Geophysical investigations of alluvial aquifers in Zimbabwe

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GEOPHYSICAL INVESTIGATIONS OF ALLUVIAL AQUIFERS IN ZIMBABWE

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INTRODUCTION

Geophysical investigations were carried out on shallow alluvial aquifers in connection with sand rivers in Zimbabwe. The primary methods used were DC resistivity imaging and ground penetrating radar (GPR). The investigated sites are situated on so called sand rivers, i.e. rivers with a seasonal surface flow. The strata of principal interest, for local water supply and subsistence irrigation purposes, are alluvial sands present in the active stream channel or beneath flood plains. The alluvium in the present stream channels consists of coarse grained sand, generally with a groundwater table within a couple of metres depth. These shallow aquifers are widespread in the dryer parts of Zimbabwe, as well as other countries in the region. Since resource development is possible with locally sustainable technology, it is of high potential value. Investigations were carried out at two sites on the Umzingwani River and one on the Shangani River with results that agree well, which is also supported by previous research (Owen 1989). The geophysical surveys have been presented in detail by Einarsson et al. (1994), Ekström et al. (1996) and Beckman and Liberg (1997).

GEOPHYSICAL METHODS

The resistivity surveys were carried out using the ABEM Lund Imaging System, however at the Shangani River site a prototype version was employed (Dahlin 1996). The system consisted of a Terrameter SAS300, a relay switching unit, a laptop computer, four electrode cables, steel electrodes and various connectors. A current booster is recommendable, but at Shangani River it was not available. The electrode cables had 21 take-outs, each with 5 metres spacing between the take-outs, resulting in a total lay-out length of 400 metres. The measured pseudosections were processed with a 2D inverse numerical modelling technique to give the estimated true resistivities down to around 60 metres depth.

The ground penetrating radar (GPR) was measured with a Malå Geoscience RAMAC/GPR system, using the 50 MHz antennas. The equipment was moved manually by carrying the antennas and the control unit. The data was plotted as time sections (radargrams), from which the reflectors were digitised where present. The digitised reflectors were used to create 3D level maps over the aquifer bottom topography, via conversion of two-way-time to depth through calibration of the radar velocities.

EXAMPLE: SHANGANI RIVER

The Shangani River site is situated about 150 km north of Bulawayo. The area lies in the Middleveld with an average annual rainfall of 630 mm. The area is sparsely populated, where the surrounding land is used for dryland farming and cattle grazing. Along the river hand-dug wells are used for small scale garden irrigation. The geology in the region is dominated by Karoo sediments and lavas with irregular deposits of Kalahari sand. The Karoo successions lie on the Basement Complex, whose upper surface, according to Stagman (1978), is likely to follow that of the present day topography. Along major rivers, such as the Shangani, the rivers the Post-African erosion has removed the Kalahari sands in a wide belt, exposing the underlying rocks (Lister 1987). Outcrops of Forest Sandstone with petrified logs are well exposed south-east of the river at this site. The river has meandered back and forth across the valley, and as evidenced by for example oxbow lakes that are seen as remnants from old stream channels.

Three resistivity profiles crossing and continuing well beyond the present day river were measured, being 1300 metres, 1600 metres and 2600 metres long respectively. Poor electrode contact necessitated considerable efforts watering and hammering the electrodes, but the resulting data quality was acceptable considering that this was the first trial with a prototype system under these conditions, and that no current booster was available. The inverted models show consistent results as shown by the examples in Figure 1.

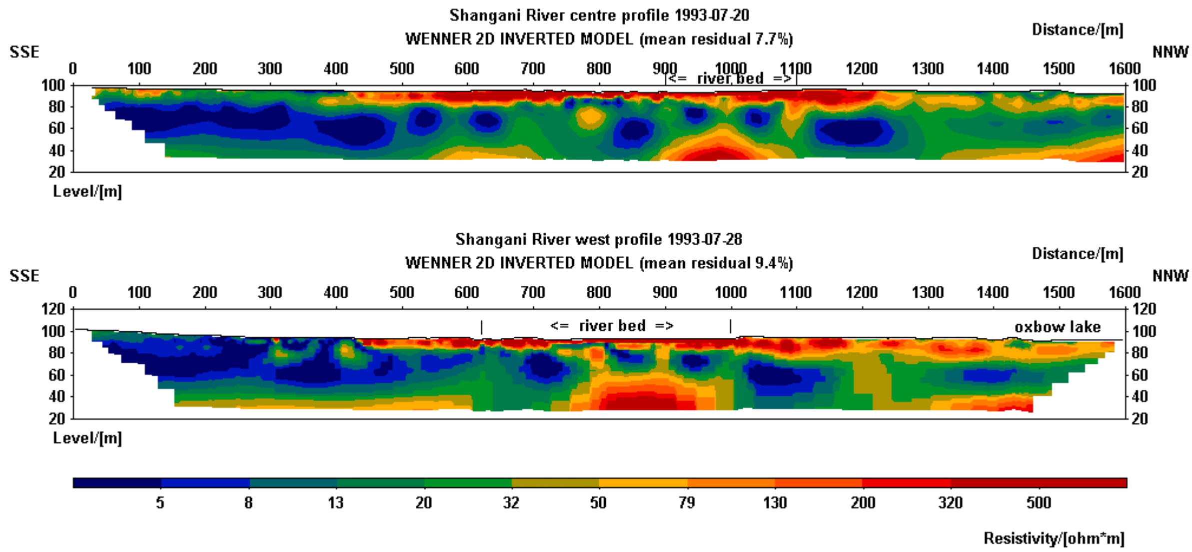

Figure 1. Examples of inverted resistivity sections from Shangani River site, a) part of middle profile, b) western profile (reprocessed data from Einarsson et al. 1994).

