatment. The farm has proved an efficient and economic method of treating sewage and it is anticipated that it will serve an important role in Melbourne's sewerage system for many years.

Sewerage Authorities operate under the provisions of the Sewerage Districts Act. There are currently 130 Sewerage Authorities constituted within Victoria, of which 113 have works in operation or under construction. These authorities are empowered to construct, maintain, and operate works for the collection, treatment, and disposal of wastewater from urban areas. In addition, they may, with the approval of the Governor in Council, make agreements with private industries for the acceptance of industrial wastes.

The Latrobe Valley Water and Sewerage Board was constituted under special legislation to provide among other matters a regional wastewater collection, treatment, and disposal scheme for the industrial area of the La Trobe Valley. The Board currently accepts wastes from a number of town sewerage systems and major industries. The sewerage reticulation systems in these townships are managed by separate authorities.

The Board transports these wastewaters to a large area at Dutson Downs, near the western extremity of the Gippsland Lakes, where the water is treated and disposed of by lagoon treatment and land irrigation.

Hydro-electricity

The base electricity requirements within Victoria are met from thermal generating stations located near Yallourn in the La Trobe Valley. These stations are based on the extensive brown coal deposits that have been proven in the region and will remain the primary source of electric power in the foreseeable future.

Peak demands are met by drawing power from the Snowy Mountains system and from a series of hydro-electric power stations located primarily in the north-eastern section of Victoria. Despite their relatively small generating capacity, these stations hold an important position within Victoria's total generating capacity because they can contribute to peak daily electricity demands quickly and at low operating cost.

The hydro-electric potential of Victorian streams is low and compares unfavourably with other countries. Although hydro-electric generation does not "consume" water, it must be considered in any evaluation of the State's water resources. In most cases, water is detained in storages and generally released down the stream for power generation purposes during the winter months. During this time water is not usually required for irrigation or other consumptive purposes.

Recreational requirements

The development of water-based recreational activities has increased appreciably since the 1950s. Prior to this period activities were few in number, consisting mainly of fishing, swimming, and to a minor extent, rowing and sailing.

This marked increase in water-based recreation reflects changes in Victoria's leisure habits. The post-war era brought with it greater prosperity and more leisure time, both in the form of a shorter working week and paid holidays. The recent introduction of "flexible working hours" has brought yet a further increase through the 9 day fortnight. To this increase in leisure time must be added greater mobility through more cars and better roads.

The post-war period has seen the range of water sports and activities widen with the introduction of new sports such as skiing, scuba-diving, and the development of smaller, easily transported powered and non-powered boats. These increasing activities have led to greater demands on available water areas. Many areas are now fully developed and often congested during the height of the summer period. There are growing demands for the use of man-made bodies of water, but the competing needs of users and the diversity of activities, in many instances incompatible, do lead to management problems.

Drainage, flooding, and flood plain management

The surface of the land is constantly changing as a result of natural forces such as earth movements, wind, rain, and frost. In most cases, these changes are slow and would not be noticeable in the course of a lifetime. However, over geological time spans they become significant.

Man has often carried out work with an imperfect understanding of the laws of nature and, in so doing, has on occasion upset the delicate balance that exists and consequently accelerated these changes. For example, the clearing of large areas of land for agricultural purposes has increased the run-off from many areas; the previously stable stream regime has been disturbed by this increased flow; and a further flooding problem has sometimes ensued. This problem may have been compounded by the destruction of vegetation on stream banks, leading to severe bed and bank erosion and resultant loss of land and sedimentation downstream. Sedimentation in turn has led to problems along the lower reaches of river systems.

It is clear that, given the circumstances that exist in many parts of Victoria, there are two basic choices: either accept the situation and do nothing until a state of equilibrium is reached once again, or carry out works such as improvement to the carrying capacity of rivers, and thereby reduce the effects of flooding, and at the same time attempt to stabilise the bed and banks of streams to reduce erosion and minimise further loss of land. In either case the catchment should be protected, in order to prevent further deterioration of the drainage system.

