# Groundwater Investigation Program Report 1978

Department of Minerals and Energy Victoria

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*Presented to both Houses of Parliament in accordance with the Groundwater Act 1969 (No. 7849).*

# Contents

# Introduction

## The Groundwater Act

Provision is made in the Groundwater Act 1969 for a program of investigation into the groundwater resources of the State of Victoria. The program provides for investigations related to the location, pressure, composition and movement of groundwater; the properties of groundwater or of the rocks containing groundwater; the availability of groundwater; its suitability for use; and its protection from depletion, wastage or pollution. Provision is made for the collation and analysis of collected data.

This report summarises the groundwater investigations undertaken by the Department of Minerals and Energy, State Rivers and Water Supply Commission and the Agriculture Department for 1978.

Abstracts of the more important reports by government officers on current projects are included. These can be subdivided into seven main types —

1 Systems design for storage and retrieval of groundwater data.
2 Exploration and regional analysis of groundwater resources.
3 Management of groundwater resources.
4 Investigation of problems of shallow water tables.
5 Investigation, design and installation for town supplies.
6 Investigation of groundwater pollution.
7 Determining the quality for various purposes.

In planning the program of investigation, the Minister for Minerals and Energy is assisted by a Groundwater Advisory Committee. This Committee comprises representatives of the Department of Minerals and Energy, the State Rivers and Water Supply Commission, the Department of Agriculture, and groundwater users.

The Department of Minerals and Energy regularly exhibits a groundwater display at various Field Days around Victoria to provide farmers with easy access to information and advice on the groundwater resources of the State.

## Water quality

In the later sections of this report, reference is made to the water quality found in different bores. The following table has been prepared to advise groundwater users of the upper limits of salinity and are acceptable for a range of uses.

**Limits of water quality**

| Uses | Upper limits of salinity |
|---|---|
| Irrigation — | mg/l |
| Tobacco | 50 |
| Citrus, legumes, garden plants | 1000 |
| Vines, grass, cabbages | 1500 |
| Cotton, Lucerne | 2500 |
| Domestic — | 1000 |
| Stock — | |
| Poultry | 3500 |
| Pigs | 4500 |
| Horses | 6500 |
| Milking cows and ewes | 7000 |
| Beef cattle | 11 000 |
| Dry sheep | 15 000 |
| Secondary Industry — | |
| Rayon | 100 |
| Paper | 150 |
| Petroleum | 350 |
| Carbonated beverages | 850 |

## Yield

In the bores sunk by the Department of Minerals and Energy it is usual practice to test the yield of water in each water-bearing unit encountered. Testing is carried out by either bailing or by pumping. Pumping is undertaken where the water is thought to be present in large supply and of good quality.

The yields shown in this report do not necessarily give the full potential yield of the tapped aquifer system because the bores may not be fully developed. When an aquifer is pumped the Department of Minerals and Energy normally measures the change in water level over the time of pumping. From this record it is possible to estimate the short-term potential yield. This detailed information is available from the Department's data bank.

# Department of Minerals and Energy projects

## Recharge at Carrum using treated effluent

R Lakey

**Abstract of published report**

Recharge experiments, conducted by the Department of Minerals and Energy, have shown that the treated sewage effluent produced by the South Eastern Purifiction Plant can be injected into the confined Older Volcanics basalt aquifer at Carrum. Although there was a fall in the injection rate during the six week injection test, 83 per cent of the optimum volume was injected and clogging was not an apparent problem. Any bacteria present in the effluent can be removed by chlorination but the possible presence of pathogenic viruses may necessitate additional treatment, and further research is required in this area. The effluent and native ground water are chemically compatible and combine together to produce a water that is of better overall chemical quality than either parent source. The promising results achieved at Carrum encourage further investigation in the Westernport Basin where a zone of groundwater depletion has developed as a result of seasonal overpumping from irrigation bores.

## Evolution of the Murray River during the Tertiary Period Evidence from northern Victoria

P G Macumber

**Abstract of published report**

Contours of the pre-Tertiary surface under the southern Riverine Plain in Victoria show elongated depressions (valleys?) suggesting that a drainage system ancestral to the present Murray system was in existence in Eocene times. The position of the bedrock depressions indicates that in Victoria the basic physiographic divisions and fluviatile provinces were established in the early Tertiary and have changed very little since that time.

From Oligocene to early Miocene time it is not possible to demonstrate the presence of a co-ordinated system because the Murray Valley was then probably little more than a swamp. In late Miocene times a co-ordinated system (deep leads) re-appeared and this system flowed into a deep marine embayment in the vicinity of Cohuna in northern Victoria. Aggradation of the deep leads is attributed to rising base levels associated with the onset of the late Tertiary marine transgression.

## Hydrologic change in the Loddon Basin: the influence of groundwater dynamics on surface processes

P G Macumber

**Abstract of published report**

The late Tertiary Loddon Valley 'deep leads' drainage system passed from the highlands across the Loddon Plains to flow into a Murravian Sea in the far north of the State near the present-day Murray River. This ancient drainage channel, now buried sixty metres below the plains, forms the major groundwater path for sub-surface flow from the Central Victorian Highlands. Within the highlands the pressure levels of the Calivil Formation aquifer formed of the deep lead gravels are well below the surface, but become artesian (flowing) in the mid-Loddon Plains. Monitoring of the potentiometric surface over a seven year period indicates that water loss to the surface contributed to present-day high salt levels on the Loddon Plain. Rapid rises in pressure levels observed during the two year wet period 1973/74 indicate a high degree of sensitivity of the deep groundwater regime to minor climatic fluctuations. It provides an important clue to the nature of the groundwater discharge elsewhere on the plains, and during the well documented phases of high stream flow of late Quaternary times.

## Groundwater for Geelong: completion report on the hydrogeological investigation of the Barwon Downs Basin

Roger Blake

**Introduction**

This report concludes an investigation, into the groundwater resources of the Barwon Downs Basin in western Victoria. The aim is to supply the City of Geelong with groundwater as a supplement to its normal surface water supplies. The scale of the intended development by Geelong is sufficient to utilise all the water available in the basin (consistent with equilibrium conditions being achieved).

The Geelong-Waterworks and Sewerage Trust recently outlined its basic requirements for a well field in the Gerangamete area. A minimum of two further bores would be needed to make the pipeline from Gerangamete to the channel feasible and a total yield from the field of 200 to 300 l/s would be desirable. Rates in excess of 300 l/s would be desirable in dry years and would be pumped for up to twelve months on the assumption that the basin would then have three to five years to recover in periods when surface water was abundant. A maximum drawdown in each bore of 90 m was considered feasible in view of operating and pumping costs using either vertical lineshaft or submersible pumps.

From a hydrogeological viewpoint the proposed development comes at an opportune time since virtually no extraction from the basin has been carried out. In addition there are five years of water level records from regional observation bores available. The conditions existing in the Basin prior to development are, therefore, fairly well known.

The main purpose of this report is to present details of the hydrogeological data which has been gathered and to use this to present alternative well field designs. The final, or optimum well field design chosen from these alternatives will depend mainly on comparison of economic factors such as initial capital costs of bores and pipelines compared with continuously incurred costs such as pumping.

## Stratigraphy

The major aquifers in the Barwon Downs Basin occur in the Dilwyn and Pebble Point Formations of the Wangerrip Group. The Dilwyn Formation in this area is non-marine and consists of fluviatile quartz sands (as channel deposits) with subordinate clays, ligneous clays and brown coal toward the base. The Dilwyn Formation overlies the Pebble Point Formation — a predominantly coarse sand-gravel which is probably in part marine.

The boundary between the two formations is gradational and the Dilwyn Formation represents the regressive part of a transgressive-regressive cycle of Middle Palaeocene to Lower Eocene age. It is the time equivalent of the deltaic-marine Dilwyn Formation in the present coastal and south-western portion of the Port Campbell Embayment.

## History of groundwater investigations in the Barwon Downs Basin

Groundwater investigations in the Basin began in 1968 when the Geelong Waterworks and Sewerage Trust employed a Groundwater consultant to recommend suitable areas for the development of groundwater in the Geelong region. Hancock (1968a) recommended the northwestern flanks of the Otway Ranges as the most promising area and proposed drilling an exploratory bore (GO-A) on the West Barwon — Wurdiboluc aqueduct in the vicinity of the small township of Barwon Downs. This bore confirmed the presence of Early Tertiary aquifer sands (approx. 40 m) which contained very good quality water (230 mg/l TDS) but of a high iron content (25.7 mg/l) (Hancock, 1968b). Wireline logs of GO-A were run with the Department's Model X Widco Logger, and CO-A (or Murroon 8001) provided a valuable addition to the stratigraphy of the basin.

On the basis of the results of GO-A, a Production Bore — GW1 and three other observation bores — GO-B, GO-C and GO-D were drilled in 1969 at Barwon Downs. In January 1970 a two week constant rate pumping test was run on GW1 and the results, together with recommendations for further Production Bore sites, were presented (Hancock, 1970).

The salinity in GW1 proved higher than GO-A (303.1-320.9 mg/l) but lower in dissolved iron (14.3-15.8 mg/l). The water from GW1 is still of very acceptable quality provided there is treatment for the removal of iron. The main drawback of the Barwon Downs site proved to be the very large drawdowns in the production well due to the close proximity of the Bambra Fault. The fault acts as a major hydrogeological boundary and effectively doubles the drawdowns that would otherwise be achieved from this aquifer.

In 1972, following the presentation of the Hancock (1970) report, the Geelong Waterworks Trust requested the Department to further assess the groundwater resources of the Barwon Downs area with a view to the eventual establishment of a wellfield. The Department carried out further drilling investigations.

## Water quality

Four samples were taken at one day intervals throughout the Gerangamete test. In addition the Geelong WWT sampled the water on the fifth day of the test and performed an on-site pH and dissolved-oxygen determination. The analyses are included in Table 1. The salinity varied between 201-232 mg/l TDS with no consistent trend over the period of the test. The main variations between analyses were in the bicarbonate, sulphate, iron and silicate contents. As each of these is dependent upon the time the samples are standing prior to analysis (and variations in pH), the results can be considered quite consistent.

Comparison with GW1 yields several notable differences. These are:

1 Lower salinity. The water from GW2 averaged 214 mg/l compared with 297 mg/l in GW1.

2 Lower iron. GW2 averaged 8.6 m/l iron compared with 15.0 mg/l in GW1.

3 Lower pH. GW2 averaged a pH of 5.67 compared with 6.41 for GW1. The value of 5.5 obtained by the on-site test is probably the most reliable indication of the pH for GW2.

The lower salinity in GW2 can be attributed mainly to the major constituents e.g. chloride 88 mg/l compared with 121 mg/l, sodium 50 mg/l compared with 76 mg/l in GW1. The lower salinity occurs because GW2 develops more sands in the upper part of the Dilwyn Formation from GW1.

Table 1 Water analyses from GW2

| Sample No. | 1 | 2 | 3 | 4 | 5(GWWT) |
|---|---|---|---|---|---|
| Time after pumping Started (hours) | 24 | 48 | 72 | 96 | 96 |
| Date | 29/9/77 | 30/9/77 | 1/10/77 | 2/10/77 | 2/10/77 |
| Sample No. (lab) | 3459/77 | 3460/77 | 3461/77 | 3462/77 | — |
| | mg/l | mg/l | mg/l | mg/l | mg/l |
| TDS (Summation) | 206 | 201 | 232 | 212 | 220 |
| Chloride (Cl) | 88 | 88 | 88 | 88 | — |
| Carbonate ($CO_3$) | Nil | Nil | Nil | Nil | — |
| Bicarbonate ($HCO_3$) | 17 | 20 | 30 | 30 | — |
| Sulphate ($SO_4$) | 6 | 9 | 12 | 2 | — |
| Nitrate ($NO_3$) | Nil | Nil | Nil | Nil | — |
| Calcium (Ca) | 2 | 2 | 2 | 2 | — |
| Magnesium (Mg) | 4 | 4 | 4 | 4 | — |
| Sodium (Na) | 48 | 50 | 53 | 50 | — |
| Potassium | 4 | 4 | 4 | 4 | — |
| Iron-Total (Fe) | 5 | — | — | — | 7.1 |
| Iron-Soluble (Fe) | 3.7 | 5.5 | 9.9 | 12 | — |
| Silicate ($SiO_3$) | 28 | 18 | 29 | 20 | — |
| Total Hardness ($CaCO_3$) | 22 | 22 | 22 | 22 | — |
| pH | 5.52 | 5.59 | 5.87 | 5.88 | 5.5 |
| Dissolved Oxygen | — | — | — | — | 0.5 |
| Copper (Cu) | — | — | — | — | 0.02 |
| Zinc (Zn) | — | — | — | — | 0.02 |
| Chromium (Cr) | — | — | — | — | 0.06 |
| Lead (Pb) | — | — | — | — | 0.02 |
| Cadmium (Cd) | — | — | — | — | 0.001 |

The salinity of GW1 is more comparable with that of Gerangamete 13 which develops only the Pebble Point Formation (at the base of the Tertiary sequence). For example the salinity in Gerangamete 13 was 280 mg/l compared with 297 mg/l in GW1, the chloride was 130 mg/l compared with 121 mg/l and the sodium was 83 mg/l compared with 76 mg/l in GW1.

