AGSO Journal of Australian Geology & Geophysics, 14 (2/3), 201–206

Groundwater resource management and community consultation — Blue Lake, South Australia

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The Blue Lake is a high value groundwater resource in a high risk environment. The lake has several beneficial uses. It is a water supply for the City of Mount Gambier. It is the premier tourist attraction for the City, because of its picturesque setting within a volcanic crater and its habit of changing colour from a steel grey-green in winter to an intense blue in summer. The lake also supports a considerable diversity of aquatic life, although individual numbers of any species are not abundant.

The City of Mount Gambier is located on the northern flank of the volcanic complex. The complex occurs within an unconfined karstic limestone aquifer, and the lake is a window into the groundwater. Historical waste disposal practices have caused a number of point-source pollution plumes within the unconfined aquifer. Sewage and septic tank effluent routinely reached the aquifer before a sewerage system was installed in the mid 1960's. The effluent has polluted the groundwater beneath the city with nitrate. Regional hydraulic gradients show that the city is located immediately upgradient of the lake. Nitrogen levels in the lake have climbed to around 3.6 mg/L. There appears to be a relationship between extraction rate from the lake and nitrogen levels in the lake. Other pollutants are not evident in the lake.

The Engineering and Water Supply Department are developing a Management Plan for the Blue Lake and the surrounding groundwaters. This Plan is being developed with the assistance of a small group from the community and with a broader community consultation program, with several benefits. These include community education about the issues and community ownership of the solutions.

Background

Blue Lake

Blue Lake, together with other lakes, is located within a complex of volcanic craters in the southeast corner of South Australia (Fig. 1). The lake has several beneficial uses. It is a water supply for the City of Mount Gambier; some 4000 ML are pumped from the lake each year (Fig. 2). It is the premier tourist attraction for the City, principally due to its unique habit of changing colour from a steel grey-green in winter to an intense blue in summer. It is also picturesque, being contained in a volcanic crater within a volcanic complex. The lake supports a considerable diversity of aquatic life, although numbers of individual species are not abundant (Allison & Harvey, 1983).

Blue Lake has a surface area of about 60 ha, reaches a depth of 77 m and contains about 37 000 ML of good quality groundwater (Tamuly, 1969). The lake has virtually no catchment, and is recharged principally with groundwater. Rainfall adds only about 1% of the total volume per year, and evaporation consumes about 2% of the total volume. EWS pumps around 4000 ML per annum from the lake to supply around 23 000 people within the City of Mount Gambier and adjacent rural areas. Groundwater inflow approximately equals extraction (Turner 1979; Ramamurthy, 1983), and there is no longer significant throughflow as once was the case.

Hydrogeology

The Blue Lake is located within the Gambier Basin. Hydrogeologically, the area is dominated by an unconfined aquifer developed in the Oligocene–Miocene Gambier Limestone. A confined aquifer occurs within the underlying Eocene Dilwyn Formation. The Gambier Limestone sediments range from richly fossiliferous calcirudites, through calcarenites, and calcisiltites to glauconitic marls (Waterhouse, 1977). The Dilwyn Formation consists of interbedded sandstones and carbonaceous claystones. The groundwater salinity in the Gambier Limestone aquifer ranges between 300 and 600 mg/L TDS. The Dilwyn Formation groundwater is slightly more saline, ranging between 500 and 670 mg/L TDS (Lawson & others, 1993).

The topography of the area is subdued. The depth to water table ranges from zero in the recharge area to 35 m beneath rare topographic highs. Despite a rainfall of between 700–800 mm/annum, there is no natural surface drainage network. Karst features are common.

