LIQUID-WASTE DISPOSAL IN PERTH
A HYDROGEOLOGICAL ASSESSMENT

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ABSTRACT

Most of the Perth area is covered by a sedimentary sequence which must be considered unsuitable for liquid-waste disposal. The importance of hydrogeological investigations prior to commencement of disposal is stressed. Examples are given where the lack of such investigations had undesirable consequences, *e.g.* excessive hydraulic mounding, unknown direction of groundwater movement, and therefore misplacement of monitoring bores and contamination of production bores. A stricter application of the existing legal framework is considered necessary if a marked improvement is to be achieved.

INTRODUCTION

With the increasing use of groundwater in the Perth area over recent years, awareness has also been growing of the potential dangers of pollution of this resource.

Of all pollution sources, liquid wastes are potentially the most dangerous: the volume is often large; in many cases they are toxic; and their application in the form of shock loads often prevents sufficient adsorption by the soils, biodegradation, or dilution by the groundwater. The danger of groundwater pollution is particularly great in areas of sediments with low adsorption capacity, which is the case with large parts of the Perth region.

Liquid wastes can be broadly classified as follows:

domestic—septic systems
municipal—sewage, stormwater
industrial

The control and supervision of liquid-waste disposal, which has been in many ways less than satisfactory, is now slowly improving. The legal framework is presented by the *Health (Liquid Waste Disposal) Regulations* 1983, and by the *Rights in Water and Irrigation Act* 1914-1981.

For the Perth area, the administration of licensing of industrial effluents has been delegated to the Metropolitan Water Authority, which is assisted by multi-departmental panels. This paper will demonstrate the importance of a hydrogeological input to any groundwater-pollution investigation.

GEOLOGY

To understand the occurrence and behaviour of groundwater, a picture of the geological environment is required. In the context of groundwater pollution in the Perth region, only the superficial formations are of direct concern. They are shown on Figure 1, and on the geological cross-section on Figure 2, and are, from west to east:

Safety Bay Sand—bioclastic lime sand

Tamala Limestone—sandy, cavernous eolianite

Bassendean Sand—leached quartz sand

Guildford Formation—predominantly sandy clays

These formations are underlain by less permeable strata, *e.g.* the dark clays of the Osborne Formation, or the top clays of the Leederville Formation.

HYDROLOGY

The superficial formations contain unconfined groundwater. Recharge to this aquifer is mainly by direct infiltration of a proportion of the rainfall, and is greatest in clean and coarse sands. In the central regions of thick Bassendean Sand, two large groundwater mounds have formed, well known as the Gnangara and Jandakot Mounds, as shown in Figure 3. This figure also shows the positions of all past and present municipal liquid-waste disposal sites.

The water-table can be contoured by lines of equal elevation above datum. Groundwater flow is always perpendicular to the contours (from high elevations to lower ones) towards discharge zones, which can be either water courses or the coast. The rate of flow is dependent on the hydraulic conductivity of a particular formation, its porosity, and the hydraulic gradient. The former two are usually obtained from test pumping and other tests, whereas the gradient is calculated from a water-table contour plan as the drop of the water-table over a measured distance. Average flow rates in a medium sand are in the order of 10-20 m a^{-1}.

The above comments outline the importance of establishing detailed water-table contour plans to derive groundwater flow direction and flow rate, and therefore the expected extent of any pollution plume.

AMOUNTS OF LIQUID WASTE

The respective amounts of liquid waste have to be put into a proper perspective in order to assess their relative importance.