The lower pH and lower iron content in GW2 compared to GW1 can probably both be accounted for by the fact that the Mepunga Formation was excluded from development in GW2. The Mepunga Formation is a highly ferruginous, calcareous sand, in which the water contains iron in excess of 25 mg/l with an alkaline pH of 7.5-7.8.

### Analysis of pumping tests

*Pumping tests carried out in the Barwon Downs Basin*

Four pump tests were carried out in the Barwon Downs Basin in the Parishes of Murroon (in Wire Lane), Whoorel (near Deans Marsh), Murroon (at Barwon Downs) and Gerangamete (Wineshades Lane). The data from two of these tests (Whoorel and Gerangamete) has not been presented before. The other two tests are reviewed and discussed in the light of the recent analysis.

*Pumping test on Gerangamete production bore (GW2) in Wineshades Lane*

1 Conditions and duration of the test

A five day constant rate test at a continuous rate of 64.4 l $sec^{-1}$ was carried out from Thursday 29/9/77 to Tuesday 4/10/77. All the bores monitored (with the exception of Murroon 25) were flowing bores and had to be sealed with a pressure cap prior to the test. The five day test was highly successful and quite sufficient to calculate the aquifer parameters.

2 Bores monitored and equipment used

Six bores in the Basin were monitored throughout the test and the observation bore details are shown in table 2.

Table 2 Observation bores monitored during Gerangamete pump test

| Bore Name | Gerangamete 14 | Gerangamete 15 | Gerangamete 13 | GO-B | Murroon 23 | Murroon 25 |
|---|---|---|---|---|---|---|
| Number of Convenience | OB1 | OB2 | OB3 | OB4 | OB5 | OB6 |
| Distance from Pumping Bore (m) | 30.48 | 152.4 | 1500 | 2920 | 5830 | 5830 |
| Measured with | Hg Manometer | Hg Manometer | Pressure Gauge | Hg Manometer | Hg Manometer | Stevens Recorder |

*Geelong Waterworks Trust (Barwon Downs) pumping test*

The results of the pump test on GW1 from 16/1/70 to 30/1/70 are represented here in the light of the other pump tests in the Basin. GW1 and the four observation bores tested all the sands within the Dilwyn Formation plus the Mepunga Formation.

Table 3 Summary of pump test results for the Barwon Downs test

| | Thies Method | | $T_{SL}$ | Time to Boundary | Dist. to Boundary |
|---|---|---|---|---|---|
| | $T(m^2day^{-1})$ | S | (mins) | (mins) | (m) |
| GO-A | 346.9 | $3.2 \times 10^{-4}$ | 380 | 140 | 377 |
| GO-B | 401.9 | $2.9 \times 10^{-4}$ | 775 | 140 | 427 |
| GO-C | 339.5 | $2.3 \times 10^{-4}$ | 2147 | 150 | 529 |
| GO-D | 376.7 | $3.1 \times 10^{-4}$ | 5550 | 160 | 549 |

### Comparison of the tests

Three main features stand out from the hydrogeological testing carried out in the Barwon Downs Basin.

*1 The Influence of the Bambra Fault*

The effect of the Bambra Fault on the southeast side of the basin is twofold. Firstly, the Dilwyn Formation is thinner on this side of the basin (probably due to differential sedimentation rates). This means that there is less sand available for development. Secondly, faulting of the aquifer results in the discharge boundary effects as exhibited in both the Barwon Downs and Deans Marsh tests.

*2 Recharge from the Barongarook area*

Both the test at Gerangamete and the test at Wire Lane exhibited recharge effects towards the end of the tests. This was most probably due to the cone of depression moving out into the outcrop area of the Dilwyn Formation in the Barongarook area.

Because the Gerangamete area is approximately midway between the Bambra Fault and the Barongarook recharge area the two boundaries would tend to offset each other during early stages of a pumping period. With continued pumping the recharge effect would become more pronounced until a new equilibrium was achieved (provided that total extraction did not exceed the available recharge).

*3 Hydraulic conductivity of the sands tested in the Barwon Downs Basin*

Table 4 below summarises hydraulic conductivity results for the Gerangamete, Barwon Downs and Wire Lane tests. There is remarkable agreement between the three tests for the hydraulic conductivity of the sands in the basin.

It is possible that the Pebble Point Formation tested at Wire Lane may be slightly less permeable because, although coarser than the sands in the Dilwyn Formation above, they are not as well sorted. The results obtained are at the lowest end of the range for clean sands.

Table 4 Hydraulic conductivity values of the sands tested in the Barwon Downs Basin

| Pumping Test | Pumping Bore | Transmissivity $m^2day^{-1}$ | Thickness Tested m | Hydraulic conductivity m $day^{-1}$ |
|---|---|---|---|---|
| Gerangamete | GW2 | 512 | 75 | 6.8 |
| Barwon Downs | GW1 | 366 | 40 | 9.2 |
| Wire Lane | Murroon 23 | 64 | 13 | 4.9 |

### Computer analysis

A computer was used to analyse the large quantity of data gathered in the Barwon Downs pump tests. This greatly simplified the otherwise tedious and time consuming process of analysing pump test data.

### Well field design

The latest testing results at Gerangamete do not significantly alter the estimate of the safe yield of the basin which had been calculated previously (Blake, 1974a). The test does however give reliable parameters on which to calculate the optimum spacings, pump settings and relative locations of wells in the Gerangamete area.

The test confirmed the basis for selecting the Gerangamete area as the most suitable site for a well field in the Barwon Downs Basin. The reasons were, briefly:

1 The area contains the thickest development of sands in the basin (therefore yielding the highest transmissivity).

2 The highest pressures are developed here (allowing greater drawdowns for similar pump settings).

3 As predicted, no observable discharge boundaries were encountered during testing. This was perhaps the most important reason for selecting this area.

4 The area is still in reasonably close proximity to the West Barwon to Wurdiboluc channel and to GW1.

### Results

A series of well fields with bores at different spacings were computed to obtain the best separation for bores. From this a figure of 1 km was settled on, as distances closer than this yielded excessive drawdowns. All the possible locations were considered for bores in the well field. From this various combinations of bores were tried, both with and without GW1 operating. For each combination of bores recharge image wells were located at appropriate sites in the Barongarook area and discharge image wells were located at appropriate sites to the east of the Bambra Fault.

### Conclusion

The results of the test at Gerangamete indicate that at least two and possibly three further production bores could be located at Gerangamete. The new bores should be located no closer than 1 km apart and from GW2 and should be on the lowest topographic sites available (consistent with precautions against flooding).

The wellfield calculations suggest that three bores at Gerangamete at one kilometre spacings, together with GW1 at Barwon Downs, all pumping at 92.6 $l/sec^{-1}$ would yield 370 $l/sec^{-1}$ continuously for one year with an average drawdown of 98 m in each bore. Four bores at Gerangamete, together with GW1 pumping with the same conditions would yield 463 $l/sec^{-1}$ continuously with average drawdowns of 106 m after one year.

The bore at Gerangamete — GW2, indicates that fresher waters with lower iron contents are available, in the upper part of the Dilwyn Formation, than thought previously. The water will still have to be treated for pH and iron removal before it is suitable for consumption.

For proper regulation and monitoring of the well field it will be necessary to record the times of pumping, pumping rates, drawdowns in pumping bores and drawdowns in observation bores. The amount of data which will be collected would be most easily handled by automatic recording of each of the above parameters.

### Further work

There are no regional observation bores in the Barongarook recharge area. Long term observations in the recharge area, once production commences, would provide the best means of assessing the ultimate production capacity of the basin.

The Boundary Creek area would be the most suitable location for the bores and at least two bores, one testing near the bottom of the aquifer, the other near the top would be needed.

Another fairly large area of Dilwyn Formation outcrop is in the Barwon Downs to Forrest area on the upthrown side of the Bambra Fault. The pumping test on GW1 suggests that the sands in this area are not connected with the sands in the graben (at least within the zone of influence of the pumping test). Further work in this area may prove groundwater reserves which are untapped by the Gerangamete bores. This could be valuable particularly as the West Barwon to Wurdiboluc channel runs through the area.

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## Summary Hydrogeological report on proposed Dargile site for disposal of hazardous Wastes

G Stewart

### Introduction

After consultation with Department officers, members of the Inter-Departmental Committee on Liquid Waste Disposal selected for detailed hydrogeological investigation a tract of State Forest just east of Plantation Road in the Parish of Dargile. This tract extends eastward for 1.5 km from Plantation Road and is from 8 km to 12 km northeast of Heathcote.

The parish of Dargile is within the catchment of Lake Cooper. The terrain in the parish forms part of a gently northward sloping erosion surface that has been dissected by Cornella Creek and its ephemeral tributaries. Cornella Creek drains into Lake Cooper some 36 km north of the sites investigated. The difference in altitude between the sites and Lake Cooper is of the order of 150 m.

The Committee has decided in favour of establishing a landfill depot to act as a repository for selected types of hazardous wastes. It is expected that the rocks beneath the depot would contain the concentrated wastes without permitting their escape by movement of the liquids themselves, or leachate, from the site.

**Hydrogeology**

The ideal hydrogeologic setting in which to establish a depot consistent with the above expectations is one where the rocks and soil (if used as a cover material) are impermeable to the transmission of fluids. A good approximation to this is a compacted clay, claystone or mudstone sequence free of open, inter-connected fractures where the water-table is deep below natural surface.

Fracture-free sediments composed of clay-size particles permit only a very slow rate of transmission of fluid through them i.e. they have low hydraulic conductivities. In addition, the chemical composition of clay minerals provides a means for ion exchange with many potentially polluting materials that may be dissolved in the groundwater. Ion exchange reactions are beneficial in that they sometimes result in the polluting material being removed from solution. The deeper the water-table below natural surface, the greater is the probability that polluting matter leached from the wastes will undergo ion exchange and bacteriological modification prior to reaching the water-table.

Another desirable feature is that the natural surface of the site should have little relief. Influx of surface waters and erosion of trench cover material is less of a hazard in areas of low relief.

From earlier geological mapping it was known that a sequence of mudstone lay beneath the sites and from the presence of deep, dry mine workings, it was inferred that the water-table was well below natural surface.

**Geology**

The mudstone sequence underlying the three sites has been categorised as the lower beds of the Dargile Formation. The sequence comprises laminae of consolidated silt and clay-size particles and occasional laminae of very fine-grained sandstone.

These sediments strike approximately northeast and dip to the northwest at angles varying from 35° to 55°.

Diamond drilling has revealed that the mudstones have some open fractures and that parts of the sequence have been intruded by quartz veins. These too are now partly open. The abundance of iron oxides in some of the laminae, fractures and some of the quartz veins suggests that these have acted as preferential conduits for the passage of groundwater in the past.

A predominantly clay soil ranging from less than 0.5 m to 2.7 m thick containing thin layers of ironstone covers most of the three areas. Throughout each area, the soil grades with depth into weathered mudstone. The thickness of mudstone penetrated by each bore is the difference between the total depth of the bore and the thickness of the soil.

The mudstones have been deeply weathered in a previous erosion cycle, and now range from soft to moderately hard.

**Details of boring**

A reconnaissance investigation of the three sites centred around a program of power-auger boring. On the basis of information gained from this program, a part of the northern area was selected for more detailed investigation.

Twenty seven auger holes were bored with a trailer-mounted Gemco HS7 power auger and almost all of them were sited adjacent to fire-tracks and roughly 300 m to 400 m apart.

With the exception of the first bore, all of the others extended to a depth of 10 m or to a point where the auger refused to penetrate the rock, whichever came first. It is understood that the disposal trenches would be about 7 m deep.

