COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1969 / 74

The Pollution of Groundwater

by

G.M. Burton

(With Appendix by A.D. Haldane)

THE POLLUTION OF GROUNDWATER

(A submission prepared for the Senate Select Committee on Water Pollution, April, 1969.).

by

G.M. Burton

(Appendix by A.D. Haldane).

RECORD 1969/74.

THE POLLUTION OF GROUNDWATER

Contents

PREFACE

The following submission outlining the nature and problems of pollution of groundwater in the modern environment was prepared to assist the Senate Select Committee on Water Pollution (Chairman: Senator G.S. Davidson). The submission together with additional verbal evidence were presented to the Committee at a hearing in Canberra on 28th April, 1969.

The submission includes an appendix on pollution of groundwater in the Australian Capital Territory and an appendix (by A.D. Haldane) on pollution of the Molonglo River by mining operations at Captains Flat, New South Wales.

One should note that in the modern human environment it is economically impossible to prevent completely any pollution of water resources. Rather man has to attempt to eliminate unnecessary or dangerous sources of pollution and control other sources of pollution so that he maintains acceptable standards of quality of his water resources.

Two valuable references on pollution not mentioned in the written submission but included here for completeness are: (1) the survey of existing world legislation (WHO, 1966), and (2) a selected bibliography of reports on underground waste disposal in Finch (1968).

FINCH, W.I., 1968 - Engineering geology of the Calvert City Quadrangle. Kentucky geol.Surv., Inform. Circ. 16.

W.H.O., 1966 - Control of water pollution - a survey of existing legislation. World Health Organ. Internat. Digest of Health Legislation, 17, 4, 629-834.

SUBMISSION TO

SENATE SELECT COMMITTEE ON WATER POLLUTION

Introduction

The Bureau of Mineral Resources welcomes the opportunity to present information to the Senate Committee on Water Pollution. The Bureau regards water pollution* as a matter of great importance and one of increasing urgency in the development and conservation of Australia's basic resources. In order not to overburden the Committee with technical detail in the early stages of its work, this submission is restricted to general principles and important matters; it does not discuss standards for quality of water, which are the province of other authorities.

Activities in water resources

The Bureau of Mineral Resources is a division of the Department of National Development and is responsible for the assessment of groundwater resources in the Australian Capital Territory and for technical advice on the management and development of the resource; the Department of Health is concerned with the potability of water from bores serving the public. The Bureau's role in other Territories such as the Northern Territory is, or has been, shared with other Commonwealth Departments including the Departments of Territories, Interior, Works and Health. The Bureau also assists the States, when requested, to assess their groundwater resources. As part of its general mineral surveys for heavy metals, oil, gas and coal, the Bureau acquires and has published large amounts of groundwater data.

The Assistant Director (Geology), Dr. N.H. Fisher+, is Deputy Chairman/Convenor of the Australian Water Resources Council's (A.W.R.C.) Technical Committee on Underground Water (T.C.U.W.) and the Bureau, through Dr. N.O. Jones, provides the Secretariat for T.C.U.W. Bureau geologists and geophysicists serve on ten of the specialist committees and panels of A.W.R.C.

General Statement on Groundwater

Groundwater resources are of the greatest importance to Australia. Figure 1 shows the very limited quantity and distribution of surface run-off in Australia and compares Australia with the U.S.A.

The Australian surface resources are for the most part close to the present major cities and naturally are heavily committed to them for water supply and to a lesser extent for hydro-electric supply.

