GROUNDWATER GEOPHYSICS IN THE KALAHARI

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Effective borehole siting methods in the Kalahari have been determined as a result of several large-scale groundwater exploration projects undertaken in Botswana.

The Botswana National Water Master Plan subdivides the types of groundwater occurrence into four major groups:

Fractured aquifers
Fractured-porous aquifers
Porous aquifers
Karst aquifers

All four aquifer types exist in the Kalahari Desert but the largest potable groundwater resource in Botswana is the fractured-porous aquifers of the Karoo Basin (Figure 1).

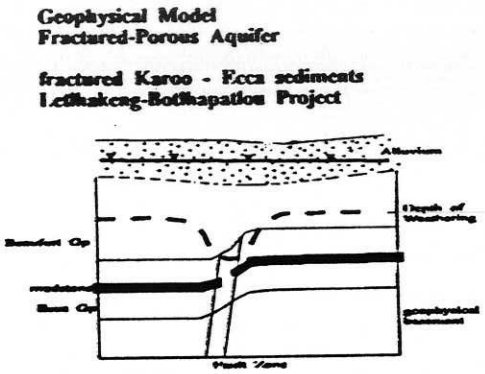

Figure 1 - fractured-porous aquifer model

Primary porosity type aquifers in the Kalahari beds are perhaps the most difficult target for geophysics, particularly with electrical techniques where current penetration is limited.

Fractured and karst type aquifers provide a small total resource, but are locally important because they occur in the densely populated area of eastern Botswana.

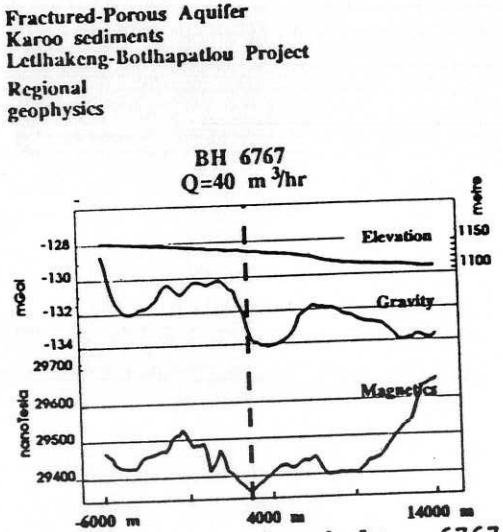

Figure 2 - borehole 6767 regional geophysics

Traditional and non-scientific methods such as water divining have been popular historically and continue to be used as an alternative to modern techniques. The effectiveness of these alternative siting methods, and the scientific explanation thereof, remains a mystery ...

In this paper we present several geophysical case histories of different aquifer types to demonstrate the effectiveness of each geophysical technique in the Kalahari environment.

One of the most important techniques for mapping regional geology and structure has proven to be detailed aeromagnetic surveys. Potentially water-bearing fault zones and dolerite dykes overlain by Kalahari beds can be effectively located with this method.

Gravity and magnetics, electrical soundings, and electromagnetic profiling techniques have proven to be the most effective combination of borehole siting methods for exploration of the important fractured-porous type aquifers in the Karoo Basin (Figure 2).

In judging the effectiveness of a particular technique, two different types of success are defined: technical success and utilization success. A borehole is a technical success if the geological and geophysical interpretation is explained. A borehole is judged a utilization success only if it meets the needs originally intended.

ISOTOPE HYDROLOGY OF SEMI-ARID REGIONS: LESSONS FROM THE KALAHARI

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The sand-covered Kalahari thirstland is devoid of surface water, except for the inland Okavango delta in the north-west. Annual rainfall, ranging from 200 mm in the south-east to 600 mm in the north-east is highly variable. Groundwater, mostly phreatic to partly-confined, is held mainly in horizontally-bedded, Carboniferous to Jurassic sedimentary Karoo aquifers. Traditionally, diffuse recharge was regarded as negligible, except in areas where the sandy, unconsolidated Tertiary to Recent Kalahari Beds cover is <6 m or during floods in ephemeral streambeds. Low piezometric gradients towards sedimentary basin centres were taken as evidence of sub-regional flow away from such "recharge areas".

Groundwater levels, at depths of 20 m to over 200 m, tend to follow the Kalahari/pre-Kalahari interface. Regional groundwater gradients are directed towards drainage levels, such as the Makgadigadi salt flats in the north-east. Although this dry lake clearly received groundwater drainage in pluvial times, at present groundwater levels lie below the perched brine level in the lake floor.

Environmental isotope and hydrochemical studies have been conducted over a period of more than 20 years in a number of areas of the Kalahari, usually as part of groundwater development projects. Most of the data was gathered from existing, low-yielding supply boreholes, usually poorly documented. Hence, a semi-statistical approach is usually adopted. Even in specially-drilled project boreholes, integrity of e.g. depth controlled samples was rarely assured.

A selection of these studies is briefly discussed. Various features of this semi-arid environment become apparent from the overall conclusions, leading to some important insights into hydrological processes which may have validity in other semi-arid to arid environments.