GROUNDWATER PROSPECTING USING SELF POTENTIAL (SP) METHOD IN MUNGONI AREA OF THARAKA NITHI, KENYA

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ABSTRACT

Self-potential method is based on the surface measurement of natural potential resulting from electrochemical reactions in the subsurface. It does not require electric currents to be injected into the ground as in the resistivity and induced potential methods. This method has been used in base metal exploration to detect presence of massive ore bodies, in contrast to the IP method which is used predominantly to investigate disseminated ore bodies. One of the most important applications of self-potential is detection of fluid flow thereby making it a complimentary technique in field applications involving fluid flow, fracture leakage detection and pollutant migration, among others. The study was carried out with the aim of investigating the underground water around Mungoni area, Tharaka Nithi, Kenya. The population within this area is growing rapidly due to the increase in the number of learning institutions; this poses a high demand for clean water for domestic use and for agricultural use. The data was collected using resistivity Terrameter and a GPS probe for recording the space coordinates of the data stations. The data analysis was conducted using Surfer 11 computer application software. From the data interpretation it was concluded that groundwater is present in Mungoni area and extents from a depth of 100 meters to 180 meters and is reliable for commercial use.

Introduction

Self-potential method has been increasingly used in groundwater and geothermal investigation, environmental and engineering applications, mapping seepage flow associated with dams, geological mapping, delineate shear zone and near-surface faults. Self-potential method ranks as the cheapest of surface geophysical methods in terms of equipment. SP method is passive, that is, differences in natural ground potentials are measured between any two points on the ground surface. The potentials measured can range from less than a millivolt (mV) to a value greater than one volt. Self-potential (SP) or Spontaneous polarization are potential differences resulting from natural subsurface processes e.g. groundwater movement, streaming fluids, and other subsurface geochemical reactions, (Keary *et al.*, 2002). The common factor among the various processes considered to be responsible for measured self-potentials is groundwater flow acting as electrolyte and solvent of different minerals. Negative self-potential values below -100mV is associated with groundwater, (Jinadasa and Silva, 2009; Reynolds, 1998). One source of these self-potential, is the "Streaming potential" (or electro kinetic potential) which arise from the flow of fluid (e.g. groundwater) through a porous medium. For this reason self-potential is used in groundwater investigation and in geotechnical engineering application for seepage studies (Naudet *et al*. 2003). Self-potential surveys are conducted by measuring electrical potential difference between pairs of electrodes that contacts the surface of the earth (or water in water covered area) at a number of survey stations in the area of interest. The data can be plotted as profiles (observed potential versus distance along the profile) or, if the data provides sufficient area coverage, then contour signatures can be plotted. For a mineral body, large negative anomalies, normally above -100mV can be observed. Keary *et al.*, (2002), describes a causative body to straddling water table below which electrolytes in the fluids undergo oxidation and release electrons which are conducted upwards through the ore body.

Electrical self potential surveying is based on the principle of distribution of electrical potential in the ground around a current-carrying electrode which depends on the electrical resistivity of the subsurface. Electrical methods have been used to monitor groundwater occurrence within fractured rock with some success. Such measurements provide information on the fluid electrical conductivity and the fractured rock porosity. Traditionally, SP surveys mainly involved the measurement of diffusion potentials in well logging for oil prospecting, and redox-related potentials generated by ore bodies in base metal prospecting (Rizzo, *et al*, 2004). The study of geophysics is basically fundamental to surface and subsurface geophysics exploration. As name implies, geophysics involved the application of physics theory and measurement to discover properties of the earth. Before the age of reason, most of the natural catastrophic events (e.g. earthquake) are attributed to superstitious beliefs, but today there are number of geophysics reasons for such events, the study of geophysics is categorized into two: exploration geophysics and theoretical geophysics. While the objective of exploration geophysics is for economic exploration, the theoretical geophysics bent on applying the physics theories to study and discover the properties of the earth. The main purpose of this study is to learn about the application of self-potential geophysical technique for groundwater investigation. The basic background of this technique is similar to the classical correction process use in magnetic prospection. In this case, the desired anomaly is affected by many undesired polarization problems due to the shift of non-polarizing electrodes along the survey line (Darnet *et al*, 2003). The origin of SP across formation can be attributed to two processes involving the movement of ions; Streaming potential (E_k) and Electrochemical potential (E_c). Streaming potential originate from the flow of an electrolyte (water) over naturally charged solids. Mathematically, streaming potential can be expressed as;

$$E_k = -\frac{\varepsilon \rho C_E \delta P}{4\pi\eta}$$

Where ε – dielectric constant of the pore fluid

E_k – Streaming potential as a result of an electrolyte flowing through a porous pot