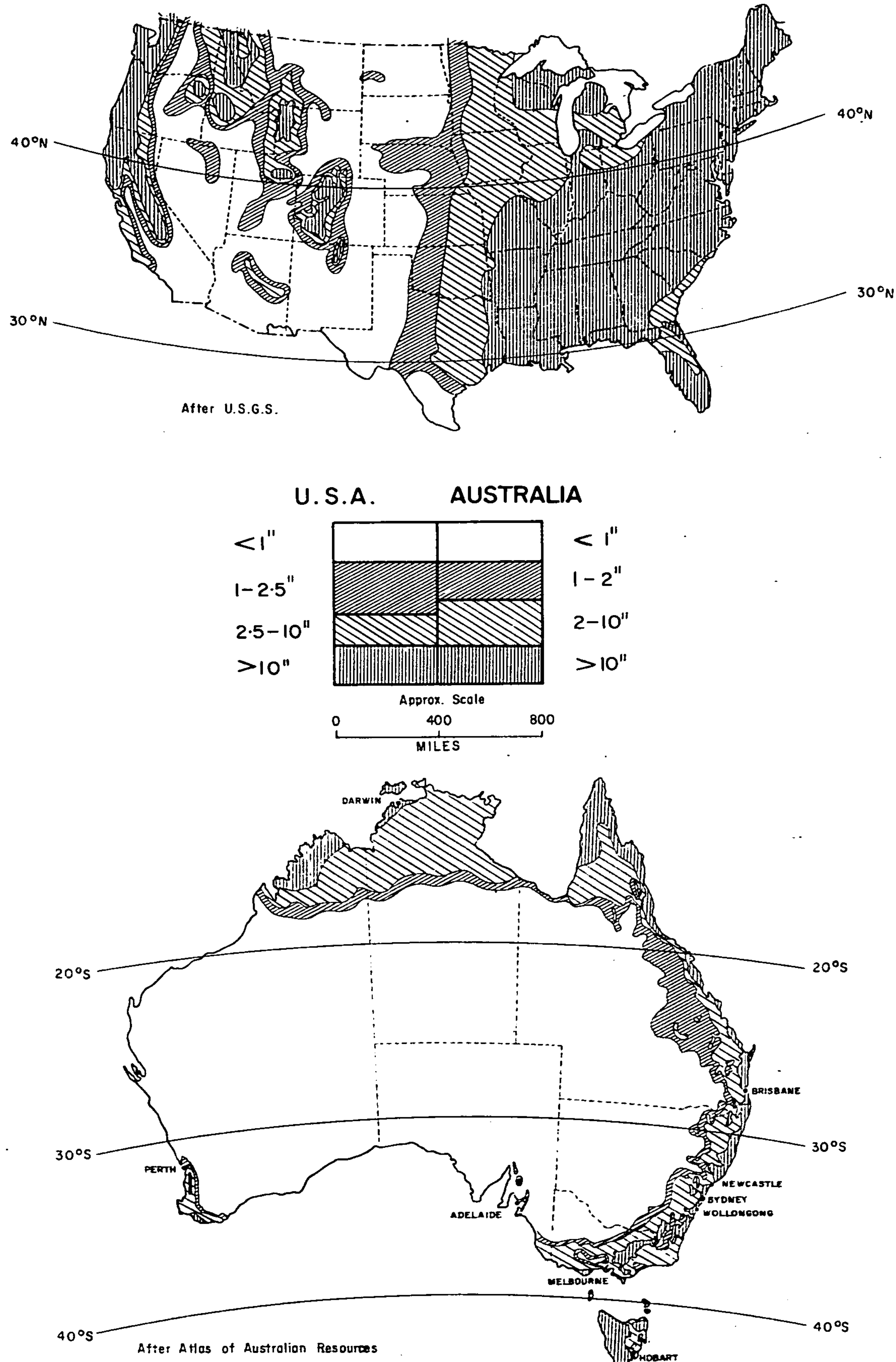
---

* Pollution of water supplies is defined for this submission as any change in the nature of the water that will impair its usefulness, directly or indirectly, to man.

\+ Now Director, Bureau of Mineral Resources.

AVERAGE ANNUAL RUN-OFF

Fig 1



Bureau of Mineral Resources, Canberra

To accompany Record 1969/74

M(G) 109

Restricted areas of the inland benefit from irrigation, flood control, and hydro-electric or multi-purpose dams in the high run-off areas. However, as the resources of the high run-off areas become fully committed the towns of the inland and major area of Australia will have to turn for their development progressively more to underground water. The preservation of these underground resources from damage by pollution is of very great importance to the well-being of inland residents and the development of Australia.

Recharge of underground water resources in many cases comes from surface run-off in major streams. The use of rivers, particularly the long major Australian rivers, as drains for waste must be examined with great care not only with respect to surfacd problems, but also for its influence on quality of groundwater, if Australia is not to build up for herself much more serious problems than most people appreciate.

Nature of groundwater

Groundwater moves and is stored below the surface of the earth; it is not observable except by observation bores and geophysical techniques such as resistivity surveying. Consequently, although most people understand the behavious of rivers etc. that are readily observable, few laymen understand the principles of the occurrence of groundwater.

Texts which treat groundwater in more detail include -

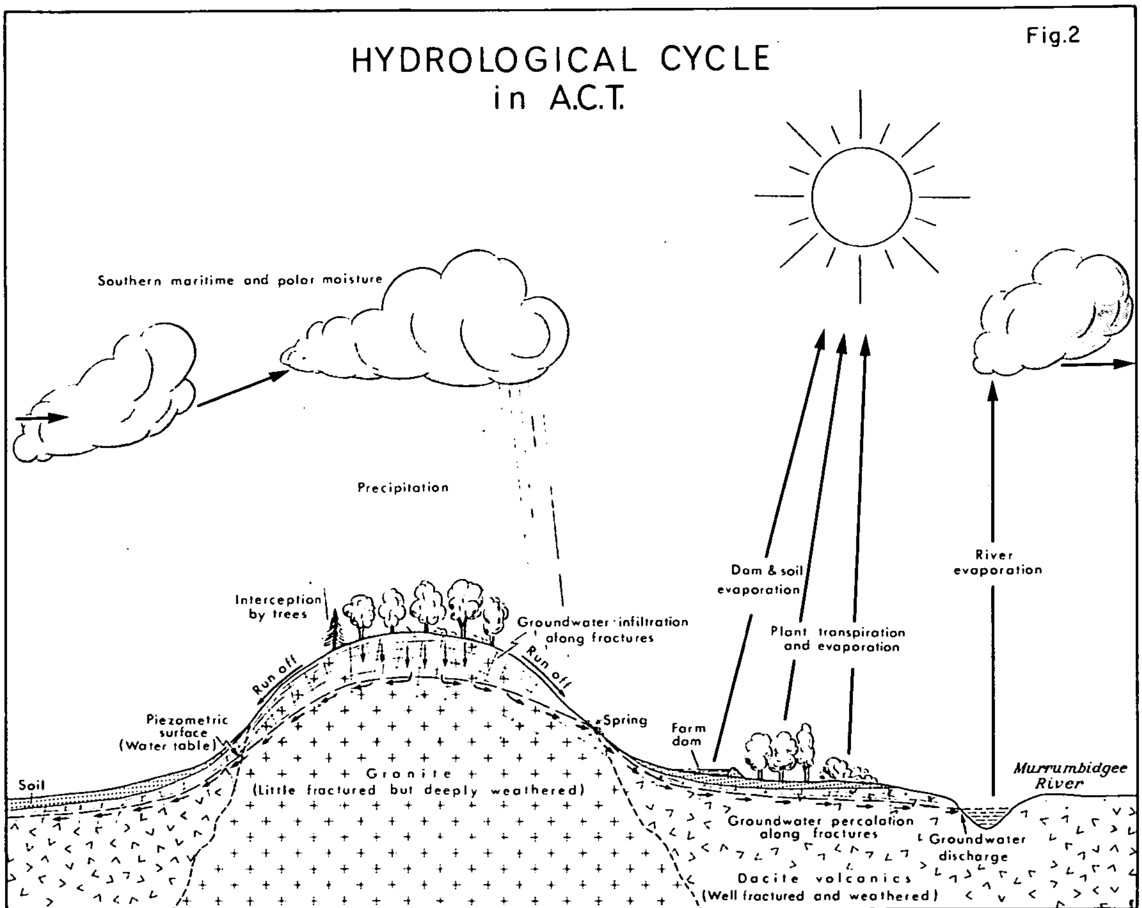
"Groundwater and Wells" (Anon., 1966, Edward Johnson Inc. St. Paul Minn.);
"Groundwater Handbook" (Anon., 1959, S.Aust. Dep. Mines, Adelaide);
"Hydrogeology" (Davis and De Wiest, 1966, John Wiley & Sons, New York);
"Review of Australia's Water Resources, 1963" (1965, Dep. Nat. Dev.)

