

REPT.BK.NO.81/35
MOUNT GAMBIER, South Eastern
South Australia - Urbanisation
in a Karst Environment

GEOLOGICAL SURVEY

by

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DME.327/75

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DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

Rept.Bk.No. 81/35
D.M.E. No. 327/75

MOUNT GAMBIER, South Eastern South Australia
- Urbanisation in a Karst Environment

ABSTRACT

Mount Gambier is a city of about 20 000 people located in the lower South East of S.A. It has been designated a Regional Growth Centre by the State Government.

Past and present growth has placed significant stress on the groundwater resources of the area. Anticipated future expansion will require careful management of these resources.

The problems are more related to groundwater quality than to quantity as at present recharge greatly exceeds water use. However, water level decline has been reported in several areas. This is caused by an interplay of artificial drainage, afforestation in recharge areas, improved pasture irrigation, and urban requirements together with the effect of seasonal fluctuations.

The karstic Gambier Limestone aquifer is particularly susceptible to pollution from cheese factories, stock sale yards, abattoirs, urban runoff, industrial wastes, and diffuse sources such as agricultural fertilisers and pesticides.

An underlying confined aquifer requires close management to keep it available as an alternative pollution-free groundwater resource. The Water Resources Act, 1976, is the means whereby this can be achieved.

INTRODUCTION

Mount Gambier, the third largest city in South Australia with a population of about 20 000 people, is located in the Lower South East of South Australia.

It was first settled in the 1850's and groundwater was first pumped from the Blue Lake by steam driven pump jacks in 1883.

Major industries of the region include forestry and related secondary industries: dairying, cheese making, grazing, and tourism.

This paper seeks to provide an insight into some of the stresses being placed on the groundwater resources of the region and presents some possible methods for reducing future problems. It is a general, non technical paper, prepared for a series of case studies being compiled by The Engineering Geology Specialist Group of the Geological Society of Australia.

GEOLOGY AND HYDROGEOLOGY

Before discussing the stresses being imposed on groundwater it is useful to put Mount Gambier into its hydrogeological setting and briefly describe the history and characteristics of the Blue Lake.

The geological setting of the area is within the Gambier Embayment of the Otway Basin (Waterhouse 1977). The units hydrogeologically significant to the study of the region are the Eocene Dilwyn Formation and the Oligo-Miocene Gambier Limestone, (Fig. 2).

The confined aquifer (Dilwyn Formation) consists of interbedded gravels sands, silts, and carbonaceous clays which were deposited in deltaic, lagoonal, and marginal marine environments. Groundwater movement is intergranular and is towards the S.W. (Fig. 4). Recharge to the aquifer occurs to the north of Mount Gambier where the head of the confined aquifer is lower than that of the water table aquifer (Fig. 3).

The Gambier Limestone (which contains both water table and confined aquifers) is a unit consisting of various facies of fossiliferous limestone. Groundwater movement is by both intergranular and conduit flow. Flow direction is generally S.W.

to S with local variation caused by solution features which generally trend N.W. - S.E. (Fig. 5). Recharge is by infiltration of rainfall and limited local surface runoff.

Total aquifer throughflow for the Gambier Limestone aquifer in the area is estimated to be 470 Ml per day. Average pumpage from the Blue Lake is 12 Ml per day (S.A. Engineering & Water Supply data) i.e. 2.5% of this flow. Data are insufficient to compute throughflow for the confined Dilwyn Formation aquifers.

In the vicinity of the Blue Lake, the head difference between the confined aquifer and the Gambier Limestone aquifer is from 10 to 20 m with the confined aquifer the higher and upward leakage can occur either through the confining bed, via volcanic conduits, or through poorly constructed wells.

THE BLUE LAKE

Physical Characteristics (Engineering and Water Supply Department data)

Circumference : 5 km

Area : 70 ha

Capacity: 36 000 Ml - which makes it South Australia's third largest water storage

Water Quality : T.D.S. - about 350 mg/l

Nitrate - about 16 mg/l and rising at about 0.4 mg/l/annum. S.A. Health Commission limit for drinking water is 30 mg/l (and the World Health Organisation (W.H.O.) limit is 45 mg/l). Therefore at present rate of increase the S.A. Health Commission standard would be exceeded in about 40 years and the W.H.O. limit in about 75 years.

Pumping Capacity (max.) : 1230 l/sec

Total water storage (3 tanks) : 13.6 ML

Formation of the Blue Lake

The Mount Gambier Volcanic Complex, of which the crater containing the Blue Lake is a component, comprises a close-knit series of maars with a complex history of eruption (Sheard 1978). Two major periods of eruption have been defined within which three distinct phases of activity are evident. Groundwater was the major hydrothermal fluid source - the gas being mainly steam

Recent seismic activity in the area indicates that volcanic activity in the area may not yet have ceased.

Age

The ages of the two major periods of eruption were obtained by radio carbon dating of charred wood fragments found at the base of the tuff and ash layers. Ages of about 5 000 years B.P. were obtained. Aboriginal legend provides some data on the relative periods of eruption of volcanoes in the lower S.E. of South Australia (Smith, 1880).

Mechanism for the Eruption

It is generally accepted that rifting of the Australian continent occurred with the break away of Antarctica during the Late Cretaceous - Early Tertiary Periods about 65 million years B.P. It is along the fractures produced by this process that later mantle derived melts made their way to the surface giving rise to volcanic activity.

Hydrology of the Blue Lake

Using a combination of environmental isotope, hydrochemical, and piezometric techniques the hydrology of the Blue Lake has been quantified (Turner 1979).