Hence, attempts were made to drill each hole to 10 m below surface in order to establish those areas where there would be at least 3 m of mudstone beneath the trenches.

The auger boring indicated that only part of the northern area has thickness of soft weathered mudstone adequate for the proposed land use. Eight vertical diamond drill holes were proposed for the smaller area.

Results from the auger boring indicate that the southern area would not be suitable as a site for a depot. There is too much relief and an inadequate thickness of soft weathered mudstone in this area.

Relief in much of the central area is too great for a depot. The area represented by auger bores 12 and 14, both of which penetrated to 10 m, is too small to suit projected requirements.

An approximately rectangular tract of forest of about 40 hectares in the northern part of the northern area is underlain for the most part by at least 10 m of clay soil and mudstone. This rectangular tract includes two broad gullies which are separated by a low, broad rise. Within the tract slopes are commonly less than 2° rising to 5° along part of its periphery.

Core from the completed diamond drill holes indicates that the mudstones have a secondary porosity in the form of open fractures and, to a lesser extent partly open quartz veins. The tests so far indicate a low transmissivity for the formation.

**Conclusion**

It is anticipated that trenches could be readily excavated in the mudstone by the larger types of earth-moving equipment.

Further injection tests are to be performed on each of the diamond drill holes in order to determine the hydraulic transmissivity of the mudstone sequence. It is also proposed to undertake laboratory determinations of porosity and hydraulic conductivity of selected parts of the bore cores.

If disposal operations are established at this site, it would be necessary to construct at least two deep bores for pollution monitoring purposes. It is envisaged that one bore would be "downstream" of the depot and the other sited so as to intersect the path of that groundwater which flows through the mudstone in a down-dip direction. Diversion of surface drainage would be a necessary additional requirement.

## Areas in Victoria where groundwater development can be expected

A C M Laing

### Introduction

Development of Victoria's groundwater resources has increased in the past 100 years from practically nothing to over 100 000 bores extracting an estimated 200 million cubic metres annually.

In terms of volume of water the major uses are for irrigation and town supply. A further major use is the pumping out of groundwater in the Latrobe Valley to dewater the open cut coal mines.

### Present usage for town supply

Approximately 54 towns in Victoria obtain their supplies from underground water. It is now apparent that a number of other towns will supplement their water supply from groundwater in the future.

The increasing use of groundwater for town supply will make it necessary to safeguard the aquifers against pollution and this will pose a major management problem in the future.

### Present usage of groundwater for irrigation in Victoria

Thirty eight million cubic metres are used annually for pasture irrigation in the Murray Valley and smaller quantities from Murrayville and Nhill-Kaniva. In addition 10.4 million cubic metres per year are used in the Loddon Valley in Northern Victoria south of Calivil, mainly for pasture irrigation (Jones 1977). And approximately 35 million cubic metres are used to irrigate 8500 hectares in southern Victoria for pasture (64%) and vegetables (33%).

The main centres of irrigation with groundwater in southern Victoria (Murphy 1977) are:

| | |
|---|---|
| Koo-wee-rup | 2200 ha |
| Warrnambool — Port Fairy | 2000 ha |
| East Gippsland | 1850 ha |
| Colac — Camperdown | 800 ha |
| Ballarat — Bungaree | 450 ha |
| Glenelg | 400 ha |
| Mornington Peninsula | 250 ha |

### Present knowledge of Groundwater in Victoria

There are two areas of low bore density, the northeast with abundant surface water where bores are little needed, and the area of northwest Victoria where the limited drilling carried out indicates high salinity. However there is inadequate bore coverage there.

There must be further development of areas where there is known to be groundwater of less than 1000 mg/l TDS. Two areas in this category, underlain by groundwater of less than 1000 mg/l TDS in irrigation quantities, where the groundwater has been overexploited are the Westernport Basin and Mitchell River Flats.

In the Westernport Basin (Lakey & Tickell in preparation) there is saline water intrusion of the Baxter Sand aquifer as a result of overpumping. There has been a *Groundwater Conservation Area* declared to limit the exploitation of groundwater in the area. A study is evaluating the possiblity of recharging the groundwater with treated sewerage effluent water from the MMBW southeastern purification plant at Carrum.

In the Sorrento-Boneo area, at the southern end of the Mornington Peninsula on the downthrown side of the Selwyn Fault, there are outcropping calcarenites and aeolianites of Pleistocene age from which groundwater is being extracted both for irrigation and domestic use. The resource is being assessed and, if the groundwater is being depleted, it would be a very suitable area for groundwater recharge using treated water from the Carrum Southeastern Purification plant. The pipeline to pump the treated water to the ocean passes through the Sorrento-Boneo area, so any recharge operations would not require expensive additional pipelines.

Under the Mitchell River Flats (see Thompson 1973), west of Bairnsdale, irrigation bores have depleted the groundwater, and the feasibility of carrying out a recharge program has been investigated.

Other areas being studied, where there are signs of groundwater depletion, are Wandin Yallock (Shugg 1976) and the Latrobe Valley.

In the Wandin Yallock areas 35 km east of Melbourne, groundwater which has a salinity of less than 500 mg per litre is being used both for irrigation and domestic use. The area is a hilly one and the principal aquifers are fractured rocks, sediments of Silurian or Devonian age, and volcanics or intrusive rocks including granodiorite of Devonian age. There are some signs of groundwater depletion. In some parts of the area there is a lowering of the water-table by as much as 20 m during the summer period.

In the Latrobe Valley, pumping of groundwater from the Latrobe Valley coal measures, to dewater the open cut coal mines, has depleted the groundwater to form a core of depression in the water-table 100 m deep, and extending over about 50 sq. km.

The areas underlain by groundwater of salinity less than 1000 mg/l TDS may not supply sufficient water for Victoria's future domestic town supply and irrigation needs. In this case the use of groundwater with salinity in the 1000 to 3000 mg/l TDS salinity range must be considered.

In areas where groundwater quantities are to be evaluated, the important factor to be determined is the 'permissive sustained yield' defined by the American Society of Civil Engineers (1961) — (See Lawrence 1972): *The maximum rate at which water can economically and legally be withdrawn perenially from a particular source for beneficial purposes without bringing about some undesired result.*

### Evaluation required

The areas where I consider quantitative evaluation of the groundwater will be necessary are shown in Figure 1 and are detailed below:

*1 Otway Basin*

The Otway Basin is deficient in surface water resources but is partially underlain by an extensive unconfined aquifer, the Port Campbell Limestone of Miocene age. It is up to 240 m thick and is used both to produce water and to dispose of waste (e.g. dairy factory wastes at Heywood and Allansford, and septic tank wastes in a number of town including Nelson).

Also underlying the Otway Basin are two confined aquifers containing fresh water. These are the Dilwyn Formation of Eocene age and the Timboon Sand Member of Upper Cretaceous age. Of these the Dilwyn Formation is 100 metres to 1250 metres thick. At least 50 percent of the formation consists of sandstone. It has been tapped for a number of town supplies, including the towns of Portland, Heywood, Port Fairy and Geelong. The Timboon Sand Member is a further virtually untapped aquifer below the Dilwyn Formation containing good quality water. Both these aquifers need accurate quantitative evaluation.

AWRC (1975) after Lawrence (1975) estimates there is 1555 million $m^3$/year of groundwater of less than 1000 mg/l TDS available in the Otway Basin and 710 million $m^3$/year of 1000 to 3000 mg/l TDS. Of the 2265 million $m^3$/year, 211 $m^3$/year was estimated as being utilised in 1975.

*2 Northern deep leads*

There are a number of known fossil river systems extending north from the Central and Eastern Highlands. These are former river valleys, now buried underground and filled with sands and gravels which have been mined for gold at their southern shallow extremities.

These deep leads represent the major aquifer system on the northern plains. The groundwater in the deep leads (Calivil Formation) increases in salinity northwards. By pumping water from the southern part of the deep leads, where the water is less than 1000 mg/l TDS, for irrigation purposes, pressure in the northern part of the deep leads will be lowered. This will prevent seepage of saline water upwards into the shallow aquifers. It may even permit drainage downwards from the shallow aquifers, thus lowering the water table.

*3 Possible deep leads Western Victoria*

North and south of the Central Highlands there may be undiscovered deep leads that contain water less than 3000 mg/l TDS. These include possible leads northwards into the Murray Basin, west of the Avoca Lead. Such leads should have existed at a period when the Murray Gulf of Miocene times was retreating. Also included are possible leads southwards, under the western basalt plains, from the Central Highlands.

*4 Murray Basin*

The Warina Sand aquifer of Eocene age is the thickest and most extensive aquifer in the Murray Basin. The water quality is better than that of the overlying aquifers. Because it is the deepest it has not been adequately explored, but it does offer considerable potential for development.

*5 Gippsland Basin*

The sands of the Latrobe Group of Eocene age are important aquifers but have not been extensively developed at this stage.

*6 Mineral water*

There will be further investigation and exploitation of the mineral water areas in Central Victoria centred on Daylesford. In this area the mineral waters occur in fractures in a folded Ordovician rock sequence. It is believed the carbon dioxide in the groundwater originates from Quaternary volcanic magmas.

*7 Fractured rocks*

Figure 2 shows the area of Victoria where the only aquifer is Paleozoic rocks or granite rocks in which the groundwater occurs in fractures. This type of aquifer has not been adequately investigated but there appears to be a relationship between the higher rainfall areas and lower salinities in the groundwater in these aquifers. The need to use these aquifers will become more important in the next few years with particular emphasis on pin-pointing areas of lower salinity.

Figure 1

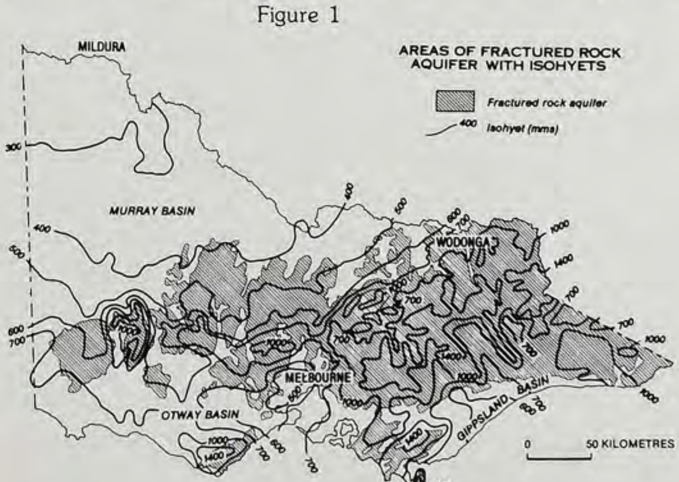
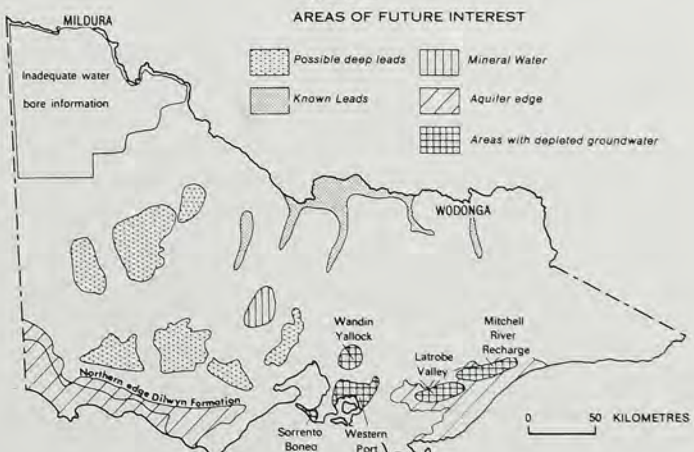