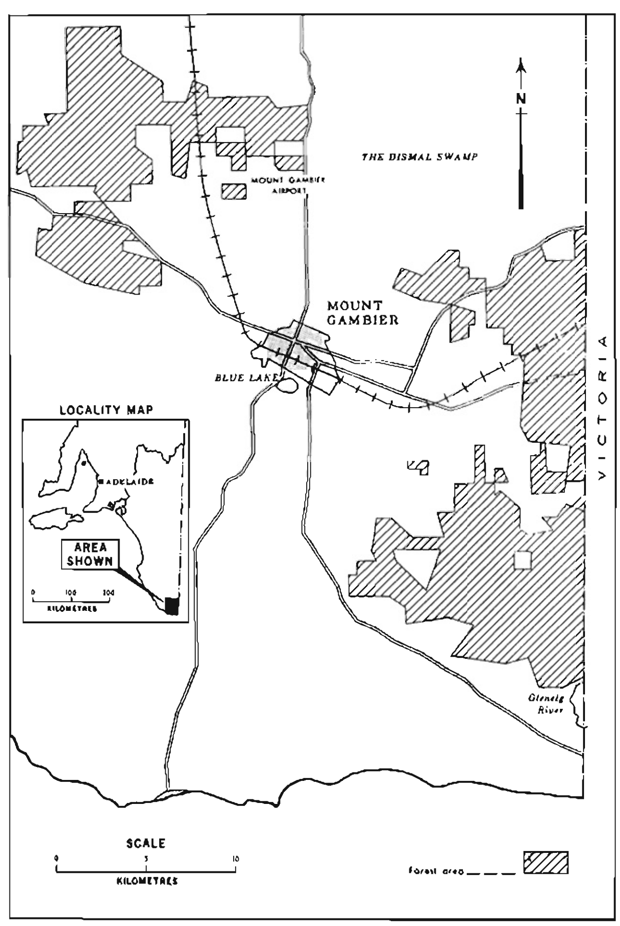

Figure 1. Locality plan (adapted from Waterhouse, 1977).

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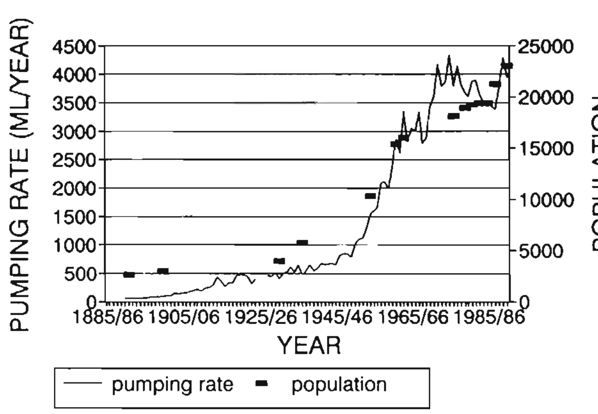

Figure 2. Blue Lake pumping and Mount Gambier population.

Groundwater recharge to the Gambier Limestone occurs throughout the area. However, a principle recharge zone (Fig. 3) for both the Gambier Limestone and the Dilwyn Formation aquifers occurs in the Dismal Swamp area (Love, 1992). Groundwater flows south from the recharge zone to the coast. The groundwater flow between the recharge zone and the coast can be divided into three zones: a flat gradient zone occurs in the vicinity of the lake (hydraulic gradient $i \approx 0.00014$); a steep gradient zone intervenes between the recharge zone and the flat gradient zone ($i \approx 0.0066$); and a zone of moderate gradient stretches from the flat gradient zone to the coast ($i \approx 0.00085$).

Numerical modelling of the area by the author using MODFLOW (McDonald & Harbaugh, 1988) achieved a reasonable steady state calibration. The model indicates that the transmissivity of the Gambier Limestone in the steep gradient zone is around 300 m^2/day, which is consistent with values measured here (Lawson & others, 1993) and for its northern equivalent the Murray Group Limestone (e.g. Telfer & Watkins, 1990; Clarke, 1992). This value represents the primary permeability of the limestone. The aquifer thins significantly northwest and west of Mount Gambier, and therefore the steep gradient zone is developed in that area to a greater extent than to the southeast (Lawson & others, 1993).