All these books are held in the Bureau's library. A more extended reading list is attached (B.M.R. Record 1968/139)*.

Groundwater occurs, generally speaking, throughout the whole of Australia (see "Groundwater Map of Australia" attached)*. The water is in the interstices and cavities that are commonly found in rocks in the upper 10,000 feet or so of the earth's crust. These openings are larger and occur over greater areas in the topmost 500 feet of the crust. Rainfall and surface streams supply water to the openings in soil and rocks and the portion of it that is not consumed by plants and evaporation passes down to the deeper openings (Figs.2 & 3a). There it enters the main body of groundwater in the zone of saturation and starts to move with it, usually to an outlet such as a river or sea.

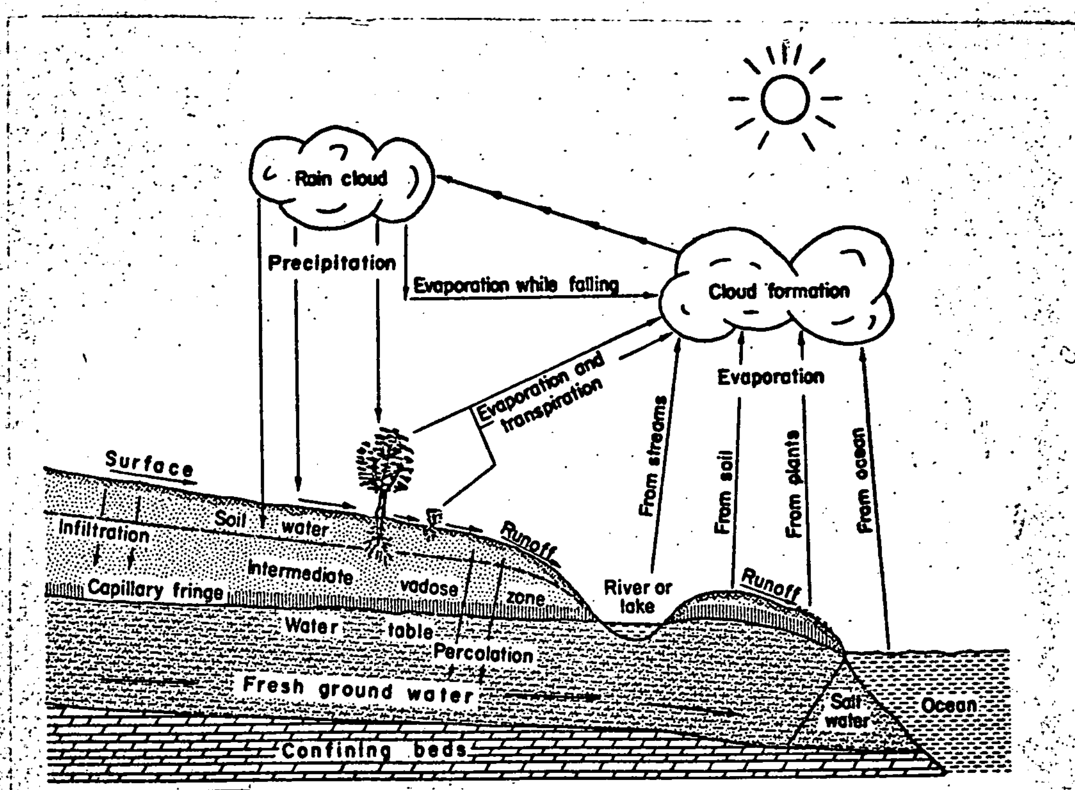
---

* Not included in this Record. See:
Burton, G.M., 1968 - Preliminary groundwater reading list and key references. Bur. Miner. Resour. Aust. Rec., 1968/139
C.D.N.D., 1965 - Australia - Underground Water Map, from Review of Australia's Water Resources, 1963. Cmnwlth of Aust Dept National Development Rept



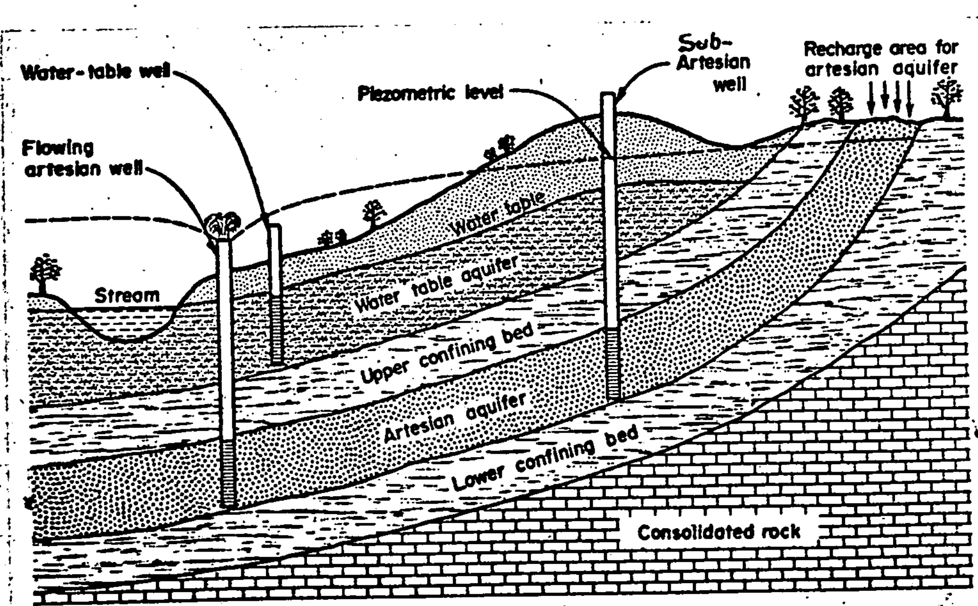
To accompany Record 1969/74 155/A16/427

(a)



Schematic diagram of the earth's water cycle—the hydrologic cycle.