The water budget (defined from tritium concentrations) indicates a groundwater inflow of 6 000 Ml a year (16% of lake

volume). About 4 000 Ml a year are withdrawn from the lake to provide Mount Gambier's reticulated supply.

From uranium series and tritium isotope analyses, between 60 and 80% of water in the Blue Lake is derived from the confined Dilwyn Formation aquifer with the remainder being provided by the Gambier Limestone aquifer.

Thus the pumping rate is very close to the inflow rate which means that the Blue Lake is at present in a state of balance. If the pumping rate increases further, water will be drawn into the lake from the Gambier Limestone thus exposing the lake to the risk of becoming contaminated at an accelerated rate.

As Mount Gambier has been designated a Regional Growth Centre by the S.A. Government, its urban area and hence water demand can be expected to increase. Therefore, water to meet this increased demand may have to be obtained from sources other than the Blue Lake if its long term water quality is to be maintained within reasonable limits.

STRESSES ON THE REGION'S GROUNDWATER RESOURCE

The stress on the water table aquifer of the Gambier Limestone is caused by industrialised western man interacting with a karstic environment. The problem is one of groundwater quality rather than groundwater availability. However, for example, large scale afforestation in the recharge areas of the Dilwyn Formation aquifers may effect a decrease in direct recharge to this aquifer system. As yet, the Dilwyn Formation is unpolluted and remains an alternative potable water resource, unlike many areas of the Gambier Limestone which have been heavily contaminated locally.

The Karstic Environment

Solution features, caves, and potholes related to karst topography have been formed within the Gambier Limestone by fluctuating water tables caused by changes in sea level during glacial and interglacial periods Marker (1975).

In origin, the solution features are related to present or past steep water gradients generated for example by the Gambier Lineament (Tartwaup Fault) and tend to be concentrated where master joints have favoured solution. Dominant joint direction is N.W. - S.E. Total sea level fluctuation is thought to be of the order of 100 m during the time of karst development.

Man's Activities

Mount Gambier with a current population of about 20 000 (1976 census) and an average annual growth rate of 1.5% was founded in 1854. Subsequent to rural development, various secondary industries were set up to manufacture primary produce:

Cheese Factories

Dairy factories were built in the area from about 1890 to 1920 after which rationalisation of the industry forced the closure of some and amalgamation of others. From a total of 15 to 20 factories only 4 or 5 survive. It seems that one of the location requirements for a factory was that it be sited adjacent to a cave or sink hole so as to make disposal of whey wastes such as whey both easy and cheap. Numerous cases of locally polluted groundwater have been documented, such as: Smith (1978a), Harvey (1979), Cockshell (1980), and Waterhouse (1977).

Abattoirs

Waste from abattoirs was also disposed of underground until quite recently. However, both of the abattoirs in the Mount Gambier area are now using land disposal by pasture irrigation as a relatively cheap and beneficial means of waste treatment and utilisation.

Food Processing

Recently a major food processor in the Mount Gambier area had to obtain its water supply from the confined aquifer after polluting its shallow Gambier Limestone production wells (Waterhouse and Valentine, 1974).

The construction of such deep well is expensive and their possible effect on the Blue Lake (to be discussed later) is a significant problem.

Timber processing

Several major wood processors operate in the Mount Gambier region. Heavy metals such as Cr, Cu, and As together with the organic preservative creosote are used in wood treatment. The disposal of such potentially dangerous materials requires both care and control.

Municipal Wastes

The major dumping site for Mount Gambier waste, on the southern slopes of the volcanic complex, is under intensive investigation to determine whether leachate generated from the dump could enter the Blue Lake (Barnett, 1976; Smith, 1978 & 1980).

Drilling to determine the hydraulic properties of the volcanic ash, chemical analyses of adjacent wells to the Gambier

Limestone aquifer, and the setting up of an observation well network around the Lake have all yielded information helpful in defining a suitable management strategy.

Stock Saleyard Complex

The saleyard was opened in mid 1977 and has an average weekly turnover of 2 000 sheep, 1 700 cattle, 250 pigs, and 160 calves (1979 figures). The complex has a 3.5 ha paved area from which stock wastes are hosed down to be collected in a catch pit and subsequently sprayed onto pasture.

Sewage Disposal

Prior to the 1960's, when Mount Gambier was sewered, domestic and industrial waste disposal in the urban area was through septic tanks and direct discharge underground.

The present system is to pipe sewage 30.5 km to Finger Point and discharge it untreated to the sea. This system poses minimal threat to groundwater quality but is a waste of a potential resource as well as having some aesthetic drawbacks - particularly for the residents of the adjacent fishing township of Port MacDonnell.

Storm Water Runoff

Mount Gambier has an urban area of about 1680 ha and a mean annual rainfall of 711 mm. Depending on assumptions made, from 2 800 to 5 200 megalitres (from 8 to 14% of the Blue Lake's volume) of stormwater is introduced into the Gambier Limestone aquifer annually through at least 350 drainage wells. As the initial slug of runoff can be heavily polluted, this practise could provide a significant threat to the lake. Well depths range from about 25 m to over 150 m, with some holes reaching the black clay at the top of the confined aquifer. This fact has had an important impact on the siting and management of the standby

town water supply which consists of deep wells to the confined aquifer. A monitoring programme has been implemented to determine the scale of the problem.