The flat gradient zone has a modelled average transmissivity of around 20000 m^2/day. This high value appears to be due principally to the development of extensive interconnected karst, although the primary permeability may also be slightly elevated. The interconnected karst around the volcanic complex appears to be due to the combination of vertical and horizontal karst systems. The vertical karst seems to have developed in a northwest–southeast direction. This is parallel to the structural fabric of the region. The volcanic vent probably coincides with deep-seated structural weaknesses, and repeated episodes of basement and cover rock faulting will have stressed the aquifer in the vicinity of the lake. The vertical karst seems to have developed along these stress planes. The horizontal karst would have developed at various depths throughout the aquifer as mixing corrosion at the water table (Jennings, 1985) occurred at various elevations in response to major glacial–interglacial sealevel fluctuations. The absence of surface drainage predicates numerous disguised subsurface karst features.

The model calibrates with the aquitard between the unconfined and confined aquifers having a hydraulic resistance (=D'/k') of $\approx 10^6$ days. This means that interaquifer leakage is minimal.

Land use and potential polluting activities

The City is located on the northern flank of the volcanic complex, and the southern flank has been used for decades for horticulture. The city is surrounded by grazing land and farther afield by extensive plantings of *Pinus radiata*. The city, therefore, is a service centre to agriculture and forestry. A number of timber milling operations, including timber preservation and particle board manufacturing, are located within a few kilometres of the lake on its northern side. Numerous small cheese factories were in existence earlier this century. A few larger operations continue, and the rest closed in recent decades. Some have been reincarnated as slaughter houses.

Groundwater pollution

The karst features of the unconfined aquifer have historically been a convenient solution to waste disposal problems. In fact, several cheese factories were located specifically to take advantage of them. They have been the commodious recipient of urban stormwater drainage, sewage and septic tank effluent beneath urban areas; whey at cheese factories and blood, etc., at slaughter houses; and industrial chemicals at the wood treatment and other industrial facilities. These practices ceased in 1976 after

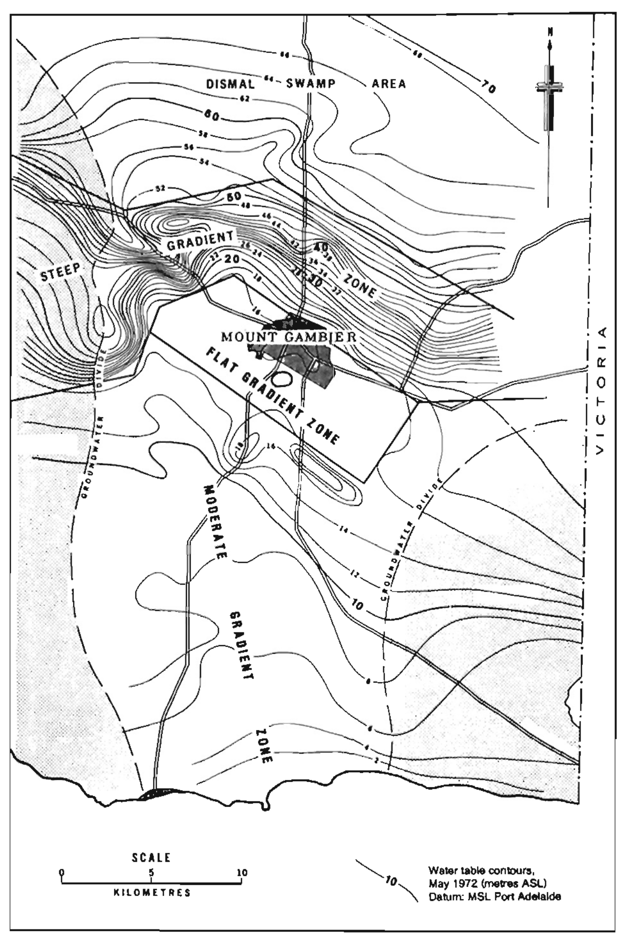

Figure 3. Water table contours (adapted from Waterhouse, 1977).

introduction of the Water Resources Act, and significant improvements in waste disposal practices have been made in the last two decades.