ρ - Electrical resistivity of the pore fluid

δP - Pressure difference

C_E – electro filtration coupling coefficient

η - Viscosity of the pore fluid

Flowing of fluid (electrolyte) through a capillary of porous medium generates potentials along the flow path. The potentials are alternatively called electro filtration or electromechanical. Streaming potentials have become more important due to applications in geothermal prospecting. In hydro geological investigations, streaming potential measurements have among other things been used to study groundwater movements and flow paths ((Wan fang *et al*, 1999) and to monitor fluid flow in the sediments of a seduction zone subjected to compression. Streaming potentials generated by leakage from a reservoir and water flow towards a well during pumping have been studied by Bogoslovsky and Ogilvy (1972).

Electrochemical potential is the sum of liquid junction or diffusion potential (E_J) and membrane potential (E_M). Liquid junction potential is established at the direct contact of the mud filtrates and formation water at the edge of the invaded formation. If the concentration of the electrolytes in the ground varies locally, potential differences are set up due to the difference in mobilities of anions and cations of different concentration called liquid-junction or diffusion potentials. For this mechanism to explain the continued occurrence of such potentials, a source capable of maintaining imbalances in the electrolytic concentration needed, otherwise the concentrations differences will disappear with time by diffusion. Electro potential is also generated when two identical metal electrodes are immersed in solutions of different concentrations called Nernst potentials (Wang fang *et al*, 1999)

At the microscopic scale of the porous rock, the electrical field is due to the drag of the excess of charge contained in the vicinity of the pore water-mineral interface by the pore water flow. The key-parameter of this phenomenon is the electro kinetic coupling coefficient (*C*) related to the electrical field difference ($\nabla\phi$) versus the hydraulic pressure difference ($\nabla\mathbf{p}$) (Revil*et al.* 1999). The equations associated to the fluid flow and the electrical current flow is related through this coupling coefficient. From a thermodynamic point of view, the existence of a measurable electrical field at the ground surface is related to the existence of a driving source current density in the ground, noted (**J***s*). The total electrical current density (**J**) in an isotropic porous material can be obtained by the summing up the conduction current described by the Ohm's Law, and the driving source current density (**J***s*) associated with the pore fluid pressure field.

$$\mathbf{J} = -\sigma\nabla\emptyset + \mathbf{J}s \quad \text{...(1)}$$

In the case of the electro kinetic effect, the driving current source is associated with the pore fluid pressure field as:

$$\mathbf{J}s = C\nabla\mathbf{p} \quad \text{..(2)}$$

And C is the electro kinetic coupling coefficient:

$$C = -L/\sigma \quad \text{..(3)}$$

Where ϕ and **p** are the electrical potential (V) and the fluid pressure (Pa) respectively, σ is the electrical conductivity of the porous rock (S m^{-1}), *C* is the electro kinetic coupling coefficient (V

Pa^{-1}) and L is an electro kinetic coupling term ($APa^{-1}\ m^{-1}$). Applying the continuity equation (conservation of charge) and equation 1;

$$\nabla^2 \emptyset = \frac{1}{\sigma \nabla J s} - \frac{\nabla \sigma}{\sigma(\nabla \emptyset)}$$

The first term is related to the current density (primary sources of polarization) and the second one is related to electrical resistivity heterogeneities in the porous system (secondary sources of polarization) Revil *et al* (2004).

Material and Methods

Data acquisition

High quality non-polarizing copper electrodes combined with a precision millivolt meter were used to record the voltages resulting from natural electrical current flow in the earth, at the surface. The electrodes were made non-polarizing by putting them in contact with a saturated solution of salt of copper sulphate. Contact with the earth was made through a porous pot. The electrode spacing of 5m-10m apart was used and a total of 20 data points taken. The data was represented in graphical form as a graph of observed potentials versus distance of separation as well as contour signatures.

Potential gradient method also known as dipole/leap frog/gradient configuration was used. In this method two electrodes were used in a fixed separation (5 or 10m). The whole system is moved from one place to another along the profile. Potential difference between the two electrodes is measured which is referred to as potential gradient [mV/V]. Two porous pots are leap-frogged along traverse with care of correct polarity of potential recorded.