Drainage, flooding, and river management are closely interrelated, but legislation covering these activities is varied and often confusing. Floods are a natural phenomenon and will inevitably occur from time to time in rivers and natural drainage systems. A flood occurs when the channel of a river or creek cannot carry the volume of water entering from its catchment or when the water is discharged onto flat country. This results in either the overtopping of banks, accumulation of sheet water, or raised water levels. Flooding can be viewed as a natural component of the hydrological cycle, potentially damaging to man wherever he has encroached upon flood plains. Flood waters also have a significant effect on the survival of native flora and fauna.

Watercourse management

By the early 1900s, as a result of clearing extensive areas of marginal agricultural land, inappropriate farming practices, and unco-ordinated control efforts, erosion had reached such proportions that it was destroying considerable areas of Victoria. In 1940, the Soil Conservation Board was established to investigate soil erosion, promote soil conservation, and recommend further action. In 1945, the Parliamentary Public Works Committee released a report which reviewed existing legislation dealing with control of flow in natural waters, the existing condition of Victoria's streams, and the effect on these streams of the condition of their catchment. As a result of this report, the *Soil Conservation and Land*

Utilization Act 1947 was enacted. This Act, as amended, provided for the establishment of the Soil Conservation Authority to control land erosion problems throughout Victoria.

Following this initial step to control land erosion, the River Improvement Act was proclaimed in 1948. The principal provision of this Act was the power to constitute River Improvement Trusts, with responsibilities for carrying out works to improve the carrying capacity and prevent erosion on streams within their district and for maintaining these works.

The districts of most of the early Trusts consisted of a small strip of land along a relatively short stretch of river. This situation gave rise to two major problems. First, while effective works were carried out within this area, problems were often intensified either upstream or downstream of the district. Second, only those landowners fronting the stream could be rated, and hence were often forced to pay large sums to meet the Trust's costs. This was particularly inequitable when it was often the actions of landowners some distance from the stream that aggravated the problems adjacent to the watercourse. These problems have been partly overcome by constituting River Improvement Trusts to cover the whole of a Shire. This results in a much more equitable rating system, but does not eliminate the problem of responsibility over only part of the length of a stream.

This second problem can only be overcome by constituting authorities to have responsibility for river improvement works over a whole river catchment. Only one such authority, the Dandenong Valley Authority, existed in Victoria at 1981. This Authority was constituted on 19 March 1964 under the provisions of the *Dandenong Valley Authority Act* 1963. The Act gives the Authority comprehensive powers to carry out river improvement, drainage, and flood protection works within its district. As well as carrying out works, the Authority may declare areas to be flood prone and subsequently control the use to which this land may be put in order to retain its function as a carrier of flood waters.

Control of land in water supply catchments

Human activity in a catchment, associated with various forms of land-use, can affect the quantity, quality, and variability of run-off. Water supply authorities are committed to the maintenance of certain quality standards for the water supplied to consumers. The factors governing the quality of water supplied are: (1) The quality of source-water received as run-off from the catchment, dependent on the condition of the catchment as modified by any human activity within the catchment; (2) changes in water quality due to detention and transmission in the Authority's works; and (3) any additional treatment by the Authority, as may be required to attain nominated standards.

A change in land-use in the catchment can be detrimental to water supply interests if: (1) It accelerates erosion with consequent worsening of the quality of run-off and of the rate of siltation of storages; (2) it reduces the volume or reliability of run-off decreasing the safe yield from existing works; (3) it adversely affects the seasonal distribution of run-off; or (4) it increases the risk of chemical or pathogenic contamination of run-off.

Continuance of existing restrictions on access or controls on uses of lands supplying waters for domestic purposes, is the surest and simplest means of providing a high degree of protection against water-borne diseases. With present technology, there can be no guarantee that a water treatment plant can remove all hazardous elements, such as viruses, complex organics, and pesticides.