Figure 2



## Groundwater usage for Victorian towns

*Does not include small towns supplied from old bores constructed under the Local Government Act or, in general, towns supplied from Springs*

| Name of local Water Authority | Name of Town | Population (1978) | Estimated Usage (1977-78) Megalitres/Year | Licensed volume M/l | Supply bore | |
|---|---|---|---|---|---|---|
| | | | | | Parish | No |
| Ararat WWT | Streatham | 110 | | 35 | Streatham | 1 |
| | Willaura | 800 | | | | |
| | Lake Bolac | 230 | | | | |
| | Moyston | 150 | | 140 | Nekeeya | 1 |
| | Glenthompson | 247 | | | | |
| Avoca WWT | Bung Bong | | | 19 | Bung Bong | |
| Barnawartha WWT | Barnawartha | | 37 | 550 | Barnawartha | 2 |
| Briagolong WWT | Briagolong | 300 | 24 | 160 | Briagolong | 2 |
| | Boisdale | 550 | 91 | 36.5 | Wadelock | 1 |
| Chiltern WWT | Chiltern[1] | 760 | 135 | | | |
| Coleraine and Casterton WWT | Casterton[5] | 2500 | 245 | 199 | Nangeela | 2 |
| Creswick Shire | Creswick[2] | 1800 | | | | |
| (Creswick Water Supply Authority) | Dean[2] | | | 146 | Dean | 1 |
| Creswick Shire | Newlyn | | | | | |
| (Springhill Water Supply Authority) | Kingston | | | 300 | Springhill | 1 |
| | Allendale | | | | | |
| | Broomfield | | | | | |
| Daylesford WWT | Daylesford[2] | | Report pending | | | |
| Elmore WWT | Elmore | 750 | 104 | | | |
| Geelong Waterworks and Sewerage Trust | Geelong[2] | 16 200 | 638 | | | |
| | Barwon Downs | | | 2183 | Murroon | 1 |
| Glenelg, Shire of, WWT | Merino | | 54 | 100 | Merino | 2 |
| Gordon and Mount Egerton | Gordon) 6 | 200 | 120 | | | |
| (proposed water supply scheme) | Egerton) | | | | | |
| Heytesbury, Shire of, WWT | Timboon | 700 | 257 | | | |
| | Port Campbell | | 43 | 949 | Paaratte | 2 |
| Heywood WWT | Heywood | 1300 | 160 | 333 | Heywood | 3 |
| Kaniva, Shire of, WWT | Kaniva | 1000 | 318 | 459 | Kaniva | 3 |
| | Lillimur | | 2 | 100 | Lillimur | 1 |
| | Miram | | 2 | 7 | Mirampiram | 1 |
| Koroit WWT | Koroit[3] | | 152 | 70 | Warrong | 1 |
| Kowree, Shire of, WWT | Goroke | 362 | 114 | 86 | Goroke | 3 |
| | Apsley | 223 | 23 | 40 | Boikerbert | 1 |
| | Harrow | 170 | 37 | 29 | Harrow | 1 |
| Lang Lang WWT | Lang Lang | | | 182 | Lang Lang | 1 |
| Learmonth WWT | Learmonth | | 31 | 36.4 | Burrambeet | 2 |
| Lexton, WWT | Waubra[6] | | | 401 | Lexton | 1 |
| Minhamite, Shire of, LGB | Hawkesdale | 180 | | 10 | Kangertong | 1 |
| Mortlake WWT | Mortlake[1 3] | | | | | |
| Mount Rouse, Shire of, WWT | Penshurst[1] | 572 | 77 | 220 | Boramborah | 1 |
| | Dunkeld | 446 | | 100 | Dunkeld | 1 |
| Murrayville WWT | Murrayville | 400 | 64 | 548 | Danyo | 1 |
| Nhill | Nhill | 2350 | 550 | 1250 | Balrootan | 4 |
| Numurkah, Shire of, WWT | Strathmerton | | 85 | 52 | Strathmerton | 1 |
| | Katunga | | 33 | 28 | Katunga | 1 |
| Peterborough WWT | Peterborough | | 15 | 10 | Narrawaturk | 1 |
| Port Fairy WWT | Port Fairy | | 1210 | 1026 | Belfast | 2 |
| Portland WWT | Portland | 8700 | 2800 | 4222 | Portland | 5 |
| Sale, City of, LGB | Sale | | 5730 | 2046 | Sale | |
| Trentham WWT | Trentham[2] | 825 | | 24 | Trentham | 2 |
| Trafalgar WWT | Trafalgar[2] | 2000 | 150 | | | |
| Walpeup, Shire of, LGB | Cowangie | | 9 | 40 | Tutye | 1 |
| Warrnambool, Shire of, LGB | Caramut[4] | | 27 | | | |
| Yarragon MMT | Yarragon[2] | 750 | 65 | 375 | Moe | 1 |
| 29 WWT's, 5 LGB's | 54 towns | | 13 402 | 16 691* | | |

*1 supplied also by springs*
*2 augmented by groundwater*
*3 nitrate concentration high*
*4 supplied by surface springs rather than bores*
*5 augmented by surface water*
*6 new scheme in progress*
*7 estimates by SR&WSC engineers*
** Accurate figures not possible due to incomplete data on usage or licenced volumes*

## Leachate discharge from a suburban landfill, Parish of Jika Jika

A Shugg

### Introduction

The landfill is located at the eastern end of Separation Street, Alphington, where it was operated by the Northcote City Council. The quarry hole that was reclaimed was a pit excavated into the Newer Basalt adjacent to Darebin Creek. The maximum depth of the quarry was 35 m, and Silurian bedrock was exposed in the floor of the quarry.

In 1972 the City of Northcote made an application under Section 49A of the Health Act 1958 to establish a garbage depot at the site. Waste disposed of at the site consisted largely of waste from municipal garbage collection. Disposal activities were wound down by 1976.



Soon after the termination of disposal activities at the site, the occurrence of *leachate springs* were noted. The springs occurred at two locations on the perimeter of the landfill. One *spring*, first noted by local residents in 1973, occurred on the southern side of the landfill, near the railway cutting. The other *spring* occurred on the eastern side of the landfill, its discharge cascaded down the valley wall and into Darebin Creek.

Flow from the second *spring* has persisted for over three years, at a rate of around 1.5 l/s. The discharge has been the subject of discussions between local government authorities, state ministries and a local residents association.

### Geology

Basaltic lavas of the Newer Basalt series have been quarried at the site. The basalt attains a thickness of at least 35 m at the site. During a field inspection of the site in 1972 it was observed that at least two flows of basalt were exposed in the quarry.

In a bore sunk in Yarana Ave, interflow rubble was intersected at 14 m below the ground surface. This discordant contact between basalt flows affords a zone for storage and conduction of groundwater, further, it serves to indicate the thickness of the upper flow.

Darebin Creek to the east of the site is a lateral stream, although to the north of the landfill it has incised into the basalt, upstream from its junction with Donaldson's Creek.

### Hydrogeology

Groundwater occurs naturally in both the basalt and bedrock systems which are fractured rock aquifers.

### Pumping test

A pumping test of short duration, lasting only 62 minutes was conducted. A drawdown of 4.4 m was obtained after 62 minutes of pumping at a rate of 0.5 l/s, Specific Capacity 10.9 $m^3/d/m$ at 60 minutes. At an assumed storativity of 0.02 this value corresponds to a transmissivity of about 9 $m^2/d$.

The waterhole in Jika Jika 492 was measured to be at 28 m AHD on 31 August 1976. The leachate spring discharge occurred at a level of at least 27.4 m AHD (the leachate level up gradient from the discharge would be at a higher level), Darebin Creek below the leachate discharge is 15.2 m AHD. Darebin Creek is therefore an effluent stream, with respect to groundwater.

In the northern portion of the landfill a small pool of water was noted to exist, with some connection to the fill and the leaching processes. The water level of this pool was noted at about 28.3 m AHD. The level of the top of the fill was between 4 m and 6 m above the level of water in this pool. It was inferred that all but the top 4-6 m of the landfill was saturated. This was circumstantially supported by the facts that the standing level in Jika Jika 492 and the level of the discharge are about the same. Therefore mounding of fluids probably occurs within the landfill site.

The basalt aquifer that surrounds the landfill site has low values of permeability, nevertheless it is a medium that may potentially transmit groundwater, or receive contaminants originating from the landfill.

### Chemical characteristics of the waters

Waters in the vicinity of the tip site have been collected from the bore Jika Jika 492, the Darebin Creek and also from the leachate spring that discharges into Darebin Creek.

The waters sampled may be split into two significantly different groups.

Firstly the groundwater and surface water; noncarbonate alkali ('primary salinity') exceeds 50 percent — that is chemical properties are dominated by alkalies and strong acids, ocean waters and many brines plot in this area, secondly the leachate samples where no cation pair exceeds 50 percent and the anions are equally dominated by bicarbonate and chloride ions.

The stream water from Darebin Creek although similar in composition to the groundwater exhibits a salinity that is about one quarter of that of the groundwater pumped from Jika Jika 492. A large proportion of the catchment of Darebin Creek is covered by outcropping basaltic rocks; it is evident that some mixing of waters occurs within the catchment. The surface water exhibits the characteristics of diluted groundwater discharge. At low stage considerable lengths of Darebin Creek may be considered as an effluent stream.

The groundwater samples taken from Jika Jika 492 contained small amounts of Total Organic Carbon (43 and 18 mg/l), in addition all the trace metals were at levels below 0.1 mg/l. Nitrate was at a level of 92 and 96 mg/l, together with the levels of TOC. Moderate contamination of the groundwater by at least these parameters may be assumed.

The leachate from the Alphington tip was a strongly polluted species of water. It was characterised by high levels of trace metals (especially zinc at about 5 mg/l), suspended solids, phenols, surfactants, ammonia and phosphate. The high chemical oxygen demand and total organic carbon provided corroborative evidence of the high degree of pollution of this water.

Nitrate and sulphate levels recorded in the leachate from the landfill were very low. By contrast the presence of ammonia presumably in equilibrium with the anaerobic landfill conditions was noted at high levels (900 mg/l as N).

Generally sulphate reduction does not proceed in the presence of nitrates. The leachate analyses indicated that nitrate was not present in the discharge from the landfill. Sulphate however was present. Therefore it was possible that sulphate reduction was not complete within the landfill, thus affording a conveyance for ionic species of some heavy metals. The concentrations of zinc recorded in the leachate would probably have also been in equilibrium with the carbonate-bicarbonate system.

The actual rate of leachate expulsion at the spring adjacent to Darebin Creek (this outlet probably does not account for the total discharge of leachate from the landfill) ranges from between 1.5 l/s and 3 l/s and this discharge has been maintained for about four years. Therefore the volume of leachate discharged from this spring so far amounts to about $1.9 \times 10^5$ $m^3$, this corresponds very closely to the volume expected if 10 percent consolidation is achieved over the period of discharge. This figure is also about 30 percent of the initial pore fluid content, or about 13 percent of the total volume of waste in the landfill.

It is apparent that the fluids expelled from the refuse play an important role in the water budget of the landfill and that the hydrogeology of the site has a significant bearing upon the nature of the egression of fluids from the landfill.

### Conclusions

Over a period of several years about $1.9 \times 10^5$ $m^3$ of leachate has been expelled from the landfill site via a leachate spring which drains into Darebin Creek; equivalent to 13 percent of the volume of waste in the landfill. The leachate produced by the landfill is a grossly polluted species of water.

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## Geological data processing system

S Mack

### Introduction

During the year further work was undertaken on the development of a geological data processing system. This preliminary report covers the 'groundwater subsystem' from a user oriented point of view in order to ascertain the final requirements of the system. It is intended to cover the needs of the Department of Minerals and Energy and the State Rivers and Water Supply Commission (SR&WSC).

### System objectives

The geological data processing system (GDPS) is a data base of all geologically oriented quantitative data collected by the Geological Survey Division of the Department of Minerals and Energy, and the other associated agencies, and is intended to achieve the following ends:

1 To provide a central register of all bore hole drilling in Victoria. At present this register would include material from the following sources.
   (a) Data presently held and generated within the Department of Minerals and Energy in relation to groundwater, coal and mineral deposits, extractive industries, and engineering investigations.
   (b) Data generated by the SR&WSC in relation to underground water.
   (c) Groundwater data supplied by private drilling operators under the provisions of the Groundwater Act (1969).
   (d) Data from other private sources (when obtained) such as mining-exploration companies and groundwater investigations prior to the Groundwater Act.

2 To provide for the storage and retrieval of large volumes of chemical (analyses) and geological (fossil/mineral/rock localities) data which cannot be handled effectively by manual methods.

3 To present data in a form capable of computational analysis.

4 To present data that can be plotted in a graphical and contour form.

5 In the long term to provide an on-line inquiry system into groundwater resources for the benefit of the public and other agencies.

6 To develop a data processing system compatible with the Australian Water Resources Council (AWRC) recommendations to facilitate the inter-state exchange of groundwater data.

7 To maintain compatability of design with other land information systems being developed under the auspices of the State Co-ordination Council Task Group on Land Information Systems.

### System concepts

A database system, such as the GDPS, attempts to store only raw data and avoids duplicity of data storage (redundancy). Raw data is obtained by scientific observation and recording and not derived by mathematical manipulation from other data elements.