Past practices have, however, left a legacy of pollution within the aquifer. The largest point-source pollution plume emanates from whey disposal at a cheese factory. The plume of whey is approximately 1.5 km long and 1 km wide. Other point-source groundwater pollution incidents are known to include creosote, pentachlorophenol, copper–chrome–arsenic mixtures, organic compounds from timber wastes, and hydrocarbons.

The City was unsewered prior to the mid 1960's. Nitrates, derived from septic tank drainage and the disposal of sewage direct to karst features, has polluted the upper part of the unconfined aquifer (Waterhouse, 1977). Nitrate is still being added to the groundwater at high rates from diffuse sources, namely grazing (Dillon, 1989) and urban fertiliser applications (Gerritse & others, 1990). Nitrogen levels in Blue Lake are currently around 3.6 mg/L, having risen from around 2.6 mg/L in the early 1970s (Fig. 4). This rise may be related to pumping rate (note similarity of Figs 2 and 4). Nitrate pollution has the potential to adversely affect the long-term viability of the lake as a water supply, and the author is developing an analytical model to examine the effect of various management scenarios on nitrogen levels in the lake.

Stormwater disposal is a potential groundwater pollution process. Stormwater drains down several hundred drainage bores completed into the Gambier Limestone within the urban area. Emmett (1985) surveyed stormwater quality draining into six drainage bores and a large karst feature. That survey showed that most pollutants were at low levels in the stormwater, although some stormwater was unpotable because of high lead, herbicide and pesticide concentrations. the conclusion of the report is that the stormwater is probably having a beneficial effect on the aquifer. The author has since conducted a survey of groundwater quality in about 40 production and observation bores within 2.5 km of the lake. The sampling locations avoided known pollution plumes. The results of the survey generally support Emmett's findings.

Despite the relatively clean bill of health for the stormwater, the drainage bores remain a significant pathway for the direct entry of pollutants to the aquifer. Drainage bores in industrial areas potentially pose a higher risk to the aquifer than roadside stormwater drainage bores. Such bores are mostly equipped with silt traps; however, these are not cleaned to remove detritus and their effectiveness in retarding soil and rubbish therefore diminishes.

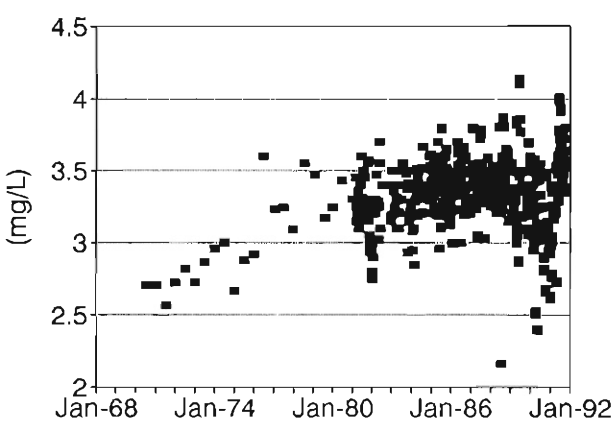

Figure 4. Nitrogen in Blue Lake water supply.

The disposal of stormwater into the aquifer is affecting the water quality of the lake. Emmett (1985) calculated that the mean salinity of the water recharging the aquifer was 64 mg/L. The groundwater has a salinity of around 500 mg/L. Trends in Na and Cl in the lake show a decline of around 10% over the last quarter century (Fig. 5).

The other major ions are relatively unchanged, which is not surprising given that they are mainly aquifer dissolution products. The salinity decline is, therefore, presumably due to an increasing influence of low NaCl stormwater in groundwater recharge to the lake. The total nitrogen in stormwater averages 3.2 mg/L (Emmett, 1985), although most of this is as Total Kjeldahl Nitrogen. The low-nitrogen stormwater may be diluting the high-nitrogen groundwater in the upper parts of the aquifer.