Relatively high resistivities (above 100 Ωm) are evident in the top layer in immediate connection with the present day stream channel. This high resistive top layer continues and thickens outside the present stream channel, giving a total width of this layer of over one kilometre. The layer corresponds to coarse grained alluvium as evident at the surface in the stream channel, and confirmed at shallow depth by means of manual mechanical sounding and hand drilling. The estimated thickness of the layer varies from a few metres to over 10 metres below the present stream channel, whereas thicknesses of 15-20 metres are indicated outside it. The results clearly indicate an extension of coarse sediments outside the present day stream channel. In places a thin low resistive layer is seen on top of this layer. This layer correlates with fine grained alluvium according to hand drilling.

South-east of the river a thick layer with estimated resistivities going well below 10 Ωm reaches the surface, and the layer continues below the river channel. The low resistivities are seen where Forest Sandstone outcrops, so the low resistivities are interpreted as Karoo sediments. Below the stream channel a high resistive indication is visible at depth. This may be interpreted as crystalline rock reaching closer to the surface due to faulting, but it may also be indicative of an intrusive dyke.

North-west of the river a layer with higher resistivities becomes more clearly visible at depth, coming closer to the surface towards the end of the profiles outside the sections shown here. This may be interpreted as the crystalline Basement reaching closer to the surface.

An irregular grid was measured with the GPR over an area of 1 km by 600 metres, where the profile layout was adopted to the geometry of the stream channel and the grid was made denser where the maximum sand depths were encountered in a preliminary evaluation of the data.

An example radargram is shown in Figure 2. The bottom reflector can be interpreted as the bottom of the coarse grained stream channel, where the bottom may consist either of bedrock or fine grained sediments. In places the reflector is weaker, and in places the signal is completely attenuated in connection with lenses of fine sediments. The velocities were used to calculate depths to the main reflector, as visualised in Figure 3. The depths vary around 6 metres in the eastern part of the area, whereas in the western parts depths go up to around 14 metres.

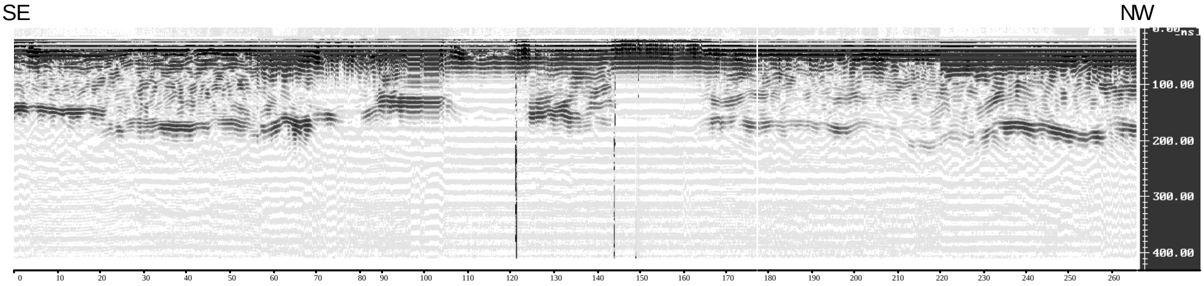

Figure 2. Example radargram from the Shangani River site, showing the main reflector and portions where the signal is attenuated by fine sediments (Beckman and Liberg 1997).

CONCLUSIONS

Resistivity imaging gave valuable results inside the present day stream channel as well as on the flood plains and surrounding terrain, outlining the extent of the aquifer and the surrounding strata. GPR only yielded useful results within the coarse grained stream channel, and depth penetration was blocked if clay or silt lenses were present. The results were used to estimate the 3D geometric extent of the aquifers, to identify different zones within the aquifers, and to locate aquifers boundaries and zones of interaction. The resulting geophysical models were highly useful for building conceptual geological/hydrogeological models of the aquifers, and an excellent basis for guiding the drilling programme.

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REFERENCES

Beckmann, M. and Liberg, M. (1997). *Ground Penetrating Radar Delineation of Shallow Aquifers in Zimbabwe*. M.Sc thesis, ISRN: LUTVDG/TVTG --5056 --SE, Dept of Geotechnology, Lund University, Sweden, 74p.

Dahlin, T. (1996) 2D resistivity surveying for environmental and engineering applications, *First Break*, vol 14, no 7, p 275-283.