The operational sections within the Geological Survey Division maintain completely independent operations for the collection and storage of raw data. Therefore it is necessary to recognise the commonality that exists in this data collection to provide a compatible retrieval system.

This commonality exists in three broad areas:

1 Borehole data
2 Surface data (rock, sediment, mineral, fossil, water samples)
3 Geophysical station data.

The nature of the data collected in these three divisions is, to a large extent, dependent on the administrative practices and the technology employed in that collection which leads to a commonality within a division and a contrast between divisions.

The Task Group on Computer Based Land Information Systems (State Co-ordination Council) recommends that all scientific databases (in Government agencies) have a *common unique identifier* based on Australian Mapping Grid (AMG) co-ordinates. This will provide a means of cross-referencing between systems when desirable.

### Borehole subsystem

The Geological Survey is a central registry for much of the underground boring activity of Victoria and maintains records of bores dating back to 1884. These records relate to gold, coal, groundwater, extractive industries etc, and are in constant demand from private industry and government agencies. Therefore the bore subsystem receives the main coverage of this design report.

The borehole subsystem contains four dependent structures:

1 The boremaster structure
2 Structure of continuous water level recordings
3 Bore completion details
4 Irrigation licence structure.

All structures are disjoint. Entry points are through the boremaster structure with links to the other three dependent structures. Each structure is a hierarchical tree of embedded data sets with a 1:n relationship between master and slave data sets.

### Bore and sample numbering systems

Although the AMG co-ordinates provide a 14 digit unique numbering system for each station it is desirable to have a simpler numbering system based on geographical regions.

The systems of bore numbering presently in use in the Geological Survey have grown up to suit independent applications without any effective co-ordination. Furthermore there is no recognisable numbering system for station types other than boreholes.

The bore numbering systems presently in use are either parish based or chronologically based. Seven different systems can be recognised.

1 A Department bore is given a consecutive number within the year for each drill rig as AA/BB/CC for sequence no/rig no/year.

2 These department bores are then surveyed (sometimes within a year of completion) to ascertain their true position in relation to parish allotments. Then they are assigned a sequence number for the parish within the range 1 - 7999.

3 Bores drilled and surveyed by SR&WSC are assigned a sequence number within the range 11 000 - 11 999.

4 Private groundwater bores drilled under the Groundwater Act (1970) are assigned a sequential Construction Permit number on issue of the permit. On receipt of a bore completion report they are then assigned a sequence number within the parish range 10 000 - 10 999.

5 Other private bores (for purposes other than groundwater or drilled prior to the Groundwater Act) are assigned a sequence number within the parish in the range 8 000 -8 999, if they are located and registered by the Department of Minerals and Energy.

6 Similar bores to type 5 when located by SR&WSC are assigned sequence numbers in the range 9 000 - 9 999. There is therefore some duplication of numbering between the 8 000 and 9 000 series system.

7 All bores finally obtain a number, within a particular series, based on parish locality. These parishes have been numbered alphabetically from 1 to 1 990. This numbering was extended in 1978 to 2 013 to accommodate the newly proclaimed parishes in the Big Desert, Sunset Country and High Plains thus destroying the original alphabetic order.

However many areas of Victoria do not fall within parishes such as the inland seas, fresh and salt lakes, coastal areas (dunes, beaches, swamps, tidal estuaries etc) and large areas of the continental shelf. These areas are becoming of increasing interest with beach erosion studies and offshore drilling. Therefore a comprehensive uniform numbering system based on a nationally or even internationally recognised format is clearly necessary, and the authority for assignment of these numbers must be clearly defined.

As previously mentioned the numbering system to be adopted by the GDPS database is based on the AMG international grid. Firstly all Stations are assigned AMG co-ordinates providing a 14 digit unique identifier which is also a location descriptor with an accuracy of ±0.5 metres. Each entity in each subsystem (boreholes, sample point, geophysical station) is also assigned a 5 digit number with the 1:100 000 AMG sheet area. The assignment of these sequence numbers is by the GDPS update program on the creation of a *Master* data set. The final sequence number for each area is stored in the database after each update and then retrieved on a subsequent update.

Victoria is covered by 148 map areas to the Tasmanian border and 183 to the Tasmanian north coast; this is a vast improvement on the 2000 odd parishes.

The present system of bore numbers based on parishes will also be retained in the borehole subsystem but will not be provided for in the other subsystems.

To meet the requirements of the borehole subsystem, for a parish and bore number as 'necessary items', all bores presently being drilled outside parishes will be assigned pseudo-parish numbers equivalent to the AMG number and pseudo-bore numbers, possibly as a 90 000 series.

### Data Collection

There is one *Boremaster* for each bore and it will contain the following types of information:

1 Type of bore — groundwater, coal, mineral etc.
2 Ownership of bore.
3 Its location as required by various instrumentalities using the system — bore numbers, parishes, drainage basins, irrigation areas.
4 Its positional attributes such as co-ordinates, RL (Reduced level) and depth.

Well-test records, which occur only for groundwater bores, are included in the *Boremaster* and at present there are 11 000 with an expected annual increase of 1 500 to 2 000. The data contained in the well-test record is pump-test information obtained on completion of the bore, or when the bore water is sampled, as distinct from a major pump test which will be dealt with later.

The varying requirements for chemical determinations pose a problem in the design of a structure to hold them. A single record with data items to account for all determination possibilities would be impractical, and heavy on system resources. A smaller record structure which fulfilled requirements at the design stage would quickly become inadequate due to the volatility of analysis requirements. To overcome this problem each determination will be coded into a separate data set which is embedded in a broader data set, representing the individual sample. This is in turn embedded in the *Boremaster*. This will provide an open-ended system to accommodate future variations in determination requirements.

The *Sample* data set represents a specified sampled interval in the bore hole (for water samples it relates to the aquifer interval from which the water is taken). Each *Sample* record is defined uniquely by its sample number (lab-no) allocated by the laboratory. Update of the system requires the addition of further *Sample* records for a particular *Boremaster*. At present there are 0-100 *Samples* per *Boremaster* but the ratio is theoretically unlimited. The number of analyses per sample varies greatly depending on the type of sample.

Each record interval of a stratigraphic log is implemented as a separate record of variable length in the data set *Geoint*. There are four options provided in the variable length part to accommodate the geological description of the interval. The data set *Geoint* is embedded in a bore header *Geolog* and there are an average of 20 *Geoint* records for each *Geolog*.

There are two types of stratigraphic logs collected by the Geological Survey — the geologists logs and the drillers logs — and both will be accommodated in the same data structure.

There are 40 000 drillers logs presently held on microfiche containing relatively brief, sometimes inaccurate, geological descriptions. In total these logs would contain some 40 megabytes of data and due to the high cost of encoding it is not proposed to include them initially in the system.

Geologists logs are available for some bores. These are more accurate and complex than drillers logs and will become part of the system.

The structure for geophysical logs is similar to that used for the lithological logs. The header data set *Phylog* is embedded in the dataset *Logpt*. At each level of embedding the relationship is 1:n. There are 14 types of geophysical logs, each collected in analog form. The graphical output of these loggers will be digitised to form a file of co-ordinate points and then stored in the *Logpt* data set. The volume of digitised data which will represent these geophysical logs is expected to be high, although no estimate of total volume can be given at this stage.

#### Water level recordings

The structure designed to store the time-variable data consists of a master data set *Waterlevel* containing three embedded slave data sets *Observation*, *Levels* and *Pumpset*. The ratio between master and slaves is 1:n and the master is linked to the *Boremaster* data set.

#### Bore completion structure

The completion report of a Department bore contains details of how a groundwater production bore is constructed. This report contains details of the diameters of the hole (ie drill bits used), the sizes and lengths of casings, the types of screens with aperture sizes, the number and sizes of gravel packs, and the number and sizes of grouted intervals. This data, when available, is highly variable for each bore. In the data base it is to be implemented as a disjoint hierarchical structure linked to the *Boremaster* data set.

#### File size estimates

| Total Number of Bores (to end 1977) | | | |
|---|---|---|---|
| Government Bores (1885-1977) | : | 20 681(1) ) | |
| Groundwater Act Bores (1970-1977) | : | 9 189(2) ) | 36 500 |
| Other Private Bores (1885-1972) | : | 6 469(3) ) | |

These figures have been obtained from biannual Drilling Division reports and annual drilling reports (1), the issue of construction permits (2), and a previous estimate by R. Lanarus (3) where the information source is unknown.

A histogram (not included here) of drilling appears to show an exponential growth with time, however this apparent relationship is caused by the successive introduction of 'constant variables'.

Government drilling since 1950 has been maintained at approximately 300 bores per year (excluding auger bores). In 1964 introduction of auger drilling (drill 27) caused a sudden increase in the number of bores by approximately 300. With the Groundwater Act of 1970 there was a second sharp increase of 1000 per annum. These increases have been maintained at a fairly constant level since their introduction to give a total rate of 2000 bores per annum.

File size estimates have been made from the assemblages of probable record populations depicted on the following table.

| | Records | Volume | | Annual inc |
|---|---|---|---|---|
| Group A | | | | |
| Station/*Boremaster* | 40 000 | 3 920 K | | |
| Welltest | 12 000 | 612 K | 11 mb | 1 mb |
| Sample/analysis | 20 000 | 6 520 K | | |
| Group B | | | | |
| Lithological logs | 40 000 | 41 280 K | 41 mb | 3 mb |
| Group C | | | | |
| Geophysical logs | ? | large | (18 mb) | 1.2 mb |
| Water level recordings | ? | large | (5 mb) | 4.2 mb |
| Group D | | | | |
| Completion records | ? | small | | |
| Licence records | ? | small | | |

### Implementation

Implementation of the GDPS data base is dependent on hardware availability, data suitability and, to a lesser degree, program development. Because computer access and storage facilities have become limited, the implementation of the system has been subdivided into a number of stages as a compromise.

The first stage is a skeleton data base confined entirely to the borehole subsystem. This contains groundwater data that is most essential to the hydrogeological studies at present being undertaken by the Geological Survey Division. Briefly this would comprise:.

1 Bore location details
2 Well-test pumping data
3 Analysis of groundwater
4 Time variable water level recordings.

The storage requirements for stage 1 would be 10-12 megabytes (not accounting for system overhead) and this would encompass all the readily available groundwater data within the Department.

Subsequent stages would see the implementation of the full database as it was conceived and designed and would require a re-organisation of the system.

## *In situ* treatment of groundwater and the need for regular bore maintenance, Merino town supply bores

M Riha

### Introduction

A small groundwater basin at Mocamboro was selected to provide a water supply for the township of Merino. Several test bores intersected two or more aquifers consisting of fine sand, lime sand and sandy limestone. Aquifer test data indicated that the coefficient of transmissivity of the unconfined upper aquifer is much smaller than that of the lower aquifer. The aquifers are separated by an aquiclude. Using water from both aquifers was necessary because the upper aquifer, although of small storage, is continuously recharged by infiltrating precipitation. The lower aquifer is of good capacity, but is limited in extent and rate of recharge by an impermeable barrier.

Two production bores were drilled 2.2 km apart, one to the north, Mocamboro 7 and one to the south, Mocamboro 9. The upper aquifer at the southern production bore was found to contain excessive quantities of total iron in the early analyses, ranging from 13 to 47 mg/l. Since 1973 a technique for treatment of groundwater *in situ* was utilised in observation bore Mocamboro 10 located 52 m east-southeast from production bore Mocamboro 9.

In this treatment method the differences in fluid potentials of the upper and lower aquifers provide the energy source for the treatment. Water from the upper aquifer is firstly enriched with air in a single or multi-stage spray aerator. The air-enriched water is then rejected by gravity so that it mixes with the groundwater of the lower aquifer. The air-enriched water has a strong tendency towards oxidation or positive redox potential.

During the passage through the gravity aerator, part of the form is converted to the ferric form and is precipitated, generally as hydrated ferric oxide. This process continues in the lower aquifer. The mixed groundwater filters through the lower aquifer on its way towards the production bore and the iron precipitate is retained in the aquifer.

In February 1976, the northern production bore Mocamboro 7 was found to be polluted by organic substances, consisting mainly of cutting oil. The lower part of the bore was blocked by a solid object and the screens in the upper aquifer were damaged. An attempt to pump the pollutants out of the bore was unsuccessful. For this reason a new production bore Mocamboro 11 was drilled 26.92 m south-southeast of the polluted bore.