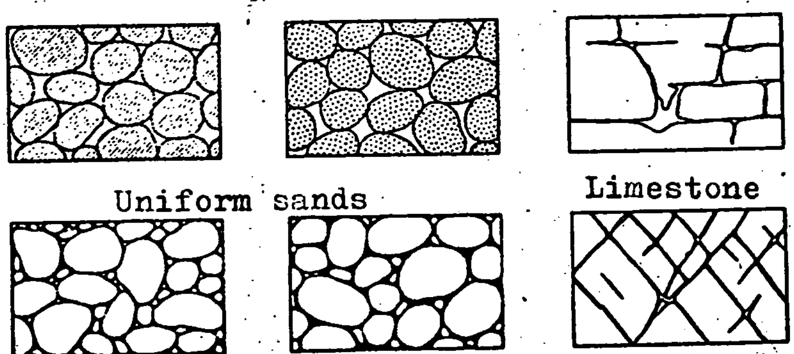
(b)



Subsurface and ground-water phase of the hydrologic cycle.

Modified from "GROUNDWATER AND WELLS".

Fig.4



Examples of rock interstices and the relation of rock texture to porosity (after Meinzer[22]).

Representative Porosity Ranges for Sedimentary Materials

Material	Porosity, per cent
Soils	50–60
Clay	45–55
Silt	40–50
Medium to coarse mixed sand	35–40
Uniform sand	30–40
Fine to medium mixed sand	30–35
Gravel	30–40
Gravel and sand	20–35
Sandstone	10–20
Shale	1–10
Limestone	1–10

Adapted from "GROUNDWATER HYDROLOGY"

D.K.TODD (Wiley,N.York)

The amount of water stored in the saturated zone and the rate at which it moves depends on the number and size of the interstices and the general structure of the earth's crust. The rate at which the supply is replenished and the depth to the top (water-table) of the saturated zone depend mainly on rainfall, evaporation, vegetation, and landform. Porosity is of two types: intergranular, and structural (joints, faults, bedding planes, etc.). As regards intergranular porosity, the nature and size of the openings is worth noting (Fig. 4). In gravel and sand the pores and voids are large and continuous; large quantities (as much as 35-40% of the volume) are stored and water can travel rapidly through. In clay, on the other hand, very large quantities are stored (45-55%) but the openings are very small and movement is extremely slow. Limestone may contain very small cavities or large caves. In the caves the water can move as rapidly as a surface river. This gives rise to the popular (diviner's) idea of underground water occurring in 'streams' which have to be precisely located.

The passage of water through earth and rock filters and oxidises it and permits soil bacteria to attack its impurities; this usually has a beneficial effect. Hence the distance and length of time occurring between a source of pollution, and consumption of underground water are very important. It is vital to understand the path, rate of movement, the nature of the minerals it will be in contact with, and the dilution that may occur over the long circuitous routes that groundwater often follows. This knowledge is important not only in preventing pollution but also in foreseeing the likelihood of pollution and selecting areas where groundwater movement may actually be used to improve polluted water.

A thorough knowledge of hydrogeology and groundwater also permits hydrologists to define areas in the earth's crust in which, because of the almost negligible movement of groundwater, very harmful wastes, such as radioactive materials, may be safely disposed of.

Both the <u>positive</u> and <u>negative</u> roles of hydrogeology in pollution must be taken into account -

(1) Groundwater commonly may be polluted easily.
(2) Many groundwater storages are preserved from pollution by earth filters and impermeable barriers of clay and other rock.
(3) Polluted water may be directed into recharge beds where it will be filtered before reaching the main storage.
(4) Rocks with low permeability can form disposal zones for very toxic wastes.

The Bureau would also emphasize the importance of studying the whole cycle of movement of water from the sea, as evaporation, to rainfall and back to the sea by surface run-off and underground drainage (<u>the hydrologic cycle,</u> Figs. 2 & 3a). This cycle can be manipulated considerably by man for his own benefit, but the manipulation has to be carefully supervised. It can be seen that stream flow is composed of surface run-off and groundwater discharge. Surface streams bear many man-made pollutants; groundwater commonly bears considerable quantities of various salts dissolved from the host rocks in its passage through the rocks.

If the flow of either is altered considerably by man, changes will occur in the quality of the stream: it is the duty of the hydrologist to achieve at all times the optimum stream-flow and groundwater storage, both in quantity and quality.

Pollutiom

General. The Bureau's definition of pollution given at the beginning of this report differs from commonly used definitions based only on the addition of biological and chemical substances, and sediments as it covers temperature, a purely physical property, as well. For instance, the uncontrolled addition of water of unsuitably temperature to a groundwater reservoir would impair its usefulness for air-conditioning and other purposes which depends on its normal relatively constant temperature.

Four types of causes stand out when considering pollution of groundwater:

(1) deliberate acts fully knowing the results;
(2) acts performed in ignorance of the consequences;
(3) accidents, the effects of which are not easily observed, such as rupturing underground pipes by a surface explosion;
(4) carelessness in the design of pipelines, tanks, and disposal systems.

When these points are considered it can be seen that legislation alone to prevent pollution will not suffice. Publicity leading to awareness will remove much of the problem and lead to easier and cheaper enforcement of legislation. The Bureau believes that the Senate Select Committee on Water Pollution has already made the public much more aware of the problem. Because the need for groundwater will increase considerably over the next ten years it will be necessary to give much more publicity to the use and abuse of groundwater during this period.

