EXECUTIVE SUMMARY

I INTRODUCTION

The Department of Water Affairs & Forestry have for many years been gathering groundwater quality data from around the country as part of ad-hoc groundwater resource investigations. However, little examination of the data has taken place, except for that depicted on the recently published Map of Groundwater Resources of South Africa (Vegter, 1995). The data gathering has intensified over the past few years as a result of the regional groundwater mapping programme and the establishment of a national groundwater quality monitoring network.

Additional value has to be added to data stored in databases. The differentiation between man-made and natural impacts on groundwater quality will in future have to be clarified. The benefitiation of the data and its presentation in the form of a groundwater quality atlas may affect various sectors thus enabling them to efficiently plan their activities as well as address important issues from a national health and environmental point of view. Water quality information is essential in the planning and management of groundwater resources – the results of this project will consequently provide valuable data for the Department of Water Affairs & Forestry's community water supply initiative.

II AIM AND OBJECTIVES

The purpose of this project was to provide intitial steps towards the national groundwater quality assessment and to update the knowledge on groundwater quality nationwide.

The research objectives for the project were defined as follows:

1. Re-evaluate the existing groundwater quality database both in terms of the availability of data and its structure

2. Outline a framework for an evaluation system to identify hydrochemical properties of groundwater resources at a national scale
3. Map and define spatial features of major hydrochemical parameters
4. Define the temporal component of groundwater chemistry
5. Identify main factors and issues that affect or indicate groundwater conditions and trends
6. Identify gaps in data collection and evaluation activities and provide recommendations to overcome these deficiencies

The main thrust of this project was to create the atlas of groundwater quality, not least as an extension of the first national hydrogeological undertaking – the map of groundwater resources (Vegter & others, 1995). By generating the atlas of groundwater quality, the visual information is created that is not apparent otherwise. The interpretation of the extracted information and seeking potential correlation with environmental and cultural factors would be the next natural step in expanding the national groundwater quality assessment project.

III APPROACH

The water quality database of the Department of Water Affairs & Forestry, QualDB, as the wealthiest source of the groundwater-quality data was utilized in this project. It contains over 55000 groundwater analyses (as of 1997), which are attributable to approximately 35000 boreholes. The distribution of points is very uneven reflecting different and isolated objectives of data-collection programmes. The analyses are comprised of major ions and a limited positional and sampling procedure data. Trace elements and organic data are rare and do not warrant an evaluation at a national scale.

The positional accuracy is uncertain although sample coordinates are mandatory. At a national scale however, the sample position accuracy is regarded as acceptable having in mind that broad regional trends are evaluated.

The probabilistic approach to the groundwater-quality assessment was chosen. This was done to overcome ambiguities from uneven data distribution and from inability to determine and separate the temporal components. A discretization approach was employed whereby the country was subdivided into units being a subpopulation of the lithological units. These units were identical to those utilized for the national hydrogeological map (Vegter, 1995). The data geographically attributed to a unit were aggregated using their log-transformed values and calculating basic statistical parameters. Each area unit was assigned a unique set of statistical values per each evaluated hydrochemical parameter. The units with similar statistical parameters were grouped using a classification scheme based on drinking water guidelines and mapped at the national scale using thematic mapping features of the Mapinfo GIS.

The probabilistic approach was given preference to contouring approaches derived from e.g. kriging, because the available dataset does not effectively allow for their nationwide application.

IV RESULTS

A set of maps at scale 1:10,000,000 was compiled using Access97 generated statistical summaries and Mapinfo GIS. All major water quality variables were mapped nationwide and are available on the CDROM attached to the report. The maps are in Adobe PDF format, which is widely used, cross-platform, with freely available viewer. The statistical summaries and maps are also available as Excel97 tables and Mapinfo formatted layers.

Although small-scale variations may be of importance for a local development of groundwater resources, the emphasis was placed on mapping broad, large-scale trends in groundwater quality.

IV.1 DATA QUALITY

Sets of maps were developed to depict the data itself, major groundwater quality parameters, a number of index parameters and derived maps. It is important to understand the quality of evaluated dataset and therefore the following maps were produced:

- Distribution of sampled sites countrywide
- Sampled site count per region
- Sample density expressed as km^2 per sample
- Sample cover for different time periods (pre-1970, 1970-1980, 1980-1990, 1990-1997)
- Sample ion balance error in three classes: more than 5%, more than 10% and more than 30%.

IV.2 MAJOR GROUNDWATER QUALITY PARAMETERS

The groundwater quality maps depict all major groundwater quality parameters as well as several derived and index parameters. All major ions were mapped nationwide.

These include calcium, magnesium, sodium, potassium, alkalinity, sulphate, chloride, nitrate nitrogen and fluoride. In addition, silica was also mapped.

IV.3 INDEX PARAMETERS

In addition to major ions other derived and index parameters include the following:

- Carbon dioxide activity expressed as log pCO_2 – to give an impression on how the carbonic acid may contribute to solute-forming processes in South African aquifers
- Chloro-alkaline distribution index (CAD) – to illustrate the dynamics of ion-exchange processes
- Saturation indices (calcite, dolomite, quartz)
- Total dissolved solids (TDS), TDS/EC correlation, TDS outliers (upper)

IV.4 HYDROCHEMICAL CLASSIFICATION

Piper diagram was considered as a classification system due to its wide use within the groundwater community. Four classes forming quadrangles of the Piper diagram were mapped as follows:

- (Ca, Mg) (HCO_3)
- (Na, K) (HCO_3)
- (Ca, Mg) (SO_4, Cl)
- (Na, K) (SO_4, Cl)

The presence of individual types was mapped as a fraction of total samples, worked out in per cent. The information can thus determine what is the probability of obtaining a hydrochemical type of concern for any region.