Initially, dissolved oxygen readings in the new production bore were near zero in the upper aquifer and the water had a bitter taste. This indicated migration of pollutants through the aquifer. To prevent any further spread of pollution from Mocamboro 7, the construction of the bore was altered in an attempt to treat the groundwater *in situ*. The technique was similar to that previously employed in the southern bores to remove excess iron.

### Construction and appliances of bores

The production bore Mocamboro 11 taps both the upper and lower aquifers. The water from the upper aquifer is released into the lower, pumped aquifer by means of an orifice. The calibrated orifice enables the discharge to be controlled at a constant rate so that the drawdown water level of the upper aquifer remains above the level of the screens. The equipment, consisting of 101.6 mm diameter PVC casing, a Johnson rubber seal and an orifice prevents, or at least retards, incrustation of the screens and surrounding parts of the aquifer.

The upper aquifer in production bore Mocamboro 9 is blanked off by 101.6 mm diameter PVC casing, and water for the town supply is produced exclusively from the lower aquifer. The additional quantities of water required from the upper aquifer are supplied via observation bore Mocamboro 10.

Treatment of iron by aeration *in situ* was introduced to observation bore Mocamboro 10 in 1973, and has now been continuously functional for over four years.

The bore is of simple, cheap construction, equipped with slotted casing and nylon mesh filter. The amount of water that is forced through the gravity aerator into the lower aquifer is equal to about 25 percent of the total amount pumped out of the production bore Mocamboro 9.

### Maintenance of bores Mocamboro 7 & 10

The new low cost method of treating groundwater, with a high iron content and containing organic substances, *in situ* uses the pressure head differences of the aquifers as the sole energy for the operation. The Merino town water supply was the first attempt to prove the efficiency of the system. The bore construction and appliances used were designed in the first place as functional with little or no consideration for maintenance. These bores are equipped with gravity aerators. The aeration system should be serviced twice a year.

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## Completion report on bore No 17, parish of Sale (production bore no 2A)

G Y Nahm

### Introduction

The Department completed a new production bore, Sale 17, during 1977. This bore was for the City of Sale water supply and replaced bore No 11, Parish of Sale (Sale Production bore No 2).

Bore No 11 had been used as a main town supply bore from 1968 until it produced a large amount of fine to coarse sands in 1977. A downhole investigation using a video-camera revealed that the steel casing in the bore was badly corroded, particularly at the joint between steel casing and stainless steel screen.

A new bore (Sale 17) was completed, 100 m north of the abandoned bore, with a rotary rig, Failing 1500 used by Mr F Fulford.

### Hydrogeology

The bore encountered alluvium and the Boisdale Formation of lower Pliocene age. The Boisdale Formation includes four principal aquifers consisting of medium to very coarse sands. In general, they are subrounded and mostly quartz grains. The main aquifer ranges from 68 m to 123 m in depth attaining a thickness of 38 m. Each aquifer is separated from the others by relatively thick and impermeable clay and/or sandy clay beds.

In general, the grain size of the sand aquifer tends to increase as the depth increases. The average 50 percent median grain size of the aquifer sand ranges from 0.7 mm at the top aquifer to 1.2 mm at the bottom. The sorting coefficient of the sand aquifer is relatively uniform throughout the aquifers averaging 1.5, but the uniformity coefficient varies from 1.2 up to 4.2.

The thickness of the alluvium in the bore is less than 20 m and that of the Boisdale Formation is more than 160 m. However, at one of the previous test bores (Sale No. 8), very sandy light grey marl of the Gippsland Limestone was reported at a depth of 190.5 m.

At the completion of the bore, the standing water level of the groundwater was 5.5 m above ground level and its initial flowing rate was estimated as about 1800 $m^3$/day.

There are more than 10 individual sand or gravel beds within the Boisdale Formation and 2 within the alluvium. Some of them are high in clay content. However, geophysical logs indicate 6 principal aquifers as follows:

| | | |
|---|---|---|
| 1 | Sand and gravel | (16.5 - 23.0 m) |
| 2 | Sand | (52.0 - 57.0 m) |
| 3 | Sand | (68.0 - 78.0 m) |
| 4 | Sand | (81.0 - 87.0 m) |
| 5 | Sand | (98.0 - 107.0 m) |
| 6 | Sand | (111.0 - 123.0 m) |

### Bore construction

The finished depth of the bore is 128 m. In order to prevent the corrosion problem which has been experienced in the previous abandoned bore, particularly by hydrochemical reaction, a bimetallic corrosion free material was used, with stainless steel casing and screen, fibreglass (glass reinforced polyester) surface casing, and rubber seals.

The aquifer system developed in the bore was 37 m in thickness and consisted of rounded-to-subrounded, medium-to-coarse, sands of the Boisdale Formation. Total length of the screen in the bore was 29 m covering 78 percent of the aquifer thickness.

### Aquifer tests

Two different types of aquifer test were carried out at the present bore using an electric turbine pump provided by the Sale Water Trust. The first test was a constant-discharge test. The objective of the test was to obtain data on the aquifer characteristics. Since no observation bore was available for the test, the analysis relied on the response of the pumping bore. The rate of discharge was 75 l/s. Both the drawdown and recovery data were used to calculate transmissivity. The transmissivity obtained from the drawdown and recovery data were well matched, within 1.8 percent difference in value. The transmissivity obtained from drawdown and recovery were 1043 $m^2$/day and 1062 $m^2$/day respectively.

For 500 minutes after pumping started, drawdown was steady but thereafter the pattern of the drawdown was disturbed. This disturbance could be interpreted as a result of the pumping effects from the near-by production bores. The nearest production bore, Sale 12 is only 300 m away from the test bore.

The theoretical drawdown expected at different rates of discharge and time have been estimated as shown in Table 1. These calculations are based on the data from the constant-discharge test.

Table 1

| Rate of Discharge ($m^3$/day) | Drawdown (m) after | | | | Specific Capacity at 8 hrs $m^3$/day/m |
|---|---|---|---|---|---|
| | 6 hrs. | 8 hrs. | 12 hrs. | 24 hrs. | |
| 6 000 | 21.82 | 21.96 | 22.14 | 22.46 | 273 |
| *6 500 | 23.69 | 23.83 | 24.03 | 24.37 | 273 |
| 7 000 | 25.46 | 25.62 | 25.83 | 26.20 | 273 |
| 7 500 | 27.28 | 27.45 | 27.68 | 28.07 | 273 |
| 8 000 | 29.10 | 29.28 | 29.52 | 29.95 | 273 |
| 8 500 | 30.92 | 31.11 | 31.37 | 31.82 | 273 |

* *Rate Tested.*

Remarks: Water level in the bore = Drawdown − 5.5 m

### Conclusions

On the abandonment of Bore No 11, a new production bore was completed some 100 m north of the previous bore. In order to prevent the corrosion problems which caused the abandonment of the previous production bore, bimetallic corrosion free materials were used in construction. The depth of the bore completed was 128 m.

## Resistivity surveys for groundwater — Mooroopna

P J Elliott

### Introduction

Resistivity surveys were carried out in the Parish of Toolamba during February 1978. They consisted of 1.7 km of profiling and one electrical depth sounding.

This survey is part of a major project covering the Campaspe and Goulburn river valleys. It was performed on behalf of the SR&WSC (State Rivers and Water Supply Commission) to assist in the delineation of shallow water-bearing aquifers immediately southeast of Mooroopna. These aquifers are sought to assist the SR&WSC to locate dewatering pump sites near orchards.

Similar investigations have been carried out near Shepparton East (Lilly 1976 b, c) Rochester (Lilly, 1978), Kyabram East (Elliott, 1978a) and Merrigum (Lilly, 1976a). These have had notable success at Shepparton East and Kyabram East.

### Geology

The main targets of interest consist of prior streams and ancestral river channels. The prior streams are usually straight, wide, and shallow and infilled with sand. Ancestral river channels, which are a later development, appear to be similar in shape and structure to the present river systems. They are infilled with sediments ranging in grain size from clay through to gravel.

### Method

Two methods of resistivity survey were employed. These were the Schlumberger depth-sounding technique and the continuous profiling dipole-dipole (Eltran) method. The aim of both methods is to determine the resistivity distribution beneath the ground surface. During this project 2 dipole-dipole profiles and one depth sounding were completed.

*Traverse 1: Dyke Road:*

The main feature in this section is a high resistivity zone beneath peg 73. This is adjacent to borehole 3223 in which an alternating sequence of sand and sandy material occurs between 5.0 m and 20.0 m. A three-dimensional model was computed for this zone using the program *Cubas* (Elliott, 1978). This indicated that the sandy material may continue below 20 m depth.

There are no other features in the section of this magnitude. However a minor apparent resistivity high beneath pegs 26 to 32 could indicate a thin sand lens between 5 and 15 m. A lens of this size would be of little use to SR&WSC hence a borehole was not advised.

*Traverse 2: Mooroopna-Toolamba Road:*

There is little of interest in this section. The water resistivity 10.7 ohm-m taken from bore 3261 at a depth of 15.0 m suggests that any sand layers encountered should show up as distinct positive anomalies. So it is assumed that none were encountered.

There is a general trend of increasing resistivity with depth along most of the section. It was decided to do a depth sounding at peg 75 to investigate this trend further.

*Depth Sounding MOOR-1*

The field curve indicated a well defined layer of about 60 ohm-m below 16 m. This would possibly correspond with deep lead material associated with the Goulburn Deep Lead.

The SR&WSC has proposed to put a borehole down within the vicinity of this sounding to a depth of about 30 m to investigate the exact nature of this high resistivity material.

### Conclusions and recommendations

It is concluded from Traverse 1 that the resistivity method is directly applicable to the location of aquifers in this area. The method confirmed the existence of the aquifer penetrated by borehole 3223 but did not reveal other aquifers of comparable size beneath the two profiles completed.

It is recommended that similar profiles be surveyed in other areas of interest within the Parish of Toolamba. Also that survey lines discussed in this report be neglected except for the possible presence of deep lead material beneath traverse 2.

# Department of Minerals and Energy, published and unpublished groundwater reports 1978

**Published reports**

Lakey, R. 1978 — Pilot study of recharge at Carrum using treated effluent. Geol. Surv. Rpt. no. 56.

Lakey, R. & Tickell, S., 1978 — Effects of channel dredging in Tyabb area on Westernport Basin groundwater. Geol. Surv. Rpt. no. 58.

Leonard, J., 1978 — Preliminary assessment of the groundwater resources in the Port Phillip Region. Geol. Surv. Rpt. no. 66.

Macumber, P., 1978 — Evolution of the Murray River during the Tertiary period. Evidence from Northern Victoria, Proc. Roy. Soc. Vict., vol. 90, pt. 1, pp 43-52.

Macumber, P., 1978 — Hydrologic change in the Loddon Basin: the influence of groundwater dynamics on surface processes, Proc. Roy. Soc. Vict., vol. 90, pt. 1, pp 125-138.

Riha, M., 1978 — Inter-aquifer flow test method for determining hydraulic characteristics of multiple aquifer systems, paper presented to the Institution of Engineers Hydrology Symposium on Sept. 5-7, 1978.

Shugg, A., 1978 — Groundwater resources and pollution investigation, Allansford, Victoria. Geol. Surv. Rpt. no. 60.

**Unpublished reports**

1978/2 Notes on mineral and stone resources of the 'Green Triangle Area', Southwestern Victoria, by D.A. McKenzie and Roger Blake.

1978/3 A case of groundwater pollution, Parish of Wollert, by A. Shugg.

1978/6 Alluvium depth in Upper-Ovens Valley from trench dredge cross-sections, by A.C.M. Laing.

1978/10 Groundwater pollution observation bore Jika-Jika, 467, by A. Shugg.

1978/16 Comments on the septic tank system at the township of Boisdale, by G.Y. Nahm.

1978/19 *In-situ* treatment of groundwater and the need for regular bore maintenance, Merino town supply bores, by M. Riha.

1978/21 Liquid-waste disposal sites, Parish of Redcastle, (confidential), by A. Shugg, (copies held in G/W section).

1978/24 Groundwater, Shire of Nathalia, by A.C.M. Laing.

1978/25 Completion report on bore no. 17, Parish of Sale (production bore No. 2A), by G.Y. Nahm.

1978/26 Resistivity survey for groundwater in the Kyabram area, by P.J. Elliott.

1978/27 Resistivity survey for groundwater — Mooroopna, by P.J. Elliott.

1978/30 Metrification of packer tests conducted at Tullamarine IWDS, by A. Shugg.

1978/31 Completion reports on Bore no. 19, Parish of Sale (production bore No. 1A), by G.Y. Nahm.