Causes of pollution

Major causes of pollution are considered in general in the following section. Specific cases of pollution in the Australian Capital Territory are considered in Appendix 1.

Chemical (including radioactive). Highly toxic organic, inorganic, and radioactive chemicals can have the same effects on groundwater as on surface supplies. However, oxidation of the pollutants by the soil profile, exchange of ions with those of the soil and rock, adsorption of ions on minerals in the earth, and chemical reactions in general often render the pollution less dangerous. Nevertheless the property of purification can be overestimated; trouble then comes on closer sub-division of land when bores are installed closer to disposal areas and the length of passage of the pollutants is decreased.

Chemical pollutants suddenly become a problem in developing towns and small cities when the development brings in more sophisticated industries using either unusual or newly developed chemicals.

In the absence of adequate and specialized disposal facilities in the new industrial centres much of the waste is disposed of to temporary soakage pits, etc.

The increasing use of chemicals on farms is important, as is the increasing use of insecticides and herbicides, particularly those which do not degenerate in the soil. Commonly, detergents and other wetting agents are disposed of along with the other chemicals - this is critical in groundwater because of wetting agent increases the rate of transmission through soil and rock very greatly and can establish a new path not only for chemical but also for bacterial pollution. The increasing occurrence of possible radioactive pollutants should be noted.

Groundwater is usually safer than surface water from nuclear accidents and even hostile nuclear or chemical attack. This advantage should be maintained by preserving the purity of groundwater so that it is available as an emergency supply.

Bacterial. The disposal of bacterial wastes from sewerage, septic tanks, abattoirs, hospitals, saleyards, universities, and other institutions is well known. The hazard is generally well recognized. The addition of wetting agents in the effluent, however, is a relatively new hazard. Joints in sewerage lines deteriorate in time, and leakage is generally to the groundwater body. High standards of installation are required in areas where the groundwater could carry the effluent into water supply points or into lakes and rivers.

Garbage. The modern community produces large quantities of garbage as distinct from chemical and liquid wastes. Pollution arising from the rotting and corrosion of the garbage, particularly in areas of shallow burial without burning, should be noted.

Oil. The development of oilfields can produce hazards to groundwater supplies. Drilling must be of a high standard to prevent pollutants entering groundwater reservoirs, or poor quality water moving from a poor reservoir to a clean reservoir. Brines recovered during drilling may also be disposed of in an unsatisfactory manner, on the ground surface.

Sediments. Water sources such as turbid streams carrying much clay may be fed to a groundwater reservoir or its intake beds. This may cause serious damage to the aquifer.

Groundwater drilling. Poorly constructed or ill-designed bores, like oil wells, may allow poor quality water to enter good reservoirs during drilling, or later through corroded casing, weak joints or poorly cemented zones.

Groundwater management. Badly designed systems of bores or pumping programmes can lead to an overdraft in some areas of an aquifer and this can incduce sea water, polluted streams, and surface drainage, or poor quality water from aquifers, to flow into the groundwater reservoir.

Earthquakes and major explosions. These may disrupt sewerage and chemical lines and tanks. The drainage from these to groundwater reservoirs can be expected if the impact is sufficient.

Major accidents. Large fires in industrial plants and stores, railway accidents and even mishaps to major road transports can result in the flushing of dangerous substances into the soil profile. These hazards become greater as installations increase in size or more toxic chemicals are transported.

Major excavations. Major excavations may establish new paths for pollutants to enter groundwater reservoirs. Excavations for deep pipelines reduce the effectiveness of the soil filter; also the gravel bed of the pipeline may transmit polluted fluids rapidly.

Effects of pollution

Most of the effects of pollution are implied in the preceding section on causes of pollution. These are the rendering of groundwater unsuitable for use by humans and animals because of bacterial contamination, toxicity, radioactivity, taste, smell, temperature change or appearance. Other effects are the introduction of trace chemicals that can render the water unsuitable for industrial processes such as paper making.

Polluted groundwater can kill crops and natural vegetation and lead to soil erosion.

When a surface stream is polluted the stream flow may remove the problem in a day. Removal of groundwater pollution, on the other hand, may take a very long time because the rate of movement is slow, and diffusion and capillary forces tend to resist the normal flushing type operation for cleaning.

Pollution may cause permanent physical damage to an aquifer. Mud entering the reservoir may permanently reduce its permeability. Also the groundwater reservoir and water passing through it are in a delicate chemical and physical equilibrium. Changes in the chemistry of the water can lead to a reaction in, or with, the reservoir rocks or soil which may affect their ability to conduct and yield water.

Many people also believe it is in order to deposit toxic substances in rocks where groundwater is not at present stored. This is correct in many cases. Nevertheless experience in the U.S.A. is now showing that some of the best potential storages for water supplies are underground and could be filled artifically. Hence care must be taken not to destroy potential storages by filling them unnecessarily with pollutants beforehand.

Prevention and Control

The need for sound legislation is obvious. The legislation should be enforced by officers well trained in the full hydrologic cycle and abreast of changes in industry and chemicals who will not only be able to detect pollution but issue warnings when new sources are likely to arise.

Publicity and information are vital. It is necessary that all Australians understand the nature and causes of pollution so that the ordinary well-intentioned citizen will play his part in preventing pollution. It is said that a law that cannot be enforced is a bad law: laws against pollution are difficult to enforce and require maximum voluntary support by all citizens. The amount of literature in various forms such as pamphlets used to train people in the U.S.A. in water supply matters was particularly noted by a geologist of the Bureau studying groundwater developments recently in the U.S.A.

Authorities should try to attain uniform legislation and avoid changes of standards at administrative boundaries. Polluted underground water can cross an administrative boundary and vitiate different standards of pollution control. To help combat pollution all workers in the technical field of water supply should be adequately trained and where necessary licensed. Poorly trained drillers, drainers, and pumping supervisors can do major harm.