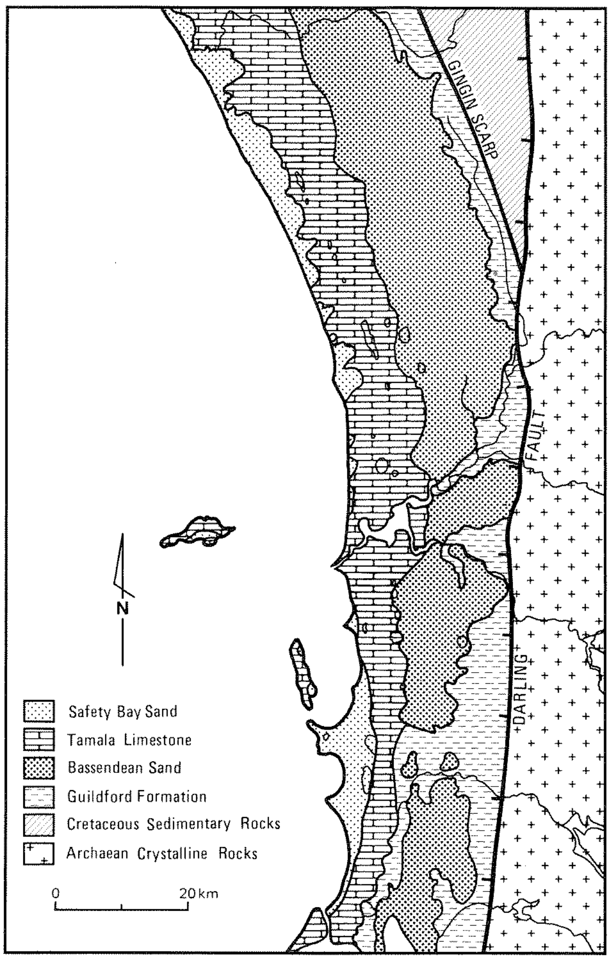

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Figure 1. Simplified geology, Perth area.

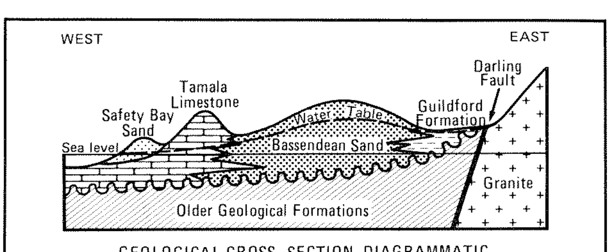

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Figure 2. Diagrammatic geological cross-section.

Figure 4 shows that of the 80 million m^3a^{-1} of total liquid waste for Perth, about half is discharged to sea, whereas the remainder is disposed into the ground. The majority of the latter is from septic systems and from industry, and only a minor amount, namely about 0.3%, is col-

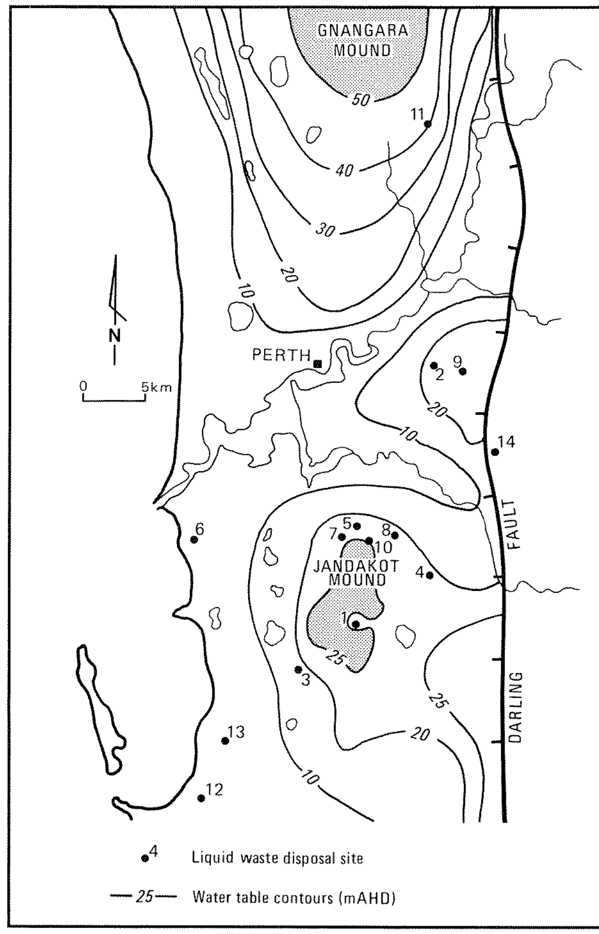

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Figure 3. Groundwater mounds and liquid-waste disposal sites.

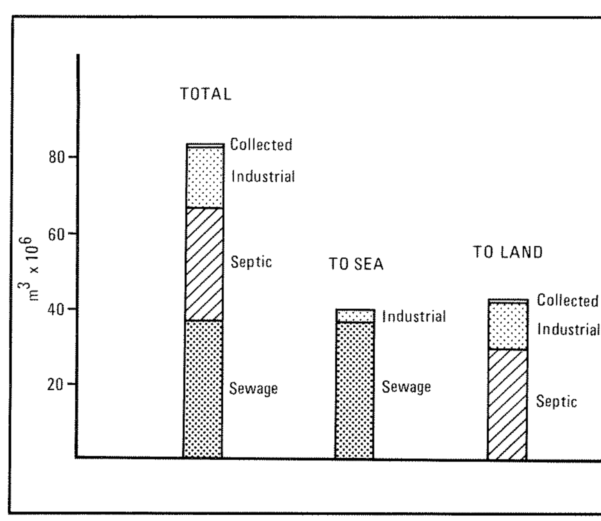

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Figure 4. Liquid waste, Perth area.

lected and disposed of on specific sites. Quite clearly, therefore, the major pollution threat comes from septic systems, and from industrial on-site disposal. The latter is further exacerbated by the often toxic nature of these industrial effluents.

