HYDROGEOLOGICAL ASSESSMENT OF SOEKOR WELL SA 1/66 AND CONCEPTUALISATION OF THE ASSOCIATED GROUNDWATER FLOW REGIME

1. INTRODUCTION

The following assessment is based on the attached locality map, conceptual cross-section and simplified log of SA 1/66. The original log was drawn-up by SOEKOR personnel at the time of drilling of the well, the first part of the well being drilled after World War 2 and then between 1966 and 1967, and is also appended. The well is located on the farm Sambokkraal at coordinates 32.65017S and 21.33345E, between the N1 and the Great Escarpment.

2. HYDROLITHOLOGY

SA 1/66 was sited on a local dome structure in the Beaufort Group sediments and is to the south of the southern extent of the Karoo dolerites. It is within the northern extent of the sub-outcrop of the Cape Supergroup, which is at a depth of about 3 600 m at this site. The well was drilled by means of coring and basic details obtained from one of the SOEKOR site technicians is that the diameter of these wells was 120 mm, with 127 mm diameter casing installed to about 1 200 m. The wells were closed by means of a concrete plug from surface to a packer inserted at 30 m.

The key hydrolithological features of the log as attached are:

- A sequence of interbedded shales, sandstones and siltstones of the Lower Beaufort and Ecca groups to 2 700 m after which the potential target shale gas horizons of the Collingham, Whitehill and Prince Albert formations occur;
- Dwyka Group diamictite occurs from 2 950 m to 3 600 m with multiple fracturing recorded and artesian flow of groundwater measured at surface of up to 3.7 L/s (physical and chemical aspects are discussed in the next section);
- Sandstones and shales of the Witteberg Group were then penetrated to the end of the well at 4 175 m, with further groundwater intersections recorded;
- The high level of fracturing recorded in the Dwyka rocks is presumed to be due to proximity to the Cape Fold Belt to the south and the relative competence of the diamictite compared to the overlying Ecca shales.

It is surmised that only water strikes that produced free flowing/artesian water at surface were recorded in the SOEKOR wells because of the core drilling method employed. Only about four of the 24 wells that SOEKOR drilled have any record of groundwater intersections, and these wells are all below the Great Escarpment.

3. HYDROGEOCHEMISTRY

Details on hydrogeochemistry of the groundwater encountered during the drilling are limited to some temperature and Total Dissolved Solids (TDS) measurements. It is not known how the TDS was calculated. The first water strike recorded, at 2 975 m, had a temperature of 65^{o}C and TDS of 6 460 mg/L. A further water strike at 3 206 m had a very high gas content, a TDS of 8 745 mg/L and temperature of 46^{o}C. Multiple fractures are recoded below this depth but there are no more details on temperature or TDS.

A water sample was collected from the well head by Prof. van Tonder in November 2012 and analysed for major ions and trace elements. A further sample was taken in September 2013 and a summary of the results of both analyses are shown in Table 1. The samples were collected from free-flowing water at a valve on the wellhead (the second after 190 minutes of flow) and results may be influenced by stagnation. There is also no way of knowing at this stage whether this water represents the deep water strikes described under the previous section and/or whether there is any influx of groundwater from the shallow aquifer. The water temperature was not recorded at the times of sampling.

Table 1: Chemical Analysis of Two Groundwater Samples from SOEKOR Well SA 1/66

Determinand/ Date	EC mS/m	TDS* (sum)	Na	K	Ca	Mg	Cl	SO_4	Alkalinity (as ?)	Sr	F	B	Br	Si	Fe	Mn
11/12	1182	7181	2612	51	150	1.9	3897	228	229	NA	4.7	18.5	3.7	25	.05	.26
09/13	1202	7032	2584	37	109	7.5	3858	237	224	15.86	NA	23.1	12	34	.08	.04