Authorities can take a positive approach to the disposal of waste by encouraging research into the design of waste disposal and treatment. Underground disposal of radioactive waste must be studied because great care is needed with radioactive products of long half-life.

Seismic hazards causing water pollution in groundwater should not be underestimated in Australia. Seismic records in Australia cover only recent years, but sufficient major shocks have been recorded to act as a warning.

During World War II a system of emergency bores was instituted in the Botany Sands of Sydney. The value of such a supply, where a surface supply may be damaged or polluted deliberately and easily, requires that such emergency groundwater supplies should be protected from pollution.

APPENDIX I

Groundwater Pollution in the A.C.T.

General

There is no legislation specifically controlling groundwater in the Australian Capital Territory; the Department of Interior has had consultation with the Bureau of Mineral Resources and other bodies.

The rocks of the inland or Canberra section of the A.C.T. are crystalline fractured rocks. These bear and transmit water in fractures. The systems of fractures are irregular and it usually requires a geologist to map the movement of groundwater and adequately predict the likely dangers from pollutants. Fortunately groundwater is little used in the Canberra area and sources of pollution up to the present have been few. Increases in industry and population, however, indicate that the problem will probably become significant. Examples of new larger users of groundwater who are raising its importance are the three space-tracking stations in the western area of the A.C.T.; particular care is taken when siting bores for installations such as these to avoid possible sources of pollution.

The main likely sources of pollution around Canberra are chemical insecticides and herbicides, house drainage, sewage and septic tank effluent, industrial chemicals and drainage in light industrial areas such as Fyshwick, and drainage from quarries or mines. Bores in rural areas of the A.C.T. do have some advantage as far as pollution is involved; they are free from turbidity and from intestinal parasites which commonly pollute surface streams in heavily grazed sheep country.

In the Jervis Bay area of the Territory groundwater occurs in coastal sands and sandstones. The course of the flow of groundwater and pollution is easier to estimate. Little pollution exists there at present. Nevertheless, in view of the increasing population, the relative scarcity of surface water supplies, and the valuable groundwater supplies that exist in the coastal sands, considerable care should be taken to prevent and control pollution. The most likely sources are septic tank effluent and sewage, forestry insecticides and herbicides, quarry and mine drainage, and chemical drainage from industrial or defence developments. Pollutants do not enter coastal sands easily, but the presence of detergents and wetting agents will make the passage into and down to the water table easy and rapid.

Examples of possible pollution

Chemical The rang and toxicity of agricultural, pastoral, and forestry insecticides and herbicides are growing, and users do not always appreciate the danger when using or disposing of them. On several occasions the Bureau has had to take great care with bores near homesteads because of the disposal of arsenical sheep dip in large quantities from the shearing sheds nearby.

Wetting agents are commonly used with agricultural chemicals and the risk of the chemicals reaching the groundwater reservoir is increased.

The use of radioactive chemicals and tracers is not yet a problem but vigilance is required.

Bacterial. Bacterial sources of pollution exist in rural settlements from septic tanks, in the city area from leaking sewerage pipes, in sewerage treatment plants from the first digestive tanks, from abattoirs and similar plants.

Several bores in rural settlements have shown preliminary evidence of coloform bacteria. On one occasion evidence of serious pollution in a bore serving a refreshment room was traced to a very badly prepared drain for the septic tank.

One particular case of likely pollution calls for special note. A night-soil can laundry was found discharging effluent into the A.C.T. from the adjoining section of N.S.W. and endangering a possible farm bore site. Pollution at administrative boundaries calls for special attention. Lack of communication and liaison between responsible authorities can lead to concealed hazards. The administrative boundary may either be adjoining regional authorities or authorities in different disciplines such as surface and groundwater.

Other sources. Soil erosion can impair or lead to the destruction of intake beds for groundwater. The destruction is not likely to be a great factor in Canberra but the soil erosion should be noted as an example of sediment that can be carried from the Southern Tablelands into other areas. Partly dissected soil profiles of up to 25 feet near Canberra show the vast amount of clay and silt that can be carried into the river systems, if it is not controlled, and there endanger surface and underground supplies alike.

A particular case of sediment pollution is the destruction of the slimes dumps at the Captains Flat mine (Appendix 2). When the slimes were carried down stream they were spread partly on the flats near "Carwoola". These flats contain alluvium bearing groundwater and now, many years later, care has to be taken in case the pollutants have been stored in some sections of the alluvium. This is an example of how groundwater pollution can exist for years after a disaster - surface pollution on the other hand is usually soon flushed away.

APPENDIX 2

Stream Pollution by Mining Operations at Captains Flat - A Case History

(by A.D. Heldane)

The first systematic investigation of the Molomglo River arose from some experimental work on geochemical prospecting methods carried out by the Bureau of Mineral Resources during 1959. This led to the selection of the Molonglo River for a study of the behaviour of metal ions (zirc in particular) in a natural stream. The results of this investigation clearly established the pattern of pollution in the river.

The Molonglo River rises in New South Wales some 32 miles south-south-east of Canberra, about 4000 feet above sea level. Fig. 5 shows the course of the river as far as Lake Burley Griffin. The numbers refer to sampling points. About 7 miles northwest of its source the Molonglo flows through the township of Captains Flat, where the now-abandoned Lake George Mine is located.

Mineralization at Captains Flat was discovered in 1878. Mining began in 1880, but was not continuous until 1938, when the Lake George Mining Company began full-scale operations. The mine was finally abandoned in July, 1962 and it was between 1938 and 1962 that the initial pollution of the Molonglo River occurred. Prior to 1938 there is no record of pollution and the Molonglo was known locally as an excellent trout stream. The inorganic pollution of the river above Lake Burley Griffin is traceable to the various mining operations at Captains Flat.