SPECIFIC EXAMPLES

In the following examples of bad and good liquid-waste disposal practice, localities and authority or company names were, by necessity, largely omitted.

MUNICIPAL LIQUID-WASTE DISPOSAL SITES

Originally, such sites were put in areas convenient with respect to access and population, and scant regard was given to potential groundwater pollution. Figure 3 shows that a large number of these sites were located in the formerly undeveloped areas of leached Bassendean Sand, which is considered generally unsuitable for liquid-waste disposal. Futhermore, housing development has now encroached upon most of these areas, with a real danger of pollution of private bores or wells. Most of these sites have now been closed down. Three sites are at present used for biodegradable waste, and one site has been established for industrial liquid waste.

Disposal Site 4 (Fig. 5) was allowed to receive, over a large number of years, practically any amount of any type of waste. The local authority received a fixed annual payment by each cartage contractor. Control at the gate was minimal.

The water-table was originally about 1 m below the bottoms of the lagoons, which is, at best, considered insufficient for satisfactory adsorption and biodegradation. Problems were compounded by the disposal of substantial amounts of liquid waste, which resulted in a large groundwater mound, with the water-table actually on or near the surface, and a much increased flow of groundwater radially away from the site.

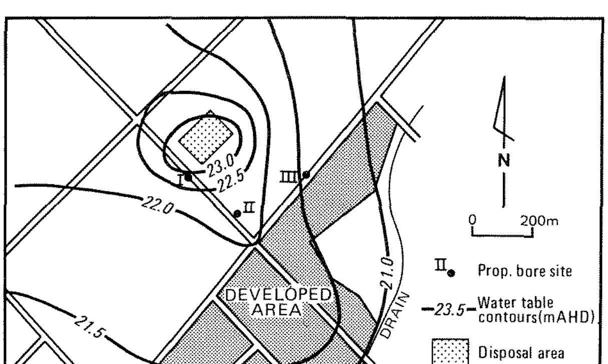

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Figure 5. Disposal Site 4: Water-table contours and proposed monitor-bore sites.

Breakdown of pollutants is insufficient, and several private bores in a developing area to the southeast have been found to be contaminated. It is considered essential that monitoring bores be installed in this area, as the pollution plume will move with the groundwater for many years to come.

The Disposal Site 1 (Fig. 6) is on top of the Jandakot Mound, in a groundwater protection area. A production bore of the Metropolitan Water Authority is located about 200 m northeast of the site, and a system of monitoring bores has been installed between the disposal site and the production bore.

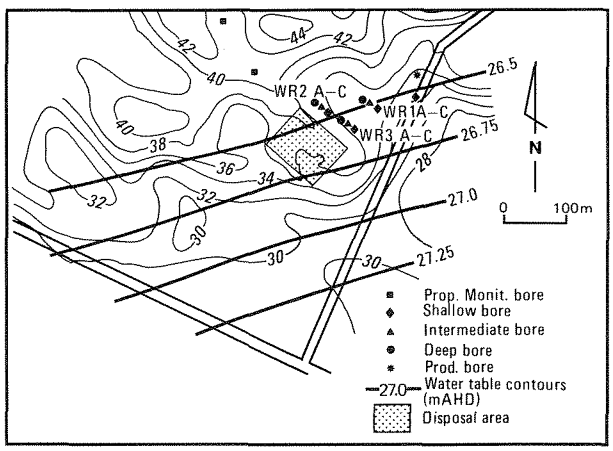

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Figure 6. Disposal Site 1: Water-table contours and monitor-bore sites.

The hydrogeological investigation revealed that the undisturbed groundwater flow is to the northwest. However, an analysis of results indicates that pumping of the production bore creates a cone of depression, with induced groundwater flow from the disposal site to the bore. The monitoring bores show strong signs of pollution, and the production bore should in fact be rested until the pollution plume has dissipated. Additional monitoring to the northwest appears necessary.