Tourism

Tourism is a major industry in Mount Gambier. The lakes complex, of which the Blue Lake is the most important feature, is Mount Gambier's major tourism asset. Tourism generates about 20% of the GDP of Mount Gambier, with a value to the community of about $75 million (personal communication, Barry Wilkins, TAFE Mount Gambier, 1993).

Although much of the appeal of Blue Lake is that it changes colour, the colour change mechanism is poorly understood. Several hypotheses have been proposed. These include the presence, in summer, of concentrations of naturally fluorescing substances, and of blue microorganisms. The colour change has also been linked to the presence of calcite crystals in the water during summer. None of these hypotheses, however, provide a robust explanation. The author is researching the problem, and the Management Plan will not neglect the impact of development on the aesthetic appeal of Blue Lake.

Community consultation in the development of a management plan — a case study

History of groundwater and lake management

There is currently no formal Management Plan for the Blue Lake and the surrounding groundwaters. That is not to say that the management is not being addressed through less formal mechanisms.

The Committee on Water Pollution Control in the southeast (EWS, 1973) recommended, with regard to Mount Gambier and environs, that;

- the City of Mount Gambier be proclaimed as a defined area under the Underground Waters Preservation Act 1969–70,
- the below ground disposal of trade wastes be phased out by the end of 1977,
- wastes being disposed below ground be given treatment, to meet approved quality standards,