Vehicular Traffic Around the Lake

Vehicles carrying liquid fuel have been prohibited from entering the road on the rim of the lake. However, fuel tankers pose a lower threat than for instance vehicles carrying pesticides, or wood preservatives as fuel floats on water and can be relatively easily treated, whereas water soluble chemicals can enter the groundwater system directly and be virtually impossible to remove.

Accidental Spillage

Over the past couple of years there have been instances of wood preservative spillage as a result of vehicular accident. In one case 500 kg of wood preservative containing 20% As was hosed down and almost entered an adjacent drainage well with apparent direct access to the water table aquifer. The irony of the story is that the drainage well was silted up thus preventing the chemical from reaching the water table.

METHODS AVAILABLE TO REDUCE GROUNDWATER CONTAMINATION

Land Disposal of organic Effluent

This form of waste treatment is being practised widely in the South East to handle wastes from cheese factories, abattoirs and stock saleyards. One such case history is provided for a cheese factory in the Mount Gambier area:

Cheese Factory Case History

Prior to 1976, wastes were introduced directly into the water table aquifer through solution holes adjacent to the factory. A recent resistivity survey (Cockshell, 1980) has defined a pollution plume 1 600 m long by up to 600 m wide in the

direction of subregional groundwater flow. After July 1976, when the Water Resources Act (1976) made this form of disposal unacceptable, management was required to consider alternatives (Barnett, et al, 1977). Land disposal was chosen and has been the subject of intensive monitoring by various State Government agencies.

The Department of Agriculture is responsible for basic farm management guidelines as well as for monitoring the unsaturated zone, and for soil and herbage analyses. The E. & W.S. Department which administers the Water Resources Act has the responsibility of defining the conditions for the Water Quality Order (W.Q.O.) together with analyses of effluent and groundwater samples. The Department of Mines and Energy provides groundwater observation wells, water level data, and hydrogeological appraisal. The activities of the three agencies are co-ordinated by the South East Water Resources Advisory Committee (SEWRIC) from which a number of field workers meet regularly to assess current results and plan future investigations.

Disposal Method

Whey and wash-down water are diluted with already polluted groundwater and distributed over the 40 ha site by means of a travelling irrigator.

This disposal method relies on the ability of plants to take up various components of the waste and use them in their metabolic processes. Any material excess to the plants requirements is able to pass to the water table.

Several techniques are used to determine waste movement through the soil and to the water table, such as lysimeters, neutron moisture metering, soil sampling, and observation wells.

Results indicate that for long term treatment the irrigation area may have to be increased, possibly by a factor of four.

Similar but less rigorous land disposal practices are used at the saleyard complex and for the abattoirs. Some farmers have for many years used this form of disposal for pig, poultry and dairy wastes etc.

Wastes as Pine Fertilizer

It has been suggested that selected wastes could be used as fertilizer for afforestation programmes. However the type of waste, its rate of application, and the timing of the application are critical in the development of the tree. Warped growth for example can result if the waste is applied inappropriately and more research is needed to determine the applicability of this form of waste utilisation.

Sewage Outfall to Sea

Outfall of raw sewage poses no threat to groundwater except for accidental rupturing of the line or by leaking pipe joints.

If however land disposal is chosen after tertiary treatment of the sewage, because of pressure from the community which objects to the current system, the disposal site will require very careful selection and subsequent monitoring if a threat to groundwater quality is not to occur.

Standby Town Water Supply Wells

An alternative to pumping groundwater from the Blue Lake is to pump directly from the confined aquifer which is unpolluted and by its nature more difficult to pollute than the overlying Gambier Limestone aquifer.

The siting of such wells is critical in that they must not cause a significant lowering of head in the confined aquifer in the vicinity of the Lake and thus allow greater movement of

contaminated Gambier Limestone water into the Lake. Two wells have already been drilled to this aquifer but proximity to the Blue Lake may restrict their use to relatively short term emergency use only. The E. & W.S. Department is using computer simulation to investigate the effect of large scale, long term pumping from a relatively unpolluted area in the Gambier Limestone aquifer, (Forth 1979). Preliminary results indicate this to be a feasible alternative although land use restrictions may have to be imposed to protect potential abstraction areas.

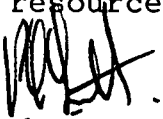
Alternative to Drainage Wells for Stormwater Runoff

Depth constraints are now being placed on drainage wells in the Mount Gambier area to prevent contaminants from being introduced close to the confining bed of the confined aquifer. There is a danger of downward leakage of pollutants where the hydraulic head of the confined aquifer is reduced locally by excessive pumping. Fig. 6 gives a diagrammatic representation of pollutant movement when relative heads are reversed by pumping.

Legislation

The Water Resources Act (1976) is the most powerful tool available to the government in promoting the orderly development of the State's water resources.