The two new disposal sites installed during 1982 deserve mentioning as they show how a site assessment should, and can, be done. The Canning Vale site which is taking most of the carted septic waste since the closure of the majority of the old sites, was the subject of an intensive hydrogeological study including the drilling of a comprehensive network of monitoring bores. Figure 7 shows groundwater flow with a low gradient to the northwest, towards the sanitary landfill site and the old liquid-disposal site. The flow is therefore away from the groundwater protection area. Although it is generally towards a new housing development region, the danger of pollution of private water supplies is small as the rate of flow is slow, and adsorption and degradation of pollutants will be substantial due to the elevation of the lagoons well above the water-table.

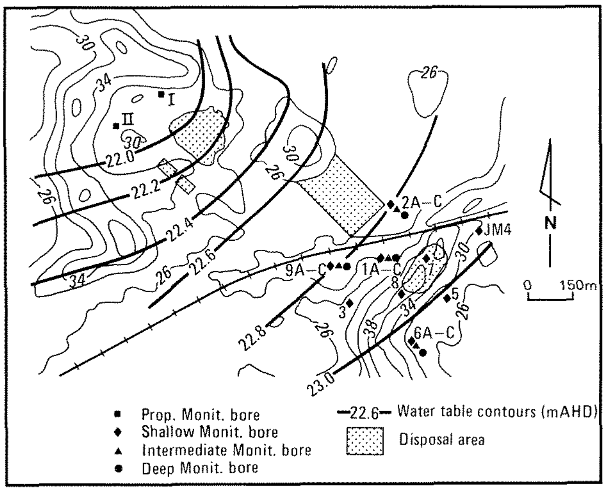

Figure 7. Disposal Site 10, Canning Vale: Water-table contours and monitor-bore sites.

It must be said that this site was established as an interim measure only, and does not meet all requirements for an ideal site. Any pollution originating here will eventually be superimposed on plumes which must be expected to exist already down-gradient of the landfill site and the old liquid-waste site. Monitoring bores are required between these two sites and the new housing area.

Figure 8 shows the new disposal site for industrial liquid waste, located within the Kelvin Road landfill site at Orange Grove. From a hydrogeological point of view, this site comes close to being ideal; it is situated just east of the Darling Fault, and lies on a wedge of clayey Leederville Formation, which is underlain by granitic bedrock at about 40 m depth. Downward leakage will be slow, with consequent good adsorption and degradation in the clayey soils. The water-table is well below the lagoons.

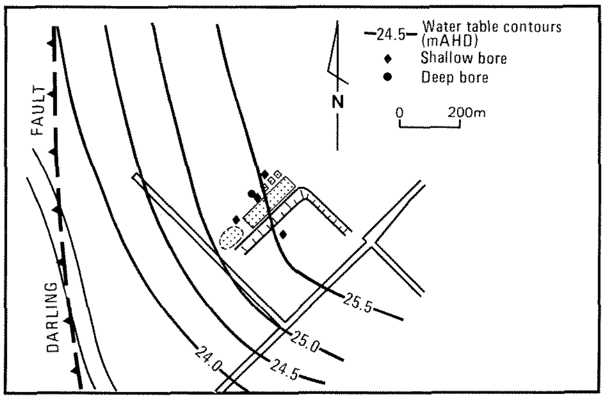

Figure 8. Disposal Site 14, Orange Grove: Water-table contours and monitor-bore sites.

The groundwater flow, as determined by a census of nearby bores, is to the southwest. The flow rate will be slow due to the expected low values for hydraulic conductivity. Rates of 1-2 m a^{-1} appear realistic. Groundwater quality is being monitored in several bores, and no pollution has been detected to date.

OTHER POTENTIAL SOURCES OF POLLUTION

Septic systems

Septic systems are still widely used in Perth, and the amount of liquid waste is substantial as was demonstrated earlier (Fig. 4). Practically all of this waste seeps into the ground and finally the groundwater. However, other studies have shown that the contamination generally appears to be confined to a small area because of strong adsorption and biodegradation in the unsaturated soil column.

Wastewater-treatment plants

Wastewater-treatment plants receive an enormous amount of liquid waste, however a substantial proportion of this is storm-water which results in a marked dilution of the effluent. Treatment reduces the contaminant strength further, and subsequently, 99% of the treated effluent is discharged to sea. The remaining small proportion is disposed of by spray-irrigation, and does not pose any significant threat to the groundwater.