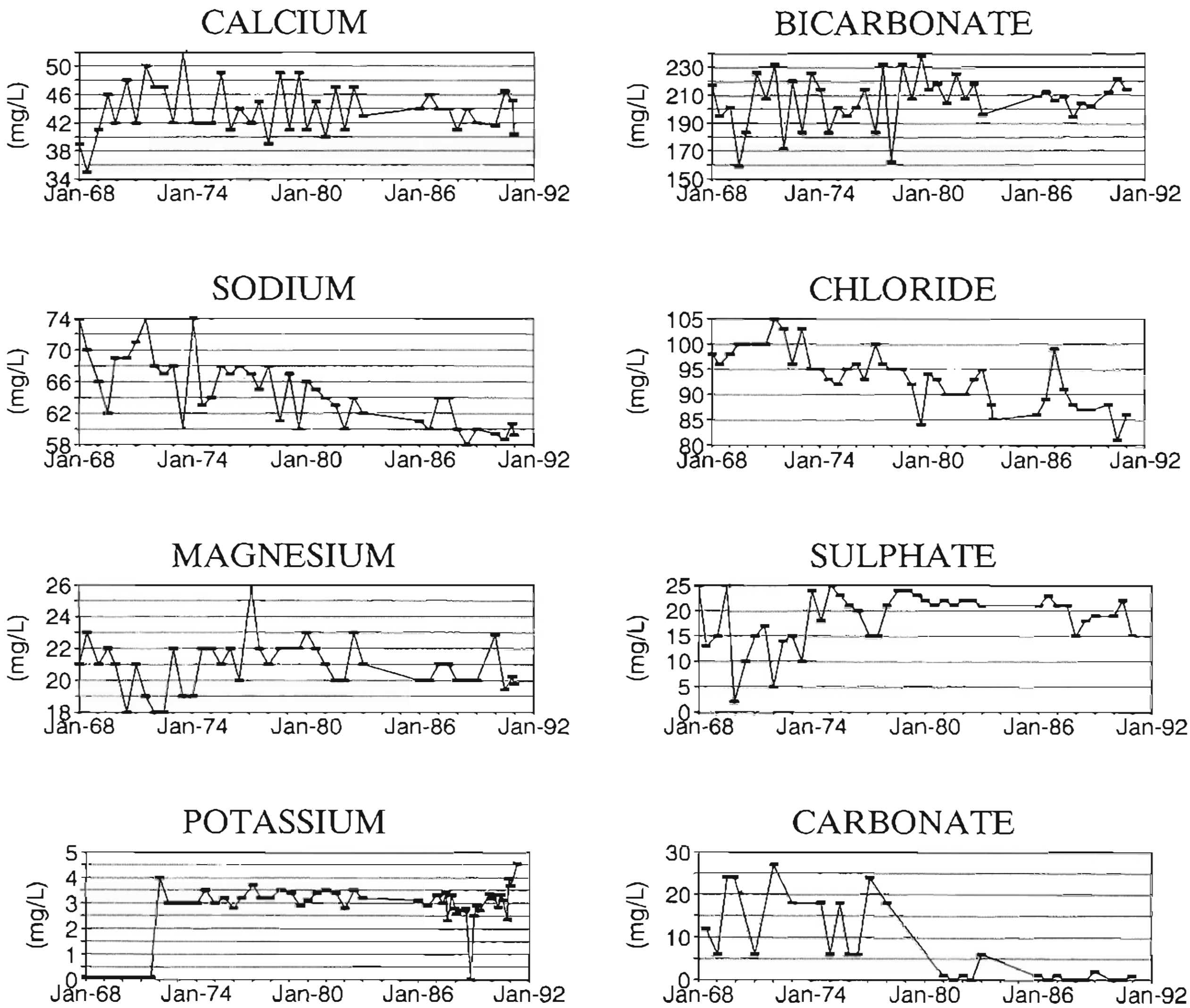

Figure 5. Trends in major ions in Blue Lake water supply.

- the rate of sewage connections be increased, and
- EWS maintain effective communication with primary producers and industry management on matters which may affect groundwater quality.

Many of these recommendations have been acted upon in the following decades.

EWS, SADME and CSIRO have been investigating various aspects of the hydrogeology and limnology of the lake ever since. The investigations continually provided insights into various processes, and the regional offices of both EWS and SADME incorporate the results into their day-to-day management of the resource. Formal management recommendations have lagged behind these investigations, although various reviews of the water resource (Waterhouse, 1977; Barrett, 1977; EWS, 1984; AG Consulting Group, 1991) have addressed water quality issues in and around Mount Gambier.

In the last two decades, there have been significant improvements in water resource management. Industry now separates trade wastes from stormwater, unsewered properties number less than 100, and emergency water supply bores have been completed within the confined Dilwyn Formation aquifer.

In summary, there is a legacy of groundwater pollution in the aquifer. Apart from increasing levels of nitrogen, the lake shows no adverse trends in water quality. The extent of ongoing groundwater pollution has been reduced to a significant extent. It is probable that dilution of existing point source groundwater pollution will render most plumes undetectable in the lake. Management of the resource can then be essentially proactive.

The need for a Management Plan

The author has been reviewing the hydrogeology of the Mount Gambier area since mid-1991, and is preparing a Management Plan for Blue Lake. It became clear during the review that management of the groundwater resource lagged behind the understanding of the groundwater processes. That is not to say that all the processes influencing water resource management were well understood. However, significant improvements to the management of the resource could be made with the help of the available information.

Community consultation has been used successfully within EWS for a number of years. The department's approach to the resolution of water resource management problems is to involve the community, and to develop community ownership of the problems. This approach has seen the development of a number of Water Resources Committees to assist in the management of areas in which water resource issues arise. The Lower South East Water Resources Committee (LSEWRC) has both private and government representatives, and assists the department in the formulation and administration of water resource management policy.

Community consultation, both through the LSEWRC and a broader public consultation process, will provide valuable input to the Management Plan. In particular, value judgements are needed in arriving at solutions to some of the issues arising from the objectives of the plan. Since the value judgements are going to impact on the community, the consultation process enables the judgements to be influenced by them. Their involvement means that the Management Plan can be implemented with a minimum of resistance from the community, because they have been involved in its development.

Aim and objectives of the proposed Management Plan

The following aim for the Management Plan was agreed upon before the community consultation process commenced. The aim recognises the many functions of the lake:

The Blue Lake Management Plan will provide guidelines for maintaining the water quality, the unique colour change of the lake, the tourism value and the environmental significance of the Blue Lake water.

There are four objectives for the Plan. These are:

- stop pollution entering the lake,
- stop existing groundwater pollution entering the lake,
- stop further groundwater pollution occurring, and
- identify alternative water supplies in case Blue Lake can not be used.