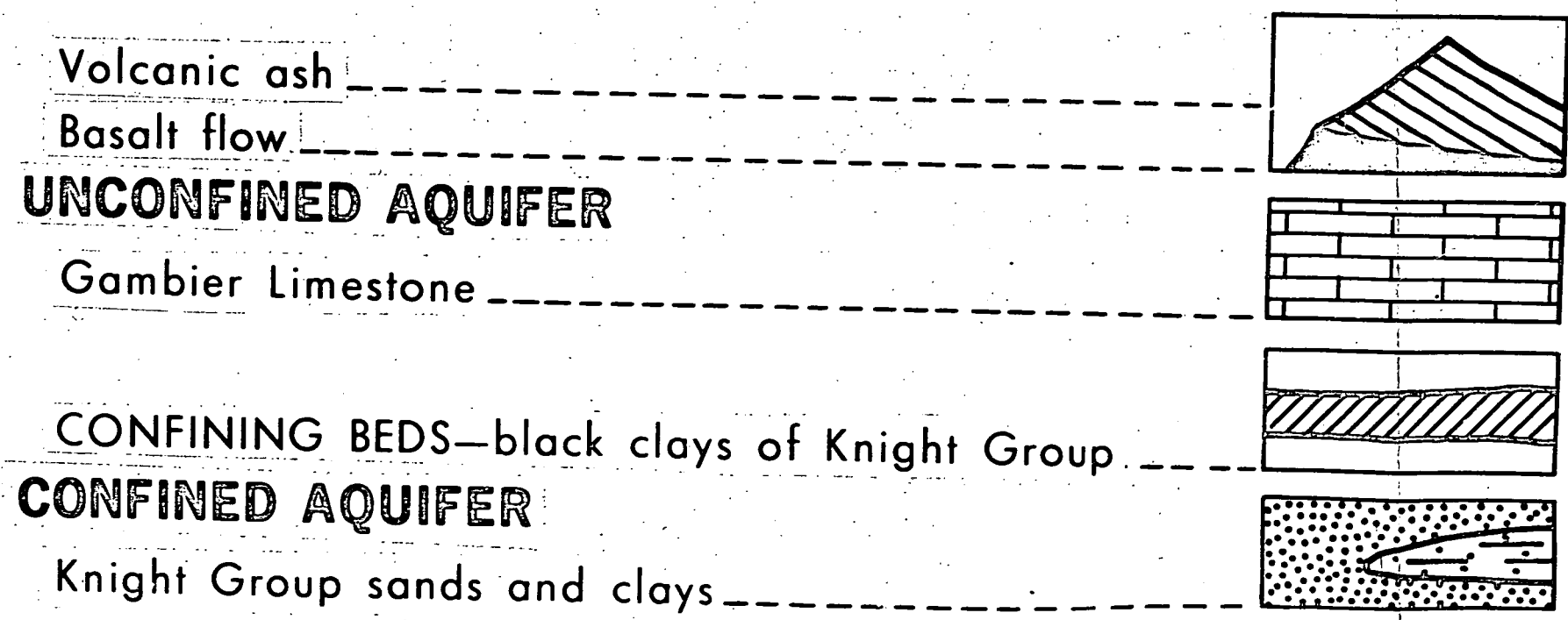
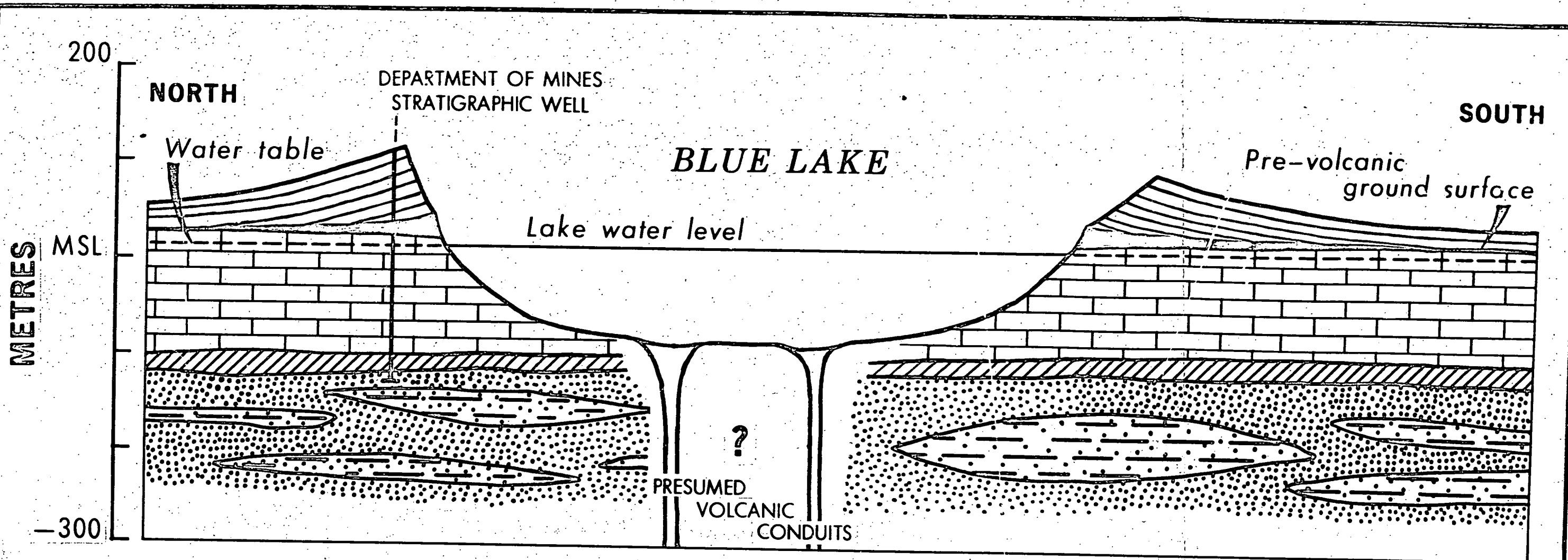
In the particular case of Mount Gambier its muscles can be flexed to reduce the effect of point sources of pollution through the issuing of Water Quality Orders, to put pressure on various water users to manage their water requirements for everyone's benefit, and to affect land use planning to maintain the availability and improve the quality of the total water resource.