Canning Vale recharge experiment

In the experiment, secondary effluent is disposed of via a system of soak lagoons, under controlled conditions (*i.e.* rotational application, wetting and drying cycles, and varying amounts of effluent). The experiment is being monitored extensively, and useful data are being obtained concerning the adsorption capacity of the soils and the fate of the various pollutants with time and distance.

The site is on Bassendean Sand, with generally poor adsorption capacity. The large amounts of effluent have resulted in a marked groundwater mound, and a pollution plume has been detected, migrating radially away from the site. The relative remoteness of the site prevents the pollution of production bores at present.

Large industries

The disposal of the substantial amounts of liquid waste, which originate from several large industries in the Perth area, is the subject of special agreements between the Government and the individual companies. The agreements generally stipulate certain disposal methods, site preparations, and monitoring requirements; companies usually adhere to the stipulated conditions. Leakages and spillages of some magnitude have occurred in the past despite stringent precautions. When monitoring has shown the presence of contamination, the companies concerned have gone to great lengths to rectify the situation.

The activities of these large industries are the subject of numerous individual reports and it is beyond the scope of this paper to go into any further detail.

Smaller industries

The disposal of liquid waste by numerous smaller industries constitutes a dark chapter in waste disposal in the Perth area. Businesses in this category are, to name just a few, plating shops, woolscourers, starch mills, chemical factories, and laboratories. Most of these do not have the means to install extensive treatment facilities or disposal systems, and disposal of effluent is usually into soak pits or bores within the premises. Although the amounts are generally only moderate, these effluents are a definate threat to the groundwater due to their often toxic nature, and the haphazard disposal practices. Furthermore, many of these companies are in well-developed areas.

Under the *Rights in Water and Irrigation Act*, companies which dispose of any effluent on their premises are now required to obtain a licence to do so. A licence usually sets maximum allowable levels for certain parameters, as well as methods of disposal, and monitoring requirements. Prior to the issue of a licence, a hydrogeological and hydrochemical investigation is done as a matter of course. The following examples show the importance of such investigations for the definition of a pollution plume and for the appropriate positioning of monitoring bores.

The first example is that of a corrosion-proofing business, called here company A, which had been dumping its effluent for several years into two soak pits within their plant site. The effluent contained high levels of cyanide, cadmium and zinc.

In order to show that groundwater leaving the premises was not polluted (requirement stipulated in the Act), the company drilled two monitoring bores. The first one was placed between the two disposal lagoons, the other near the boundary fence, downgradient of the expected groundwater flow. Analyses showed indeed that the first bore was heavily polluted, as expected, whereas the second bore showed no contamination.

When the licensing authority decided to expand the monitoring network, a detailed water-table contour plan was established (Fig. 9) which shows the surprising feature of a local flow direction to the southeast, in variance to the regional flow to the southwest. This means that the second monitoring bore could not show any pollution, as it was sited well outside the flow path of the pollution plume.

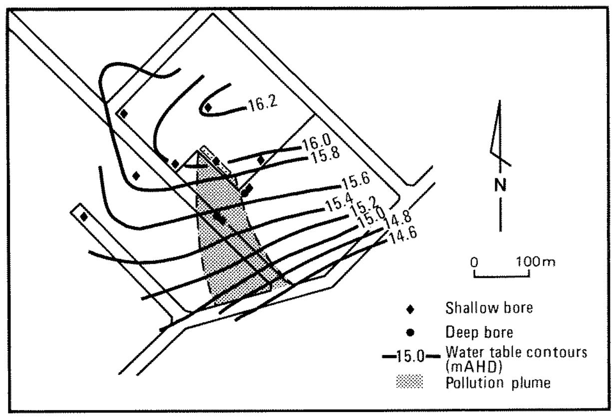

Figure 9. Company A: Water-table contours and groundwater flow lines.

New bores were drilled subsequently directly downgradient of the lagoons, and they delineated a strong pollution plume moving in a southeasterly direction. In consequence, the company is now required to review and improve its disposal system to meet the conditions set out in the licence.

The second example is that of a large woolscouring business (company B) producing a considerable volume of effluent with high values for nitrogen, phosphorous, and BOD_5 (5-day biochemical oxygen demand). This disposal system consists of a number of lagoons, and is considerably larger than some of the municipal liquid-disposal sites.

The hydrogeological investigation resulted in the determination of a water-table contour plan which showed a groundwater mound, with increased flow rates towards some farmlets and towards a nearby lake. The investigation revealed also that there were already several monitoring bores nearby, drilled and sampled in 1973. Strong groundwater pollution was detected even then, but for some unknown reason, monitoring was discontinued.