1978/38 Groundwater for Geelong. Completion report on the hydrogeological investigation of the Barwon Downs basin, by R. Blake.

1978/39 Summary hydrogeological report on a proposed disposal of hazardous wastes, (confidential), by G. Stewart.

1978/40 Investigation of the hydrogeology and groundwater pollution in the basalt aquifers west of Melbourne, by P.R. Kenley and M. Riha.

1978/49 Notes on the occurrence of saline efflorescence, Parish of Kororoit, by A. Shugg.

1978/51 Areas in Victoria where groundwater development can be expected, by A.C.M. Laing.

1978/53 Groundwater resources of Victoria, by C.R. Lawrence.

1978/56 Geology and hydrogeology of the Westernport Basin, by S.J. Tickell.

1978/61 Groundwater and drought relief — preliminary report, by M. Malone.

1978/65 Comments on static water levels of various spa water bores near Daylesford, by B.J. Foley.

1978/68 Extant records of standing water levels from small diameter basalt bores in the northern portion of the Port Phillip Sunklands, by A. Shugg.

1978/69 Leachate discharge from a suburban landfill, Parish of Jika Jika, by A. Shugg.

1978/72 Effect of quarrying on Donnybrook mineral springs, by A.C.M. Laing.

1978/82 Geological report on proposed tip site Parish of Sandhurst, (Golden Gully) section H.1, by E. Wilkinson.

1978/84 Report on inspection of Addlam's and Napiers sandpits, Shire of East Loddon, by E. Wilkinson.

1978/89 Evidence pertaining to an appeal by Mr. R. Bould. Dalmore, to Groundwater Appeals Board submitted by the Dept. of Minerals and Energy, by R. Lakey.

1978/90 Suitability of the 'Wilsons Quarry', Berwick, for the disposal of industrial and liquid wastes, by M. Riha.

1978/95 GDPS data base — preliminary analysis & design (no. 1), by S. Mack.

1978/96 GDPS data base — preliminary analysis & design (no. 2), by S. Mack.

1978/97 GDPS data base — program GW040, by S. Mack.

1978/101 Seismic survey — Heathcote, by P.J. Elliott & I.J. Lilly.

1978/103 Temperature correction of tests on deep thermal aquifers, by G.Y. Nahm.

1978/105 Salinity of lake system from Douglas to the South Australian border, by R. King.

1978/110 Occurrence of springs at Campbellfield, by A. Shugg.

## Groundwater (water table) control programs for irrigation areas

### Project No 1

**Locality: Northern irrigation areas (general)**

This project commenced in 1975 and is presenting evidence to the Parliamentary Public Works Committee of Inquiry into Salinity Control and Drainage, and other relevant bodies, in support of specific proposals to mitigate high water table and salinity problems in the northern irrigation areas.

Evidence submitted to the Inquiry in the past year has been:

(a) *Shepparton region drainage and the Lake Tyrrell Scheme, part I, Shepparton region drainage* April 1978.

(b) Two reports on the *Mineral Reserve* Basins proposal, one in September, one in December 1978, and submission of the Environmental Effects Statement for that proposal as an exhibit.

(c) Proposals for *Financial Assistance to Irrigators and Augmented Advisory Services and Research* December 1978.

Further work is in progress on the preparation of additional supporting submissions as required, and the preparation of answers to questions raised by other interested bodies.

### Project No 2

**Locality: Shepparton Region**

*(a) Water table control program permanent works*

Location of groundwater pumping sites to protect all significant horticultural areas from high regional water tables and salinisation. A summary of progress during 1978 is shown in Table 1. The main objective in 1978 was to ensure that all sites previously located were completed. Exploratory drilling was therefore limited, only five new potential sites being located. However, a large number of sites were brought to completion or near completion. Total capacity of the installed pumps is about 100 Ml/day. The total area of horticultural land protected by Commission controlled pumps is estimated at about 50 percent of that for which control is thought to be feasible and necessary. Under extreme conditions, however, the area protected could be significantly increased by operating many of the rejected private pumps, together with suitably placed irrigation pumps which were hired in 1974.

*(b) Investigations*

The aims of this program are:

1 To obtain the necessary data to define more accurately those pastoral areas for which groundwater pumping is both feasible and necessary as a means of water table control. This will enable the proposals already put forward (under Project 1) to be considerably refined.

2 To assess more accurately both the volumes and the salinity of the groundwater which would be pumped from various project areas, and hence the requirements for disposal of the groundwater.

3 To evaluate the actual and potential extent of waterlogging and salinisation problems in areas which cannot be protected by groundwater pumping; and to develop appropriate remedial measures.

**Table 1**

**Shepparton region water table control program progress.**

| | | |
|---|---|---|
| 1 | *Commission Developed Sites* | |
| (a) | Since December 1974 | |
| | Sites drilled or in progress | 110 |
| | Sites located [1] | 43 |
| | Units under construction | 3 |
| (b) | Prior to December 1974 | |
| | Sites completed [3] | 13 |
| 2 | *Privately Developed Sites* | |
| | Number known | 102 |
| | Rejected after initial inspection | 44 |
| | Investigated in detail [4] | 58 |
| | Rejected | 26 |
| | Under assessment | 2 |
| | Under hire | 22 [5] |
| | Taken over | 8 |
| 3 | *Total Units Operating Under Commission Control* [3] | |
| | Pre December 1974 Units | 13 |
| | Post December 1974 Units | 30 [2] |
| | Hired Units | 22 [4] |
| | Total | 65 |

*Notes:*

1 *Includes two sites discarded because satisfactory facilities for disposal were not available.*

2 *Sites which are operable although some minor works are outstanding in some cases.*

3 *One of the original sites has not been satisfactory and consideration is being given to locating an alternative site.*

4 *Forty four of the private water table control pumps were rejected because of defects or lack of capacity which were obvious at the initial inspection. Others were subjected to more detailed investigations, including in most cases, short or long term pump tests.*

5 *Two private irrigation pumps which were hired in previous years were suspended.*

*The report to February, 1977, also listed pumps operating under private control. As the Commission's policy is to provide water table control in all horticultural areas, where it is necessary and feasible, these will become redundant in the future and have been omitted from this report. They are available for use, however, if the need arises before substitute Commission pumps are installed.*

Investigations continued to more accurately assess the geomorphology of the region, measure water table levels and trends, identify causes of waterlogging and salinity and assess drainage requirements.

These included —
Analysis of regional water table records.
Regional water balance studies.
Regional drilling and geomorphic studies (about 200 holes were drilled along regional sections).
Correlation of water table levels, soil salinities and crop health.
Surveys of salt affected pastures within the region.
Assessment of groundwater pump and tile drainage performance.
Drainage disposal.
Relation between pasture health and groundwater levels in selected cross sections.

Investigations continued in the Shepparton East area, which seems atypical of the region generally. These included drilling and geomorphic studies, pump testing, soil salinity, water table monitoring and tree health. The Department of Minerals and Energy is evaluating the use of electric resistivity survey techniques.

Intensive investigations continued in Campaspe Irrigation District. A two-month pump test was carried out using a well-point system tapping an aquifer about 10 m below surface. Results were disappointing but inconclusive. Additional drilling has commenced with the aim of locating a second pump site close enough to the original site to allow the combined effects of two pumps to be observed.

Co-operative projects will be developed, with officers of the Department of Minerals and Energy, at Shepparton to examine the relationship between water table levels in shallow strata (up to 20 m below surface) and piezometric levels in much deeper strata.

## Project No 3

### Locality: Kerang Region

*Water table and salinity investigations*

This project, which commenced in 1969, continued to investigate and monitor the water table levels in the Kerang Region to determine (a) the effects of the groundwater on the natural lakes and depressions, (b) the movement of groundwater in relation to irrigation problems, and (c) the effects of proposed works on the groundwater situation.

Regional investigations continued along similar lines to the Shepparton Region, including monitoring of water table levels and salinities and monitoring of levels in some natural lakes.

Specific investigations being undertaken include:

1 Monitoring of water table levels at 'The Marshes', where native trees are affected by salting.

2 Investigation of Lake Charm area, where new bores have been installed and extensive monitoring has been undertaken to assess the inflow of saline groundwater to the lake.

3 A study of the 'Mineral Reserve' Basins to determine their acceptability as evaporation basins in the Lake Tyrrell Scheme. Permeability testing at shallow depth has been carried out around the basins and along the proposed channel leading to the basins, and additional bores have been drilled for geological information and water table monitoring.

Trends in regional water table levels were analysed and a report written for the Pyramid Hill Irrigation Area. A monthly report was commenced on water table levels in four irrigation areas, these being Cohuna, Boort, Kerang-Koondrook and Tragowel Plains.

Study of piezometric levels in strata at different levels to determine whether significant vertical flows of groundwater are occurring. An intensive study continued at Calivil (in conjunction with the Department of Minerals and Energy) to assess piezometric responses, at various levels, to pumping from private bores. An interim report was produced in 1978.

All investigations will be continued, with an intensification of water table monitoring being undertaken at the Mineral Reserve Basins. In the future, a study of the feasibility of groundwater interception in the Lake Charm area could be undertaken.

A study of water tables in the Fish Point area adjacent to the Little Murray river to determine salt accessions to the Murray from this area could also be recommended in the future. A report was written on the analysis of regional water table levels in the Pyramid Hill Irrigation Area.

## Project No 4

### Locality: Lake Tyrrell

Monitoring of lake levels (in Lake Tyrrell) and water table levels in the vicinity continued as part of the assessment of present inflows to the Lake and the likely effects of proposed works on regional water tables. Eight shallow holes were drilled in the lake bed area. The geology of the area was analysed and a report prepared. A report summarising the geological information obtained from drilling investigations around the Lake Tyrrell area was prepared.

## Project No 5

### Locality: Mildura-Merbein

This program aims to install groundwater interception bores and associated works to intercept groundwater seepage to the River Murray and to divert the water to inland disposal basins. During 1978 the installation of Stage one of interception works was commenced. Stage one consists of 14 interception bore sites between the SR&WSC Merbein Pumping Station and Chaffey Bend.

## Project No 6

**Locality: Karadoc Swamp**

An investigation is being made into the cause of salt accessions to the Murray River in the vicinity of Karadoc Swamp, and to determine a feasible method of preventing the salt accessions. Monitoring of water table levels measured in existing bores, a pump test on Lambert Island, and a salinity traverse along the river were undertaken during the year. Additional drilling and pump testing, and monitoring of regional water table levels including areas around potential disposal sites, will be undertaken.

## Project No 7

**Locality: Nangiloc-Colignan**

A study is being made of the water table movements in the Nangiloc-Colignan area. During 1978 the monitoring of existing bores continued.

## Project No 8

**Locality: Macalister Irrigation District**

*Desirable future investigation*

An assessment is being made of water tables, in areas adjoining existing irrigation, to determine the effects of irrigation on the water table from Thomson Dam surplus water; at Toongabbie, Bushy Park, Kilmany and Thomson River flats.

## Project No 9

**Locality: Mitchell River Flats**

An examination has been made of the need for artificial groundwater recharge on the Mitchell River Flats following construction of the Mitchell River Dam. The final draft has been prepared for submission to the Commission. Its main conclusion is that groundwater supplies in the area of most intensive use are expected to be adequate to meet the likely demand for groundwater following construction of the Mitchell Dam.

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## Investigations into dryland salting

A joint investigation with Soil Conservation Authority, of dryland salting in the Kamarooka area, has commenced during 1978. A field program will be implemented to measure the location of the main parameters determining the location and extent of salinity problems at Kamarooka. A mathematical model will be developed using the measured parameter values to explain the present situation and predict future changes in water table values and salinisation.

# Department of Agriculture projects

## Pasture irrigation with poor quality bore water

**Locality: Animal Research Institute, Werribee**

Large volumes of groundwater are available for irrigation in Victoria. Much of the water is, however, of poor quality and information on the response of pasture/crops to irrigation with moderately saline water is required to enable farmers to make economic assessments of potential groundwater irrigation schemes.

The present experiment is to determine the productivity of pasture on a heavy clay soil using water of 2700 mg/l salinity and with various irrigation intensities and gypsum applications. The data will be particularly applicable to the basaltic plains west of Melbourne.

A lucerne dominant pasture has been successfully grown using bore water for seven years, but the pasture yield is now falling because of the decline in lucerne. Pasture yield was directly related to the intensity of irrigation, the most intensive treatment using about 700 mm of irrigation water per year.