During August, 1939 a slimes pond (1, Fig. 6) used for the settlement of tailings from the flotation plant burst its retaining wall and discharged polluted water into the town reservoir. This apparently was a minor mishap as there is no record of complaints of pollution. In July, 1943, however, there was another slimes dump collapse (3,Fig.6) in which an estimated 40,000 cubic yards of tailings consisting mainly of siliceous gangue and pyrite with lesser galena, chalcopyrite, and sphalerite slipped into the town reservoir. An equivalent volume of water was displaced from the reservoir carrying large quantities of tailings and associated weathering products (iron, aluminium, magnesium, copper, and zinc sulphates) into the Molonglo River. The resulting flooding of the river deposited tailings as far downstream as point 10 (Fig. 5) but mainly between points 5 and 6. Widespread destruction of the vegetation from the excessive metal concentration and acidity followed. Even today, some affected areas have not fully recovered. Although the pollution by the slimes dump collapse cleared from the river in 10 to 14 days, the tailings deposited on the flood plain have continued for twenty five years to release metal (mainly zinc) in soluble form which is leached back into the river.

During the period of mining from 1939 to 1962 acid mine water from the lower levels was pumped into the Molonglo River via Copper Creek (Fig. 6). Waste water from the flotation plant and other mine drainage also flowed along the same route. This water contained iron, copper, lead, zinc, arsenic, antimony and sulphate ions derived from natural oxidation of the ore and from time to time thiocyanates, sulphides, and phenolic substances derived from treatment of the ore. Table 1 shows the distribution of some of these along the length of the river.

When the mine closed in 1962 pollution from active mining naturally ceased; but pollution from acid mine water (Table 2) overflowing from the abandoned workings continued. An officer of the N.S.W. Department of Mines inspected the area and following his recommendations the ventilation shaft, from where the now flooded mine overflowed, was effectively sealed in December, 1966. This resulted in a marked decrease in the zinc concentration in the river, as shown by the following table.

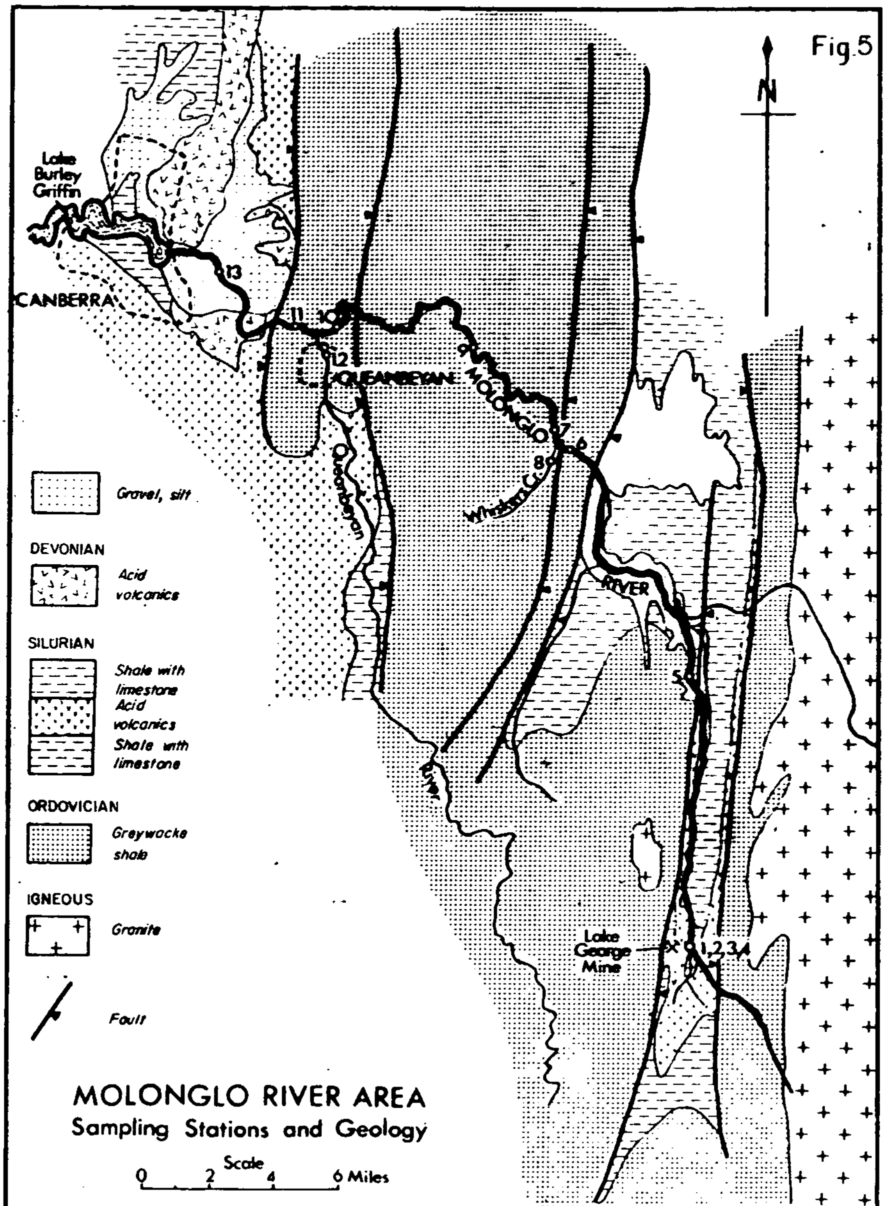
Zinc Content of Molonglo River

Sampling Site (fig. 5)	Average for 21 months prior to December, 1966	Average for 27 months following December, 1966
2 (downstream of mine)	100 ppm	19 ppm
5 (6 ml. downstream)	63 "	23 "
6 (17 ml. downstream)	30 "	7 "
10 (35 ml. downstream)	11 "	2 "
13 (42 ml. downstream)	0.72 "	0.72 "

Since pollution from the mine workings has ceased the present level of zinc in the river is considered to be derived from the oxidation of sphalerite spread over its flood plain by the 1943 slimes dump collapse.