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Geologist

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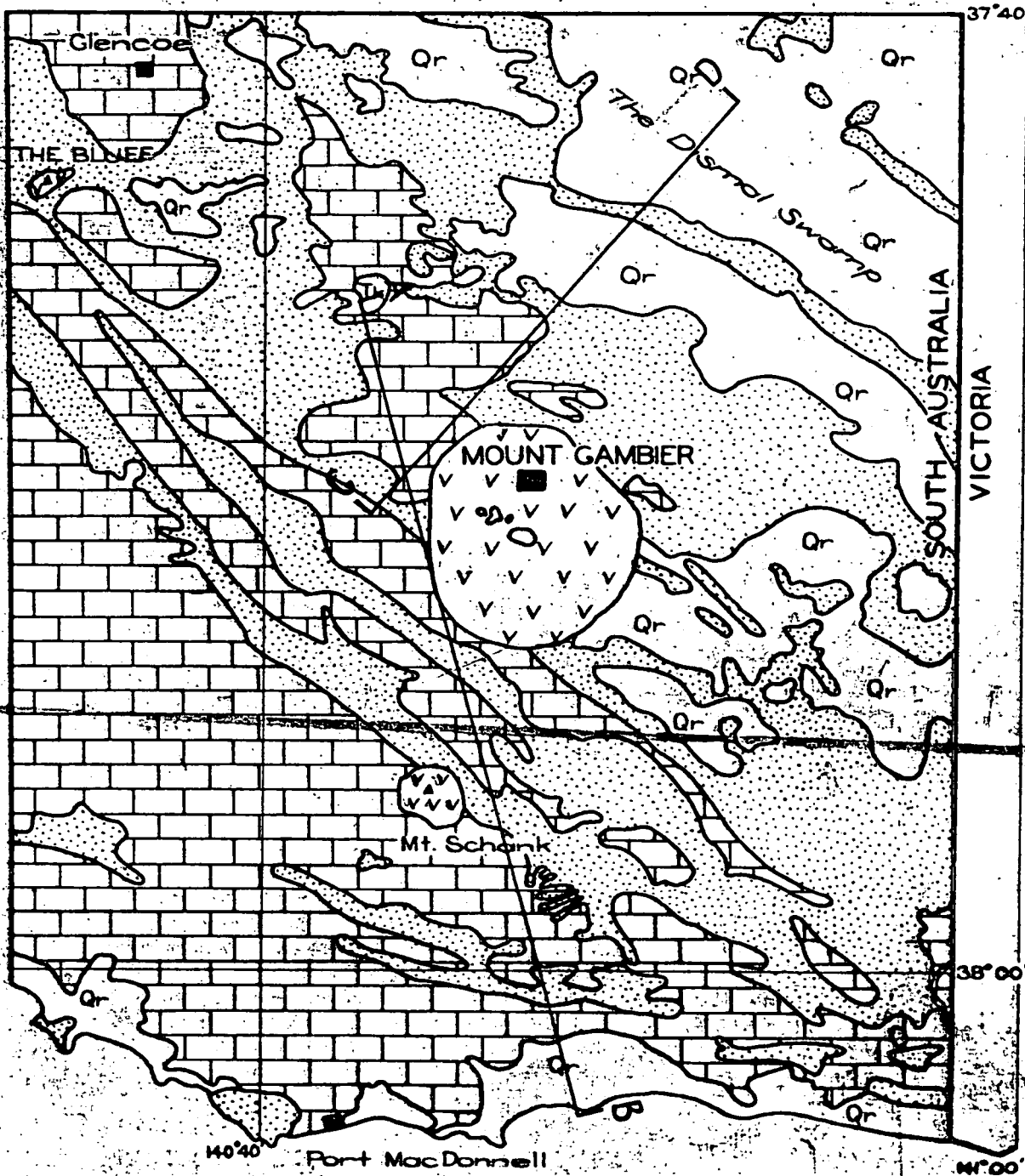
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76-862

S.A. Department of Mines

Fig. 1 Cross-section through Blue Lake, Mount Gambier



LEGEND

- | | | | |
|----|---|--|-------------------------------|
| Qr | Recent undifferentiated deposits. | | Tertiary - Gambier Limestone. |
| | Quaternary aeolianites - Bridgewater Formation. | | Tertiary - Knight Group. |
| | Quaternary volcanics. | | Line of Section |
- FIG. 2**
(GEOLOGY after Sprigg et al., 1951)

DEPARTMENT OF MINES — SOUTH AUSTRALIA

HYDROGEOLOGY SECTION	Drn. J/W	SOUTH EAST WATER RESOURCES MOUNT GAMBIER AREA INVESTIGATION	SCALE: 1:250,000
	Tcd. J/W		S10898
GEOLOGIST J.D. WATERHOUSE	Ckd.	GEOLOGICAL PLAN	K/W/S/17/18+20/21
	Exp.		DATE: 6th June 1978