STATUTORY FUNCTIONS OF OTHER WATER SUPPLY AGENCIES

There are a number of other agencies which have statutory functions affecting water supply. These include particularly agencies under the umbrella of the Ministry for Conservation.

The Environment Protection Authority (EPA) is specifically concerned with pollution management and control. This is mainly achieved by operating a licensing system for waste discharges to air and water. Under section 68 of the *Environment Protection Act* 1970, the EPA has delegated its powers and functions in regard to licensing procedures for the discharge of wastes to all waters, except marine, to the Melbourne and Metropolitan

Board of Works in relation to waters within the Melbourne metropolitan area; to the Latrobe Valley Water and Sewerage Board and Dandenong Valley Authority for their respective areas; and to the State Rivers and Water Supply Commission for all other areas of Victoria.

Long-term objectives for pollution control management are established by way of State environment protection policies. Beneficial uses of waters with objectives and indicators for attainment are set down in these documents, of which a number have already been declared State policies, and others are currently in draft form.

The Soil Conservation Authority has a specific statutory role in proclamation and land-use determinations for water supply catchments. Its basic responsibilities are to achieve the best possible use of Victoria's land resources and to ensure sustained yields of high quality water from Victoria's catchment areas.

All major public works may require the preparation of an Environment Effects Statement and be subject to the environment assessment procedures of the Ministry for Conservation. The procedures are designed to ensure that potential environmental problems are recognised and quantified during the planning stage, and provision is made during assessment for public comment.

The Fisheries and Wildlife Division and the Land Conservation Council also play significant roles affecting management of Victoria's water resources. Proposals for works affecting stream flows and wetlands are undertaken in consultation with the Fisheries and Wildlife Division, and the Land Conservation Council is responsible for investigating and recommending on the balanced use of public lands throughout Victoria. These recommendations may influence land-uses especially affecting water supply catchments and are designed to recognise present and future needs of Victoria in relation to preservation of ecologically significant areas, areas of natural interest or beauty, and preservation of areas for recreational, forest, and other public uses.

On a broader basis, the issue of Statements of Planning Policy provides direction for water and wastewater management, and the annual budgets and capital funds allocations of State and Commonwealth Governments directly influence the timing and standards for the provision of the water, sewerage, and drainage services.

Further references: History of Victoria, *Victorian Year Book* 1961, pp. 1-28; Land flora, 1962, pp. 1-36; Mammals, 1963, pp. 1-24; Soils, 1964, pp. 1-9; Palaeontology, 1965, pp. 1-24; Birds, 1966, pp. 1-28; Fish, 1967, pp. 1-27; Molluscs, 1968, pp. 1-21; Insects, 1969, pp. 1-26; Minerals, 1970, pp. 1-29; Amphibians and reptiles, 1971, pp. 1-36; Forests, 1972, pp. 1-29; Meteorology, 1974, pp. 1-29; National Parks, 1975, pp. 1-35; Victoria at the time of settlement, 1976, pp. 1-45; The Victorian environment, 1977, pp. 1-46; Victoria's forests and man, 1978, pp. 1-35; Transport in the Victorian environment, 1979, pp. 1-25; Great Dividing Range in Victoria, 1980, pp. 1-33; Grazing in the Victorian environment, 1981, pp. 1-23

BIBLIOGRAPHY

GRAHAM, W. A. E. *The Present Position with Water Salinities in Victoria.* Water Research Foundation. 1979. Victorian Symposium.

MEACHAM, I. R. *Water Use Survey in Victoria.* Victoria's Resources Vol. 19 No. 4. December 1977.

STATE RIVERS AND WATER SUPPLY COMMISSION. *Annual Reports.*

VICTORIAN YEAR BOOK. *Rivers and water resources.* Vol. 77, pages 30–43, 1963.

VICTORIAN YEAR BOOK. *Victoria at the time of settlement.* Vol. 90, pages 1–45, 1976.

WATER RESOURCES COUNCIL. *Review of Victoria's Water Resources and Utilisation Part 1.* Ministry of Water Resources and Water Supply. 1980.