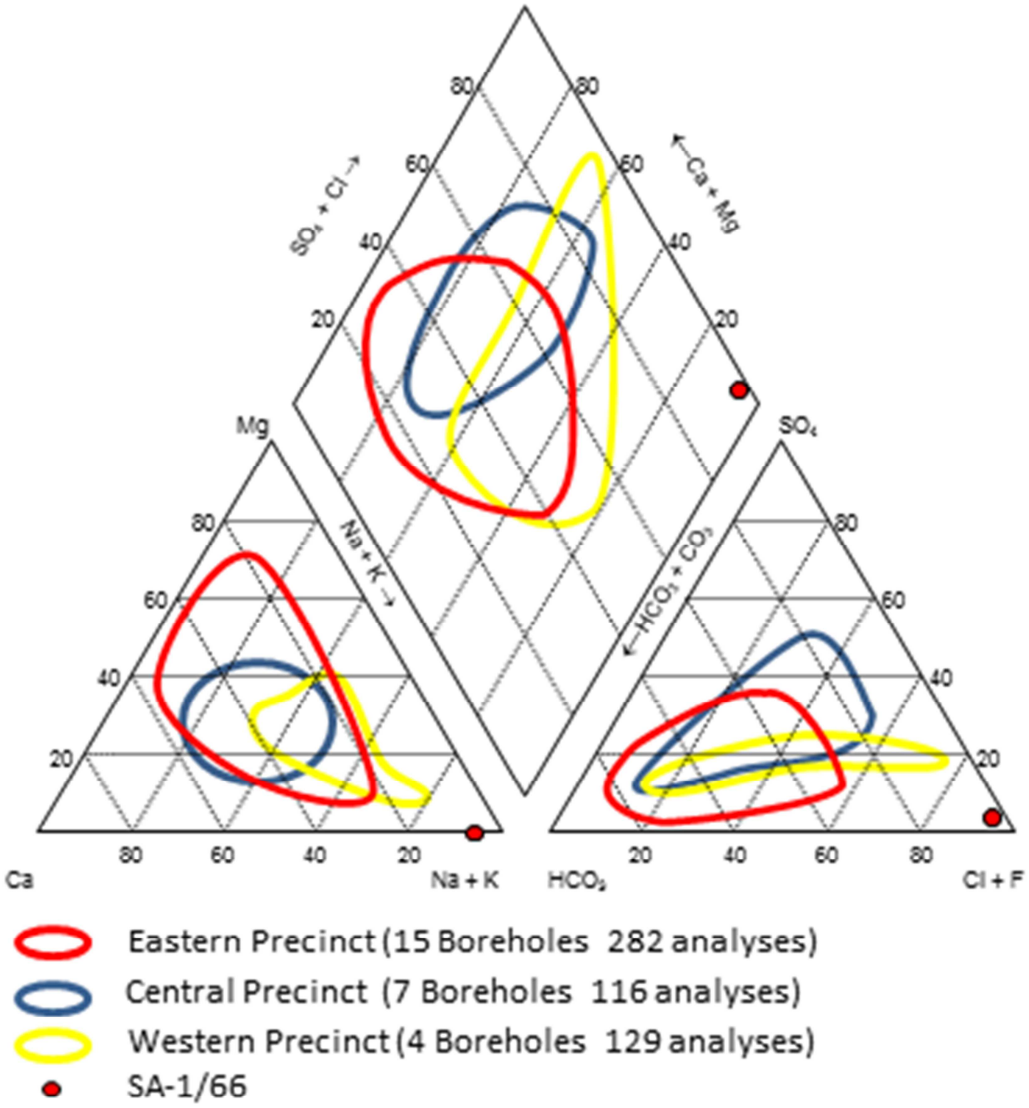
*all values in mg/L except EC; NA not analysed; larger numbers rounded off

The high TDS, Na and Cl are to be expected in deep, probably fairly stagnant/old groundwater and the electrical conductivity (EC) is within the values of the two water strikes recorded at the time of drilling. The high concentrations of B, Br and F may possibly indicate that these ions could be used for 'fingerprinting' deep groundwater in the Karoo. Strontium was analysed for in the September 2013 sample and had a concentration of 15.86 mg/L and perhaps indicates that this ion could be added to the list of possible 'deep' groundwater trace element indicators, i.e. F (also likely to be present in appreciable concentrations in shallow groundwater), Br, B and Sr.

The Piper plot below is of average chemical analyses of CHART boreholes. The main features of the spread of data points are:

- The western area boreholes plot in two distinct groupings;
    - Cl dominant, no dominant cation with TDS values >1 000 mg/L; and
    - HCO_3 dominant , no dominant cation with TDS values <1 000 mg/L;
- The central area boreholes mainly plot in the Ca/Mg Cl/SO_4 and Ca/Mg$(HCO_3)_2$ fields;

- The eastern area boreholes show a greater variation in composition than those in the western and central areas (possibly due in part to the larger number of boreholes in this area). The water types are generally $Ca/Mg(HCO_3)_2$, indicating recent recharge, plus some in the NaCl and $NaHCO_3$ fields, the former possibly being influenced by some boreholes situated in the coastal zone.



The SA 1/66 analyses have been plotted on the Piper diagram and both analyses plot in the same positions in the cation/anion and composite diamond fields. However, they plot in a totally different position to the CHART chemistry plots from all precincts but fairly close to that for average seawater.

4. CONCEPTUAL MODEL

A conceptual N-S cross-section from George to north of Fraserburg is shown in the attached Figure. The vertical scale is approximately 30 times the horizontal so some artistic licence has been used in order to represent the concepts put forward. The basic geological section has been taken from Figure 2 on p 463 of The Geology of South Africa (GSSA, 2006). The main features of this section are:

- Rocks of the Cape Supergroup are highly folded and faulted within the Cape Fold Belt on the southern margin of the Karoo Basin and the sub-outcrop of these rocks (the Witteberg Group) extends almost as far north as Fraserburg;
- Deep-seated (thousands of metres) groundwater circulation takes place along faults within the Cape Supergroup rocks, as evidenced by thermal springs with temperatures of up to 62^{o}C (Brandvlei);
- The influence (structure and deep groundwater circulation) of the Cape Fold Belt extends into the southern Karoo, probably up to the Great Escarpment, and the southern limit of dolerite intrusions runs parallel to and just to the south of the escarpment;
- Recharge on the exposed Cape Supergroup rocks in the Langeberg, the presence of these rocks at depth below the Karoo rocks, deep groundwater circulation and fracturing in the Dwyka Tillite related to the Cape Fold Belt are possible key factors giving rise to the artesian groundwater encountered in some of the SOEKOR wells to the south of the Great Escarpment;
- This groundwater is likely to be confined by the Lower Ecca formations, which is where the shale gas is postulated to occur;
- The highest TDS measured during drilling of the SOEKOR wells was 10 000 mg/L, which is only an order of magnitude higher that some groundwaters from the shallow aquifer. However, the TDS of deep groundwater may increase to the north of the Great Escarpment away from the influence of the Cape Supergroup rocks/Cape Fold Belt.