Recommendations in this case are to resume monitoring of the existing bores, to improve the monitoring system with additional bores farther downgradient, and, if possible, to improve the quality of the effluent. The nearby lake is certainly in danger of eutrophication by the strong nutrient input, and some action is required in this respect.

The third example concerns a chemical factory (company C) which produces, among other things, herbicides. The effluent, which until recently was mixed with process cooling water, and then discharged into a soak pit, contains high amounts of phenols, 2,4-D, and 2,4,5-T.

The geological sequence in this area consists of Safety Bay Sand separated from the underlying sandy Tamala Limestone by a thin layer with high silt and clay content, which largely inhibits downward percolation.

The hydrogeological investigation revealed that the large amount of combined effluent and cooling water had produced a marked groundwater mound with elevations of up to 2 m above the regional water-table. This localized elevation of groundwater created greatly increased flow rates radially away from the site, until the regional gentle flow to the west prevails again, as shown on Figure 10. The existence of the mound requires a monitoring network which ideally covers the disposal area on all sides, and preferably at various distances.

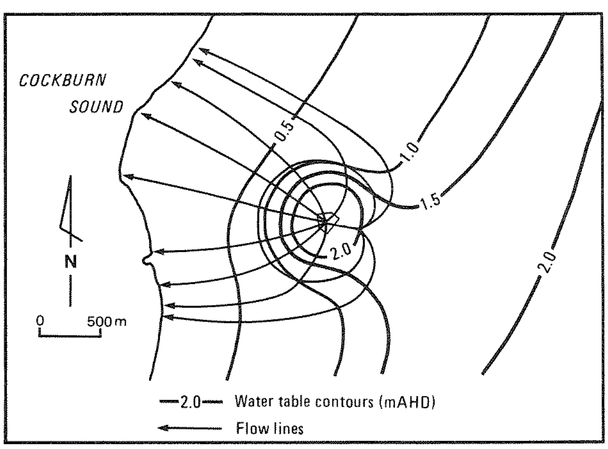

Figure 10. Company C: Water-table contours and groundwater flow lines.

A reasonably adequate bore network has now been completed, and the results of analysis are as expected—high to very high pollution levels in practically all bores. One bore, in fact, shows concentrations several times higher than the present neat effluent, indicating that the effluent was much stronger some years ago. Although the disposal system is no longer in use, monitoring will have to continue for years to come.

The results of the hydrogeological and hydrochemical investigations led to stringent measures being imposed on this company's effluent disposal.

GENERAL RESULTS OF INVESTIGATIONS

One of the aims of these hydrogeological and hydrochemical investigations has been to delineate the pollution plumes, and to predict their migration and decline in pollutant concentrations with time.

With a detailed water-table contour plan and the knowledge of the basic hydrogeological parameters, the direction and rate of flow can be ascertained with a fair degree of accuracy. This was done in the case of the last example, as it was thought important to know when the pollution plume would arrive at the discharge zone.

The calculations suggest a first arrival of the pollution plume at the discharge zone, along the shortest flow lines, in about 70 years, and progressively later along the longer flow paths. The expected maximum width of the pollution plume is also marked on Figure 10.

CONCLUSIONS

Although the few examples given above are by no means comprehensive, they help to show that liquid-waste disposal practice in the Perth area cannot be considered to have been very satisfactory. Disposal at municipal sites has greatly improved in the recent past; however, the disposal of industrial liquid waste still leaves a lot to be desired.

The Bassendean Sand and the Tamala Limestone must be considered unsuitable for safe disposal of liquid waste. This is because the retention times in the clean Bassendean Sand, and in the cavernous Tamala Limestone, are often too short for good biological degradation in the unsaturated zone above the water-table. In addition, the adsorptive capacities of both formations are generally too low for sufficient removal of chemical pollutants. Unfortunately, these formations cover a large part of the Perth region, and relocation of all industries concerned will not be possible. This means that improved treatment and disposal methods are the only means of reducing the pollution threat to our groundwater. First steps are being taken, as outlined above, by the requirement of licensing with more stringent licence conditions and monitoring requirements.

Hydrogeological and hydrochemical investigations are being done nowadays as a matter of course before a licence is issued, and their importance in this context has been demonstrated. Perth is lucky enough to have large usable groundwater resources, and it is certainly worth every effort to maintain this resource for the future. The legal framework exists already, however, stricter application and a more determined approval appear desirable.

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