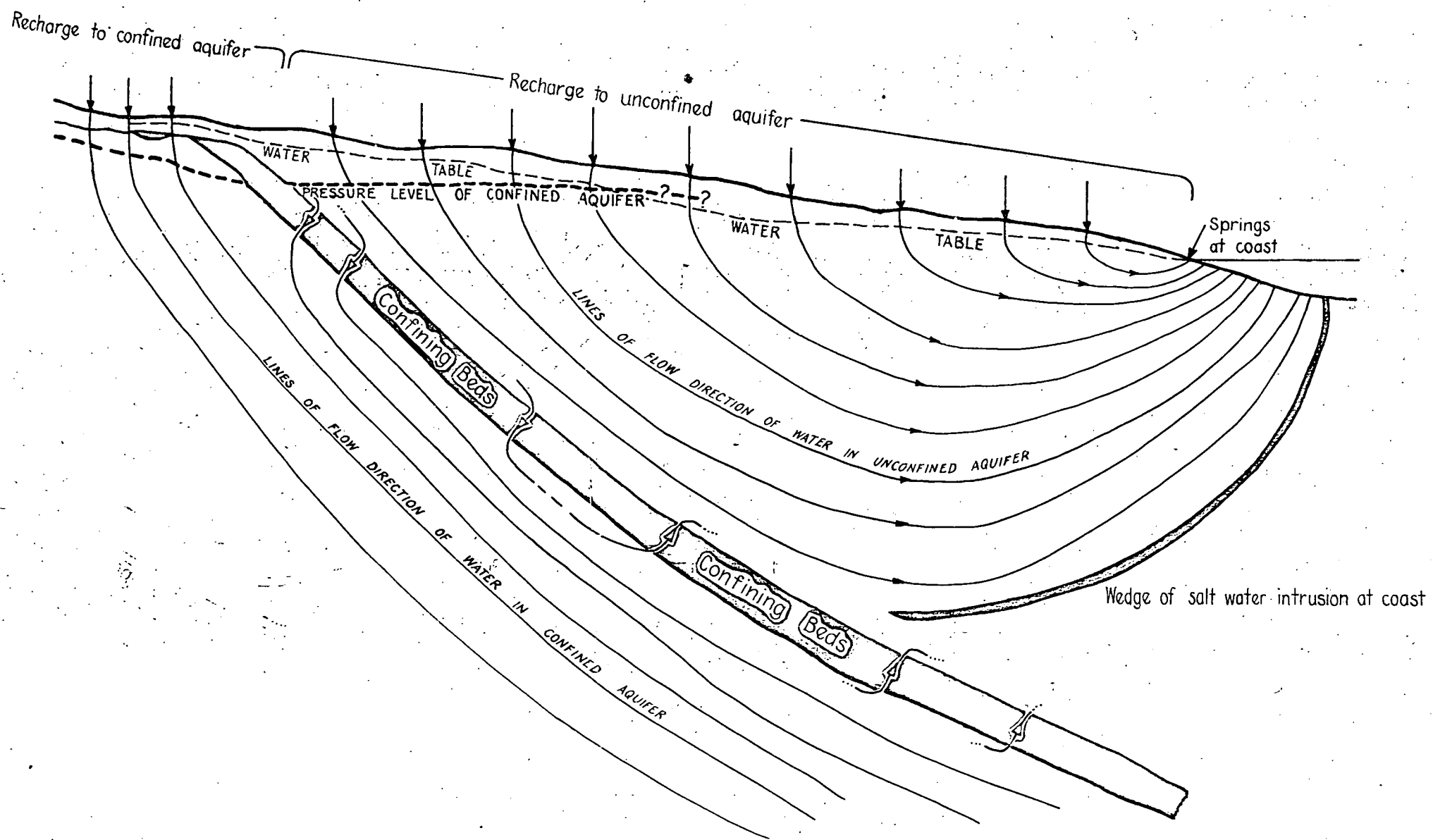


FIG. 3

DEPARTMENT OF MINES - SOUTH AUSTRALIA		Scale: <i>Diagram</i>
Compiled: J.W.	MOUNT GAMBIER AREA HYDROGEOLOGICAL CROSS-SECTION	Date: <i>6 Aug. 1975</i>
Drn. T.E. Ckd.		Dwg. No.
<i>J. Chalkin</i>		<i>75-731</i>