IV.5 DRINKING QUALITY PROSPECTS

A set of maps was generated to show compliance of groundwater for drinking water purpose. The classification was based on major ions, other parameters such as minor elements or bacteriological quality was not taken into account.

- Total hardness – to summarize the technological parameters of groundwater in various areas of the Republic
- Drinking water compliance – based on concentration of major ions
- Drinking water prospects – the probability of striking water of either drinking or acceptable water quality
- National monitoring results – selected representative results to illustrate the performance of national monitoring so far

IV.6 CAUTIONARY NOTES FOR DATA INTERPRETATION

Unstable parameters such as pH were mapped using the analytic value determined in the lab. This may differ from the in-situ conditions and therefore the results should be taken with caution. The same applies to alkalinity as it is the parameter closely associated with pH.

Several other ions may be affected by the standing time between sampling and the analysis. Large number of analyses have had their standing times in excess of three months. The redox sensitive parameters such as nitrate and sulphate may undergo significant changes during standing times, quite often mediated by bacterial activity.

No consideration was given to vertical variation of groundwater within the borehole – the available dataset does not really allow for such an examination. At a site-specific scale it may be of importance to examine vertical variations of groundwater quality when installing a groundwater abstraction system.

The data records do not reflect a snapshot of a single representative period. All available data had to be used in order to obtain acceptable coverage of the studied area. The temporal changes in groundwater quality could thus not be screened out in any acceptable way and units are compared using data records from different time periods. Most records fall into the 1970-1997 period, though. To visualize the spatial distribution of time intervals used for characterization of groundwater-quality trends a map was compiled. The map shows proportion of data records for the period 1990-1997 out of the total record count.

IV.7 TEMPORAL CONSIDERATIONS

Due to lack of historic long-term monitoring attempts very little exists to define and separate temporal components from spatial variations. An example from Springbok Flats is used to demonstrate the temporal variations in groundwater quality due to natural causes such as recharge. National groundwater-quality monitoring initiative is discussed and broadly evaluated as a means to obtain the information necessary to extract the temporal components nationwide.

The preliminary results were obtained from the national groundwater-quality monitoring, but the relatively short lifespan of national monitoring prevents from making authoritative statements as yet. Recommendations were made to adjust the network design to reflect manpower and budgetary constraints.

The factors contributing to groundwater quality are evaluated only from a broad angle. Much more work will be required to exactly identify and quantify impact of main factors. For example, rainfall seems to be a main controlling factor often overriding lithological controls. Another example, closely associated with the rainfall distribution is the availability of carbon dioxide, which is the main agent in hydrochemical dissolution of aquifer materials. The attribution of factors to groundwater chemistry should be the main thrust of the interpretive reporting that should follow this report.

Two fundamental activities have been discussed in this regard – the on-going data-collection as a product of the regional characterization and national groundwater-quality monitoring. While the former will in time fill in the gaps in the spatial distribution, the latter aims to cover the temporal dimension.

Other parameters have to be included into routine analyses such as more routine field measurements and redox indicators such as iron and manganese. Little is known about trace elements and organics, this should warrant focused initiatives to obtain the information on ambient levels of trace elements.

The more structured approach to bridging the gap in data-collection and evaluation activities is discussed in the section on reporting formats.

V RECOMMENDATIONS

The wealth of information transformed in the visual format will undoubtedly trigger other research initiatives. As this phase can be characterized as largely descriptive, the emphasis should be placed on the interpretation of the results achieved in this report.

For the first time the distribution of a number of hydrochemical parameters is presented nationwide. It will be necessary to try and distinguish the reasons for the spatial and temporal distribution of a number of parameters and try to use this knowledge in managing the water resources.

It will also be necessary to strengthen the link between two groundwater-data databases, the NGDB and QualDB. There is also a need for including other parameters into routine sampling such as iron and manganese. The field measurements of unstable parameters such as pH and alkalinity must be made more routinely and stored on the database.

The assessment of groundwater quality should be seen in broader hydrological perspective and the interaction between different parts of the hydrological cycle can be used to benefit of all hydrological agents and impactors.

The natural next phase will be to try and define or quantify existing causative relationships between groundwater quality and environmental factors. The description of major lithological units together with more detailed analysis of these units is recommended as the next step in the groundwater quality assessment programme.

The national monitoring programme, once fully implemented, will have to evaluated in terms of its representativeness and cost benefit analysis. This can be done by a more rigorous development of the reporting formats that should ideally streamline the flow of the groundwater-quality information. This can be done however only when statistically viable observation dataset is available, so it would be ideal to couple the monitoring analysis with lithological unit analysis.

Due to low pace of the implementation of national monitoring it is recommended that few adjustments be made to the monitoring strategy:

- Adopt a multi-tier strategy. The monitoring network will consist of several subnetworks with different frequencies and variable scopes. There is a potential for a scaled-down reference network, which will be sampled most often. The size of this network should not exceed 100 sites. The full network will be identical with the present design (once fully implemented) and may be sampled less frequently (every 1 or 2 years). Special networks will be designed to study certain groundwater quality phenomena or problem and will be more or less research-related.
- Adopt a cluster strategy. A sampling site may consist of more than one borehole. This is to avoid sampling failures when existing boreholes become unavailable. This however implies that a clear correlation must exist between boreholes forming a cluster.

- Re-evaluate the network design using spatial analysis available in this report. This is important from the representativeness point of view. Before the network was implemented no background information was readily available. The maps and statistical summaries generated by this study may be used to improve the network design and make it more representative.

VI REFERENCES

Vegter JR, 1995: GROUNDWATER RESOURCES OF SOUTH AFRICA. *Two map sheets and explanatory brochure, Water Research Commission project TT74/95, Pretoria*