Heavy surface applications of gypsum increased pasture yield in periods of high rainfall and reduced salt accumulation in the topsoil. The salinity of the topsoil has varied considerably with periods of moderate accumulation (1971, 72 and 75) and periods of leaching (1973/74, 1976/77). The salinity of the surface 0.3 m of soil was scarcely any higher in 1977 than pre-irrigation (1970).

The irrigation water has a high sodium content, but this has not reduced soil permeability, presumably because of the continuing high salt content.

The field experiment is concluding. Data processing and reporting are in progress.

*Authority for Project: Department of Agriculture*
*Program 103/02 Project 009*

Published and unpublished reports:
Groundwater Investigation Program Reports, 1971 *et seq.*
Australian Salinity Newsletters, nos 2 (1974), 4 (1976), 5 (1977), 6 (1978).

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## A field assessment of the productivity of a perennial pasture when irrigated with saline water

**Locality: Kerang Agricultural Research Farm**

The re-use of saline water, either surface drainage or groundwater, is becoming increasingly important in endeavours to prevent saline pollution of the Murray River.

The present experiment is to determine:

1 Pasture yields obtained for a range of water salinities over several years.

2 The accumulation of salt in the soil which these saline irrigations cause.

3 Other soil changes occurring, e.g. to structure, permeability.

Pasture yields have been recorded for six years and six water salinity treatments (100 up to 6000 mg/l). Pasture yield has always been much reduced (relative to channel water) for treatments of 4000 mg/l and 6000 mg/l irrigation water, but even so these yields are superior to dryland pasture yields in non-saline conditions. At 2500 mg/l, pasture yields were similar to those of channel water for nearly three years (although one of these years was very wet), but have since declined to about 60 percent of channel water. Water of 1800 mg/l or less has given good yields throughout the six years. Moderate soil salt accumulations have occurred with the waters of 1800 and 2500 mg/l, with severe accumulations at the 4000 and 6000 mg/l levels. The field experiment is concluding. Final data processing and reporting are in progress.

*Authority for project: Department of Agriculture*
*Program 103/02 Project 003*

Published and unpublished reports:
Groundwater Investigation Program Reports, 1972 *et seq.*
Australian Salinity Newsletters, nos 2 (1974) and 3 (1975).

The effects of saline irrigation water and gypsum on perennial pasture grown on a sodic, clay soil at Kerang, Victoria. Mount and Schuppan (1978) Aust. J. Exp. Agric. and An. Husb. 18:533.

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## Effects of irrigation with saline water on perennial pastures

**Locality: Animal and Irrigated Pastures Research Institute, Kyabram**

Pumping water from aquifers is being used increasingly in the Goulburn Valley by both the Water Commission, and individual farmers, as a means of lowering water tables.

Irrigation is regarded as a desirable method for the within-district disposal of the saline pump effluents, but data are required on the effects of this irrigation on pasture productivity and soil properties.

This experiment seeks these data for five irrigation water salinities (up to 3000 mg/l) and for perennial pasture.

Results from two irrigation seasons are now available. Soil salinity has increased in all soil layers to 1.20 m in proportion to the salinity of the applied water. This increase indicated that some water is percolating well below the root zone and thereby contributing to the water table.

The annual dry matter production of the pasture was found to be related directly to the salinity of the surface 0.6 m of soil.

White clover yield and soil salinity followed a similar relationship, but white clover yield was reduced more (in proportion to normal yield) by any particular salt content of soil, than was the total pasture yield.

A relationship has also been established between the chloride content of white clover leaves and soil chloride content.

Gypsum (5 tonnes per hectare) treatments increased soil water intake at irrigation and increased the pasture yield (8 percent) in the first year only. Experiment to continue for several years.

*Authority for Project: Department of Agriculture*
*Program 103/02 Project 019*

Published and unpublished reports:
Groundwater Investigation Program Reports, 1976 *et seq.*
Australian Salinity Newsletters nos. 5 (1977), 6 (1978).

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## Effects of irrigation with saline water on annual pastures

**Locality: Animal and Irrigated Pastures Research Institute, Kyabram**

This experiment concerns annual (spring and autumn irrigated) pastures, but follows the same aims as set out for the similar investigation on perennial pasture.

The first irrigation was applied in this experiment in autumn 1978. Two subterranean clover varieties, Clare and Woogenellup, were then established independently on subplots within each water salinity/gypsum plot. Pasture yields in 1978 were not significantly different between treatments. This is a long-term experiment.

*Authority for Project: Department of Agriculture*
*Program 103/02 Project 017*

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## Kyabram district soil salinity and water table survey

**Locality: Conducted from the Animal and Irrigated Pastures Research Institute, Kyabram**

Rising water tables and associated salinity problems threaten the continued prosperity of the Goulburn irrigation areas.

The present survey is to monitor water table levels and salinities, and soil salinities over a large, selected area. This data is then examined in relation to land use, irrigation intensity, climatic effects and pasture productivity.

Water tables continued to rise in the 729 sq. km survey area through the 1976-78 period. The percentage of test sites which, at the end of the irrigation season, had a water table within 1.8 m of the ground surface, increased from 40 percent in 1976, to 46 percent in 1977, to 53 percent in 1978.

In July 1976, 33 percent of the survey area had a soil salinity above 800 mg/l in the surface 0.6 m. Reductions in clover productivity occur above this level of soil salinity, although much of the area so affected is in dry land pasture.

Soil salinity is likely to continue to increase unless a greater number of pumps are installed in the district to lower water tables. The survey will continue to monitor salinity status of sample portion of Goulburn Valley.

*Authority for Project: Department of Agriculture*
*Program 103/02 Project 005*

Published and unpublished reports:
Groundwater Investigation Program Reports, 1975 *et seq.*
Australian Salinity Newsletters nos 3 (1975), 4 (1976), 5 (1977), 6 (1978).

Changes in water tables with irrigation in the Goulburn Valley. Mehanni. Proc. Symposium Hydrogeology of the Riverine Plain, Aust. Soc. Soil Sc., Griffith, 1977; p. 129.

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## Salt accumulations in unirrigated land

**Locality: Animal and Irrigated Pastures Research Institute, Kyabram**

Water tables of low to moderate salinity have risen to within 2 m of the land surface during the past six years in much of the irrigated Goulburn Valley. The lands at greatest risk, in terms of salt accumulation in topsoil, are the unirrigated, clay soils at lowest elevations.

The current study at Kyabram is intended to trace the soil salinity changes in such a situation, where the water table is usually within one metre of the land surface.

This investigation commenced in 1972, although some data from 1959 is available, which assists in tracing long-term soil salinity changes.

The general indication up to 1978 is that salt is accumulating in all soil layers to 1.2 m and particularly in the surface 0.3 m. The salinity of the 0 to 0.15 m soil has increased sixfold since 1972, whilst the 0.3 to 0.6 m soil has increased sevenfold since 1959. The 0.9 to 1.2 m soil salinity has more than doubled since 1959.

The present rate of salt accumulation indicates that within about ten years this land will be unable to support subterranean clover and therefore inferior pastures with declining soil fertility will result. The project will continue indefinitely.

*Authority for Project: Department of Agriculture*
*Program 103/02 Project 002 (part of)*

Published and unpublished reports:
Groundwater Investigation Program Reports, 1975 *et seq.*
Australian Salinity Newsletter no. 5 (1977).

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## Soil salinity surveys and water table studies

**Locality: Animal and Irrigated Pastures Research Institute, Kyabram**

The purpose of this project is to obtain evidence of the amount of hydraulic continuity between water in the upper aquifers and the water table; to record water table behaviours for a range of irrigation intensities and for various soil types;

and to follow soil salinisation processes due to high water tables and/or leaching by irrigation and rainfall.

Soil salinity tended to increase slightly between 1959 and 1972 in the heaviest soil types and in unirrigated land. Leaching of salt occurred in all soil types and under all irrigation conditions during 1973/74 when very high rainfall was received. These wet years caused substantial water table rises, e.g., from a mean of 2.5 m (depth of water table below ground level) in 1968 to 0.6 m in 1973. Further salt accumulation in soil then followed in 1977, by which time both the water table and the deep (10 m below ground level) pressure level had fallen to 1.8 m. These studies will continue indefinitely.

*Authority for Project: Department of Agriculture*
*Program 103/02 Project 002*

Published and unpublished reports:

Groundwater Investigation Program Reports 1971 *et seq*.
Australian Salinity Newsletter nos 1 (1973), 3 (1975), 6 (1978).

Water table conditions and soil salinity status in part of the irrigation areas of the Goulburn Valley. Mehanni and Repsys (1978). Department of Agriculture Research Project Series no 46.

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## Reclamation of saline soils for pasture production in the Goulburn Valley

**Locality: Tongala. Conducted from the Animal and Irrigated Pasture Research Institute, Kyabram**

The area of saline land in the Goulburn Valley is increasing; this is mainly in pasture. Reclamation techniques must be developed to improve pasture production on deteriorated areas. This experiment tests the applicability of reclamation methods, widely used in other areas, to the Goulburn Valley soils which have low subsoil permeabilities.

The experimental site was regraded and laid out for flood irrigation in 1975/76. Subsoil ripping and gypsum treatments were also then applied. Plastic pipe sub-surface drainage was installed in January 1978 on half the experiment. Oats were grown in 1978 and the yield on the drained area was double that of the no-drainage (sub-surface) area. There was a marked response to gypsum, but on the drained area only. No response was obtained to the ripping.

The whole site was sown to millet in November 1978 and perennial pasture will be established in autumn 1979.

The soil salinity of the drained area has been greatly reduced, but the undrained part of the experiment has improved only slightly in this regard. The experiment has several years to run to satisfy objectives.

*Authority for Project: Department of Agriculture*
*Program 103/02 Project 010*

Published and unpublished reports:

Australian Salinity Newsletters no. 6 (1978).

## Effects of water table depth and salinity on two pasture species

**Locality: Animal and Irrigated Pastures Research Institute, Kyabram**

Water tables of various salinities and depths now occur throughout the Murray Goulburn Irrigation District.

This experiment seeks to determine the relationships between water table depth (distance from the water table to the ground surface) and salinity, and the productivity of two pasture species grown in a typical Goulburn Valley loam soil. This information is of great importance in indicating the degree of water table control necessary to ensure satisfactory plant production.

The first year's results showed that a very high water table (0.3 m) caused a yield decline, but this was overcome if the water table was at 0.6 to 0.9 m.

Increasing water table salinity (levels of 600 to 6000 mg/l was used) decreased the yield of white clover, but perennial rye grass was more tolerant to salinity. This study is in the concluding stages.

*Authority for Project: Department of Agriculture*
*Program 103/02 Project 006*

## Definitions of Commonly Used Groundwater Terms

**Aquiclude.** A material of such low hydraulic conductivity that it effectively prevents any movement of water through it or reduced water movement to such a low value relative to the surrounding materials that it can be considered a barrier.

**Aquifer.** any water-saturated body of geological materials from which enough water can be drawn at a reasonable cost for the purpose required.

**Aquitard.** A material of low hydraulic conductivity which however on a regional scale allows the passage of groundwater through it.

**Groundwater** as used here includes all water in the zone of saturation beneath the earth's surface except that water chemically combined in minerals.

**Hydraulic conductivity** (intrinsic permeability). Ability of a material to allow a fluid, in this instance water, to pass through it. It is controlled by the size and interconnection of the spaces in a rock or soil. In groundwater studies, it is normally expressed as the number of cubic metres of water per day that will pass through a cross-section of one square metre under a hydraulic gradient of one i.e. one metre to the metre. (A hydraulic gradient represents the difference in head in water between any two points). The unit for hydraulic conductivity is metres per day.

**Observation bore** or **piezometer** is a bore tapping an aquifer, used to measure regularly or continuously, water level temperature and chemical composition.

**Perched groundwater** is unconfined groundwater separated from any underlying body of groundwater by an unsaturated zone.

**Porosity.** The ratio of water-filled spaces in a saturated rock or soil to the total volume of rock or soil. It is usually expressed as a percentage.

**Potentiometric surface.** A pressure surface or an imaginary surface passing through all points to which water would rise from a given depth or material. It is usually represented by contours. As used here the potentiometric surface has been mapped for a given aquifer.

**Storage coefficient** is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

**Transmissivity.** The measure of the amount of water in cubic metres per day per metre that will flow through a vertical strip one metre wide extending from top to bottom of the material being investigated and under a one metre to one metre hydraulic gradient. The unit for transmissivity is square metre per day.

**Water table** is the upper limit of completely saturated material.