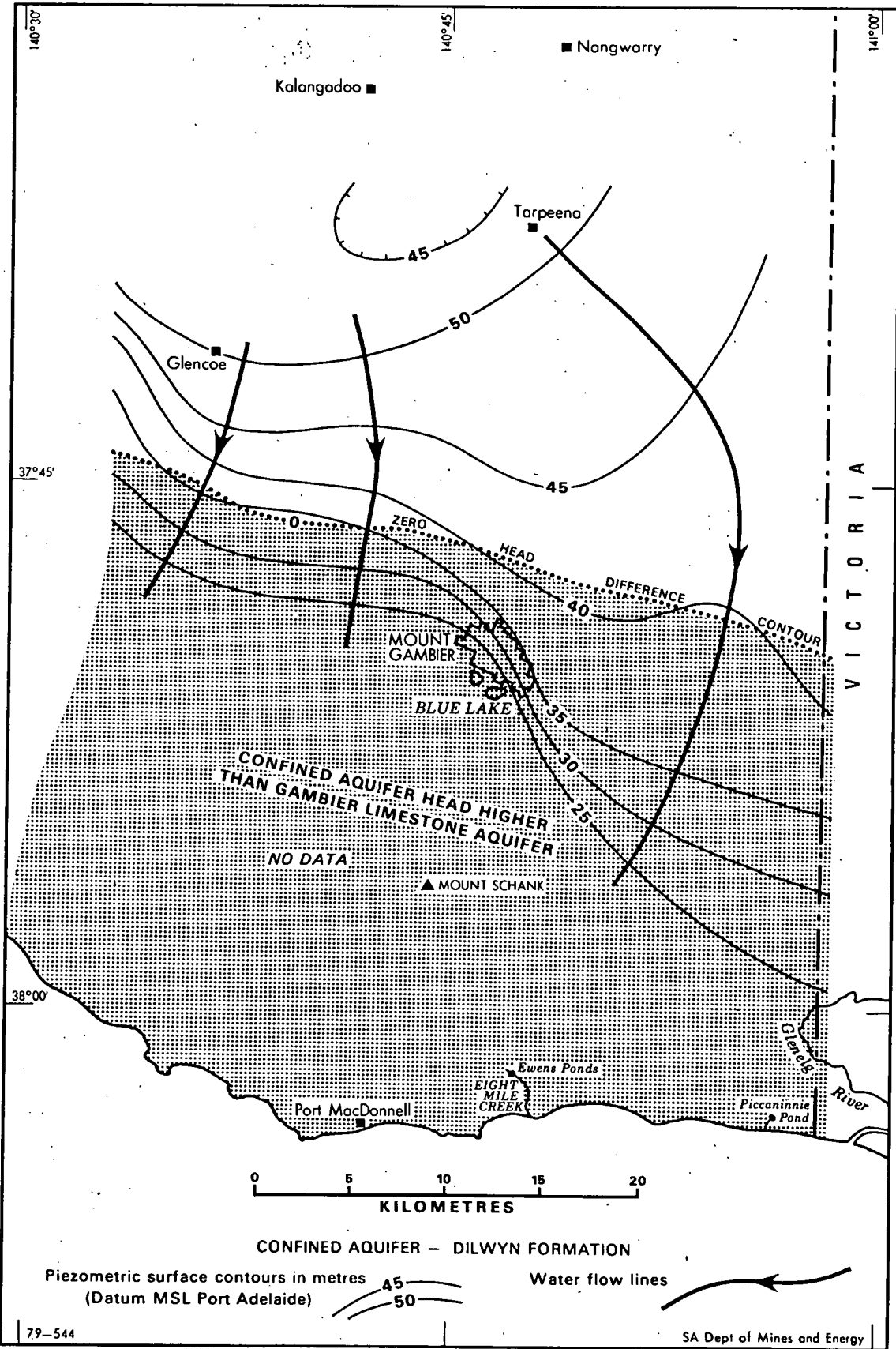


Fig. 4 Confined aquifer piezometric surface contours and flow lines

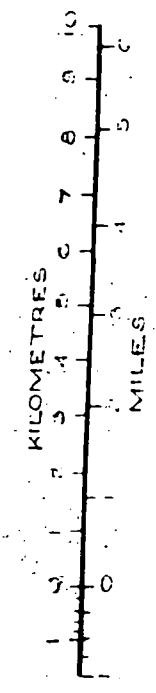
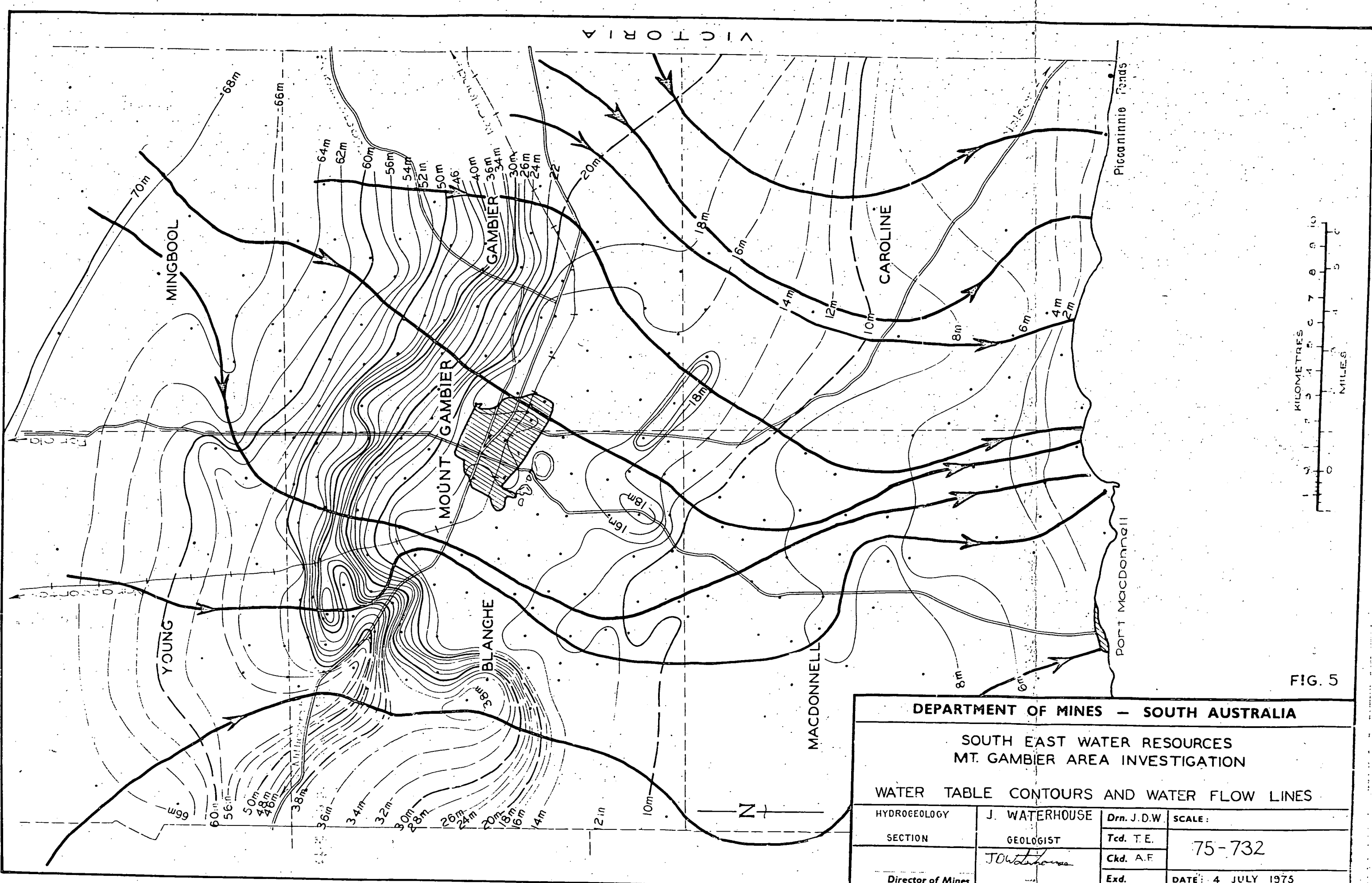