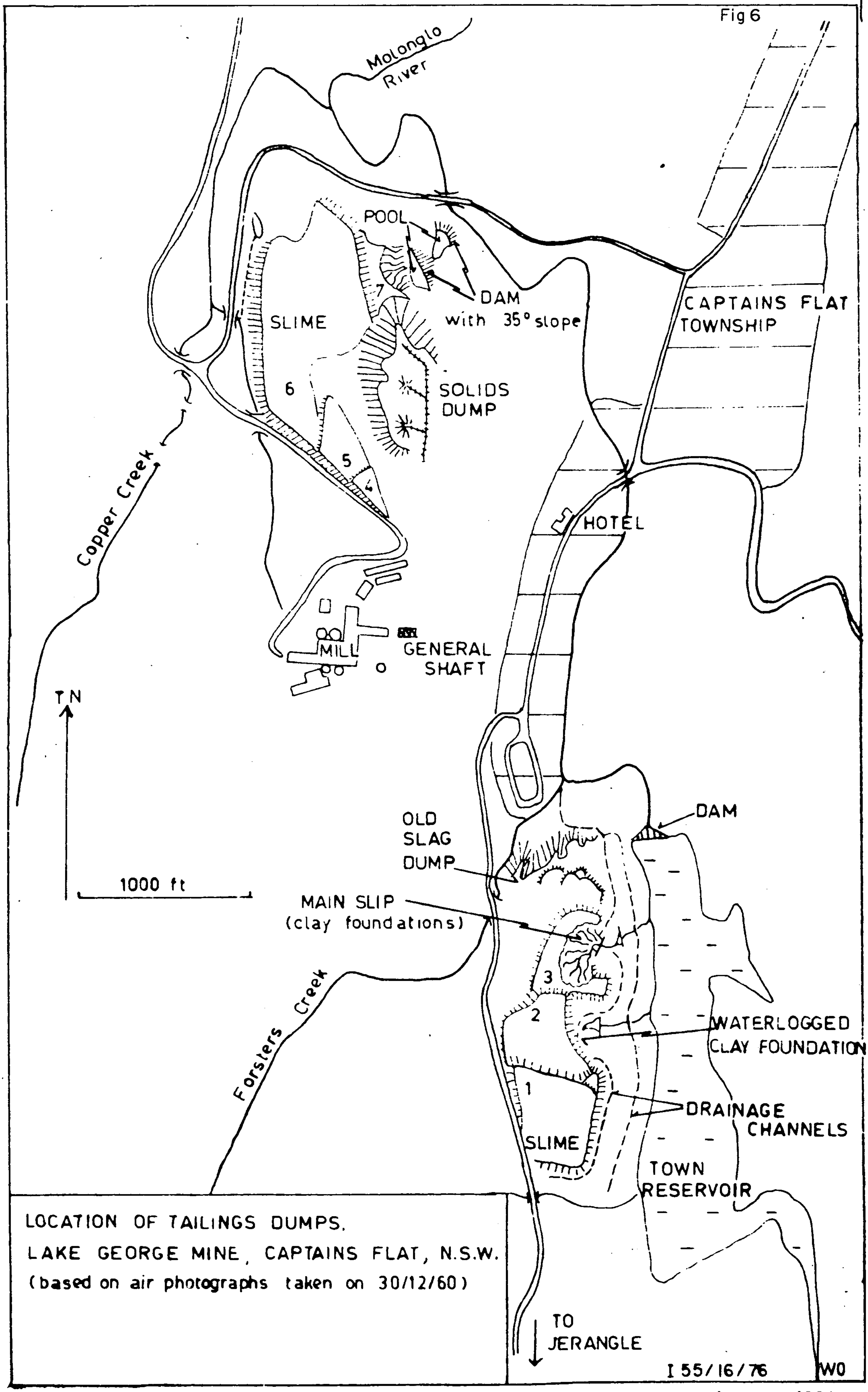
The slimes dumps still remain a potential source of pollution, not so much from the possibility of further collapse as from the leaching of soluble oxidation products from the stacks during periods of wet weather.

As the Molonglo River forms the natural drainage system for the area all material leached from the slimes dumps must gravitate to the river unless ponded and the water removed by evaporation. Of course there is a practical limit to what pond capacity can be provided and when run off and drainage during wet weather exceeds this capacity the excess is discharged into the river (fig. 6). This has happened on numerous occasions over the years and can be expected to continue. Such pollution will persist only for short periods but because of its periodic nature and the time available for the accumulation of soluble weathering products the pollution level can be quite high, particularly in the upper reaches of the river.



To accompany Record 1969/74

I55/A16/302



LOCATION OF TAILINGS DUMPS.
LAKE GEORGE MINE, CAPTAINS FLAT, N.S.W.
(based on air photographs taken on 30/12/60)

The effect of pollution on the ecology of the river system has not been dealt with here, as this formed the subject of an investigation under the direction of Dr. A.H. Weatherley, School of General Studies, A.N.U. carried out on behalf of the National Capital Development Commission.

Table I

Pollutant Distribution in the Molonglo River -

April 1960

Sampling site (fig. 1)	pH	Iron	Zinc	Copper	Sulphate	Thiocyanate
1(upstream of mine)	6.7	nil	1	0.05	28	nil
2(downstream of mine)	3.5	14	211	1.5	1146	15
3(mine effluent)	3.7	28	539	5.0	2630	30
5(6 ml. downstream)	4.9	6	90	0.5	540	4
6(17 ml. ")	6.7	1	54	0.05	374	nil
9(26 ml. ")	7.3	nil	39	0.05	312	nil
10(35 ml. ")	7.3	nil	38	0.05	410	nil

all values except pH are in parts per million

Table 2

Partial Analysis of Mine Water

Lake George Mine - November, 1964

pH	3.6
Iron	1290 ppm
Zinc	3000 "
Copper	0.1 "
Lead	2 "
Arsenic	0.1 "