Einarsson, J., Johnsson, G., and Lalic´, A. (1994). *Resistivity Mapping of Shallow Aquifers in Zimbabwe*. M.Sc thesis, ISRN: LUTVDG/TVTG --5038 --SE, Dept of Geotechnology, Lund University, Sweden, 115p.

Ekström, K., Prenning, C., and Dladla, Z. (1996). *Geophysical Investigation of Alluvial Aquifers in Zimbabwe,* M.Sc thesis, ISRN: LUTVDG/TVTG --5061 --SE, Dept of Geotechnology, Lund University, Sweden, 79p.

Lister, L.A. (1987). *The Erosion Surfaces of Zimbabwe*, Bulletin 90, Zimbabwe Geological Survey, Harare, 163p.

Owen, R. (1989) *The Use of Shallow Alluvial Aquifers for Small Scale Irrigation, with Reference to Zimbabwe*, Final Report of ODA Project R4239, Civil Engineering Dept., University of Zimbabwe, 109p.

Stagman, J.G. (1978). *An Outline of the Geology of Rhodesia*, Bulletin 80, Rhodesia Geological Survey, Salisbury, 126p.

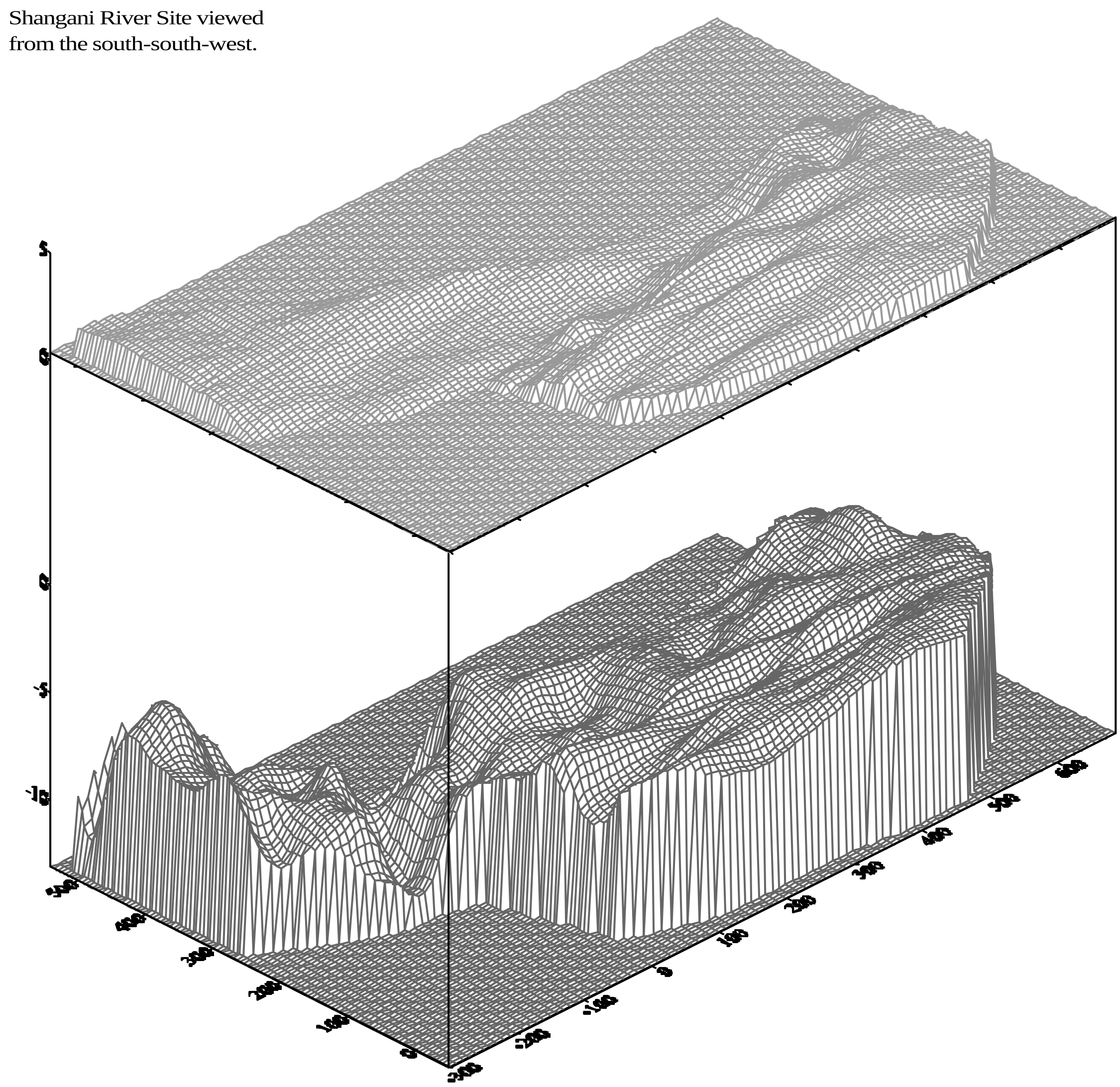

Figure 3. Interpreted depth model based on radar sections from the Shangani River site (Beckman and Liberg 1997).