FIG. 5

DEPARTMENT OF MINES — SOUTH AUSTRALIA			
SOUTH EAST WATER RESOURCES MT. GAMBIER AREA INVESTIGATION			
WATER TABLE CONTOURS AND WATER FLOW LINES			
HYDROGEOLOGY	J. WATERHOUSE	Drn. J.D.W.	SCALE: 75-732
SECTION	GEOLOGIST	Tcd. T.E.	
	<i>J. Waterhouse</i>	Ckd. A.F.	
Director of Mines		Exd.	DATE: 4 JULY 1975

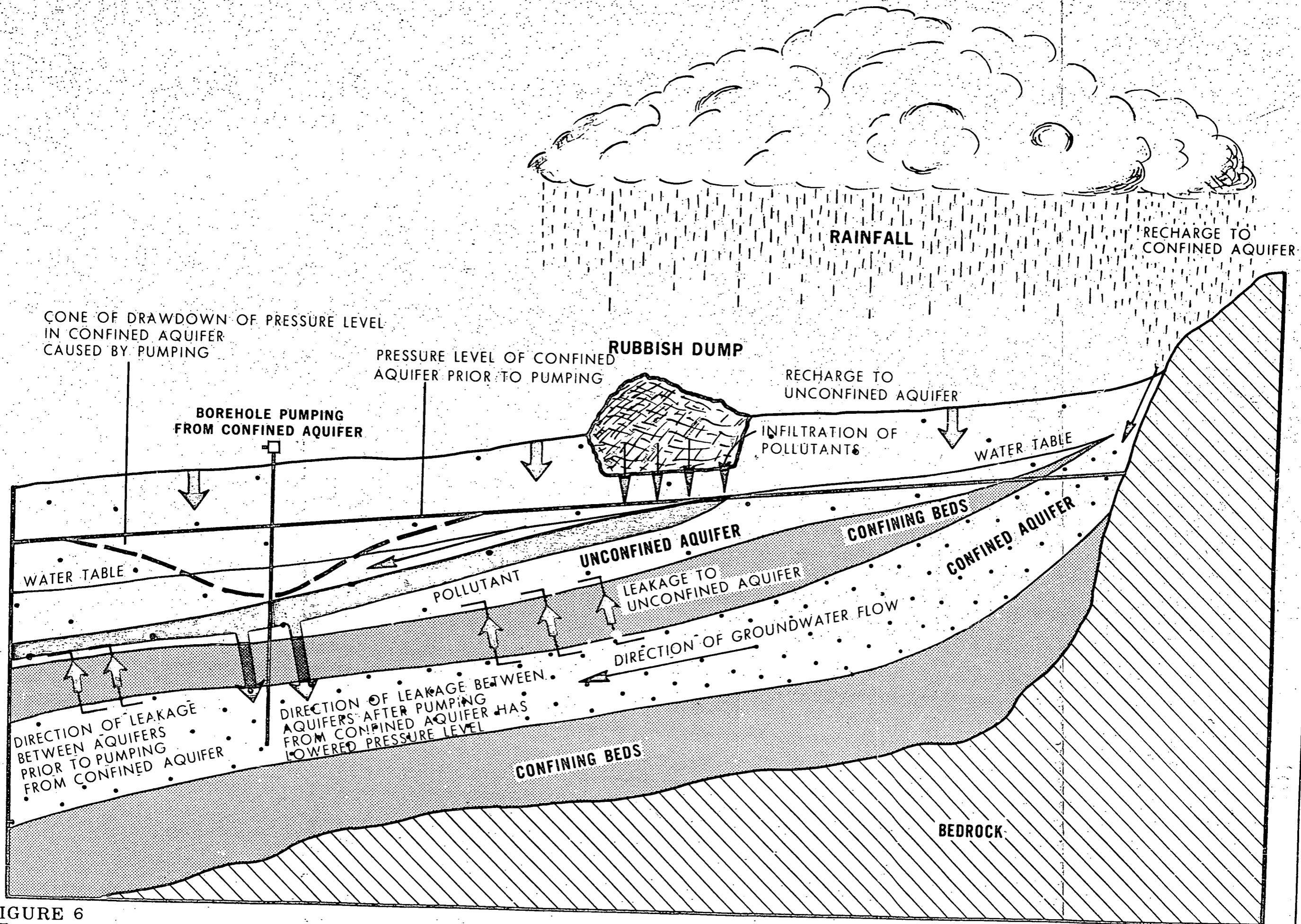


FIGURE 6

POLLUTION OF AN UNCONFINED AQUIFER BY LEACHATE FROM A RUBBISH DUMP, AND OF A CONFINED AQUIFER BY LEAKAGE THROUGH THE CONFINING BEDS