Development of the Management Plan through community consultation

The Management Plan is being prepared in three phases, each of which involve community consultation. The consultation program was developed with the assistance of a consultant experienced with water resource issues and community consultation.

The first phase of the consultation culminated in a community workshop. The author developed an information package prior to the workshop. The package contained information on the community consultation process, an outline of the problem, the aims and objectives, simplified technical information, and a summary of the issues and possible solutions to the issues. EWS also provided several releases to the local media, and articles were run in the local paper. The author also conducted a number of radio and television interviews.

The information package (called Blue Lake Water) was mailed directly to approximately 80 people who had been identified as having an interest in the management issues. Another 80 were distributed through local business houses and local council offices.

The workshop had 40 attendees, and the following format was found to work well. The first 30 minutes were taken up with a problem summary and an explanation of the workshop agenda. Six predetermined groups, each with a trained facilitator, sat down and listed the issues which were of importance in the development of the Management Plan. These were then prioritised. After a break, each group addressed the high priority issues and proposed solutions for them. The issues and solutions were summarised by each group and presented to the entire gathering. Informal discussion followed over a light supper. The information package and workshop results are reported in Telfer (this special issue).

Following the workshop, each groups' lists of issues and solutions were typed up. The major issues were tabulated, as were all the issues raised. The tables and the group lists were compiled and posted to the participants within nine days of the workshop.

Results of the workshop

The workshop participants mostly came from industry, local and State government. The range of management issues developed in the workshop were very similar to those that EWS had considered. This is encouraging, given the level of industry representation and the paucity of "concerned citizens" at the workshop.

The workshop identified that a high priority issue is community education on water resource issues. Of interest is the recognition that the prevention of further groundwater pollution is important. On the subject of groundwater cleanup, two of the groups identified a polluter pays approach to remediation.

Preparation of the Draft Management Plan

Following the success of the workshop, a small group has been formed to take the development of the Management Plan through to a draft plan stage. The group has representatives from local government, industry, small industry, tourism and environmental groups, as well as EWS and SADME resource people.

That group has a tight schedule to meet, because the Plan needs to be available to the community within a short time to capitalise on the community education started by the consultation process. The group is aware that the Management Plan has to be developed with the available information. The group has decided that they want to work from a draft of the plan, rather than build the plan from scratch. There also needs to be a transfer of information from the resource people to the group.

The principle issues, which the group are being asked to consider, are:

- how to amend the Development Plans of the City and District Councils, so that water resource management issues are a high priority in land use zoning and in the consideration of development applications;
- how to address existing pollution plumes (i.e. what to do with them, who does it, who pays for it, when does it need to be done); and
- how best to disseminate information on water resource

issues to the community.

These issues involve subjective judgement and will impact on local government (regarding planning issues) and industry (regarding pollution plume assessment/remediation). EWS aim to preserve a high-value water resource, and the most effective way to do this is to develop pragmatic management plans with the cooperation of those who are affected by its management.

The draft Management Plan should be acceptable to the community, as the straightforward issues have been addressed by the workshop participants, and the more difficult issues dealt with in detail by a group representative of the main stakeholders.

Conclusions

The limnology of Blue Lake and the hydrogeology of the surrounding aquifers is a fascinating and complex example of groundwater–surface water interaction. Thus, the development of the City of Mount Gambier on the flanks of the volcanic complex housing Blue Lake has led to a complicated water resource management problem.

Considerable information has been collected on individual aspects of the limnology, hydrogeology, and resource management issues. These results are being collated. A Management Plan for the Blue Lake and surrounding groundwaters is being developed.

The Management Plan is being developed using a community consultation process. This has the dual benefits of raising public awareness of the water resource management issues, and allowing the community to contribute to and develop ownership of the directions set by the Management Plan.

Acknowledgements

Drs. D.I. Smith (ANU) and C. Otto (CSIRO) have reviewed this paper; the author thanks them for their helpful comments.

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