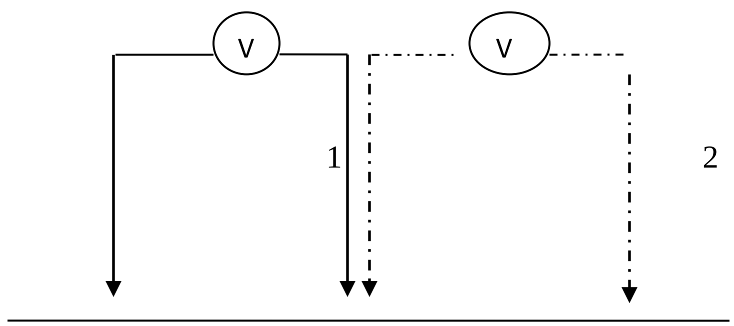


Figure 1: Potential gradient method array

The point with the highest potential was identified. Potential amplitude method also known as total field method (fixed-base) configuration was also used. One electrode is kept fixed at a base station. Potential difference [mV] is measured between the base electrode and the second moving electrode along the traverse. This method has a lower level of accumulative errors and confusing polarity.

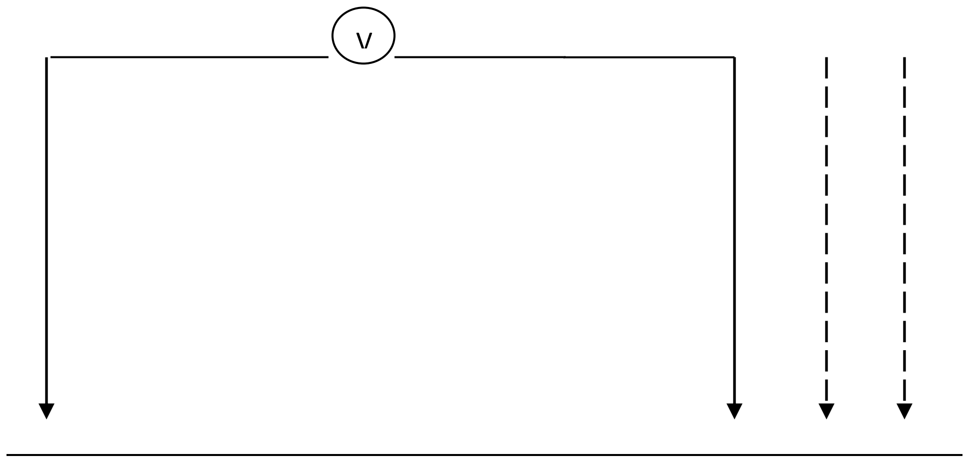


Figure 2: Total field configuration

Data analysis

Data analysis was done using Surfer 11 computer application software for drawing contours and profile for self-potential anomalies. Self-potential anomalies are often interpreted qualitatively by profile shape, amplitude, polarity (positive or negative) and contour pattern. For qualitative interpretation, it is possible to calculate the potential distributions around polarized bodies of simple shape, such as sphere, ellipsoid, and dipole, by making some simplification and assumptions. A graph of Sp against distance of separation (Figure 3) was plotted to display how the observed self-potentials varies with depth.

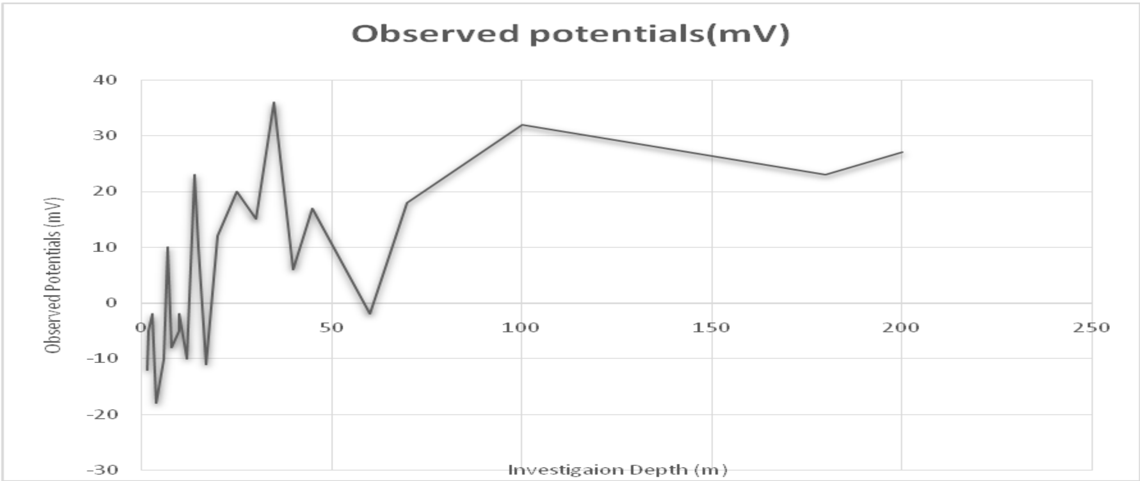


Figure 3: A graph of observed potentials against depth

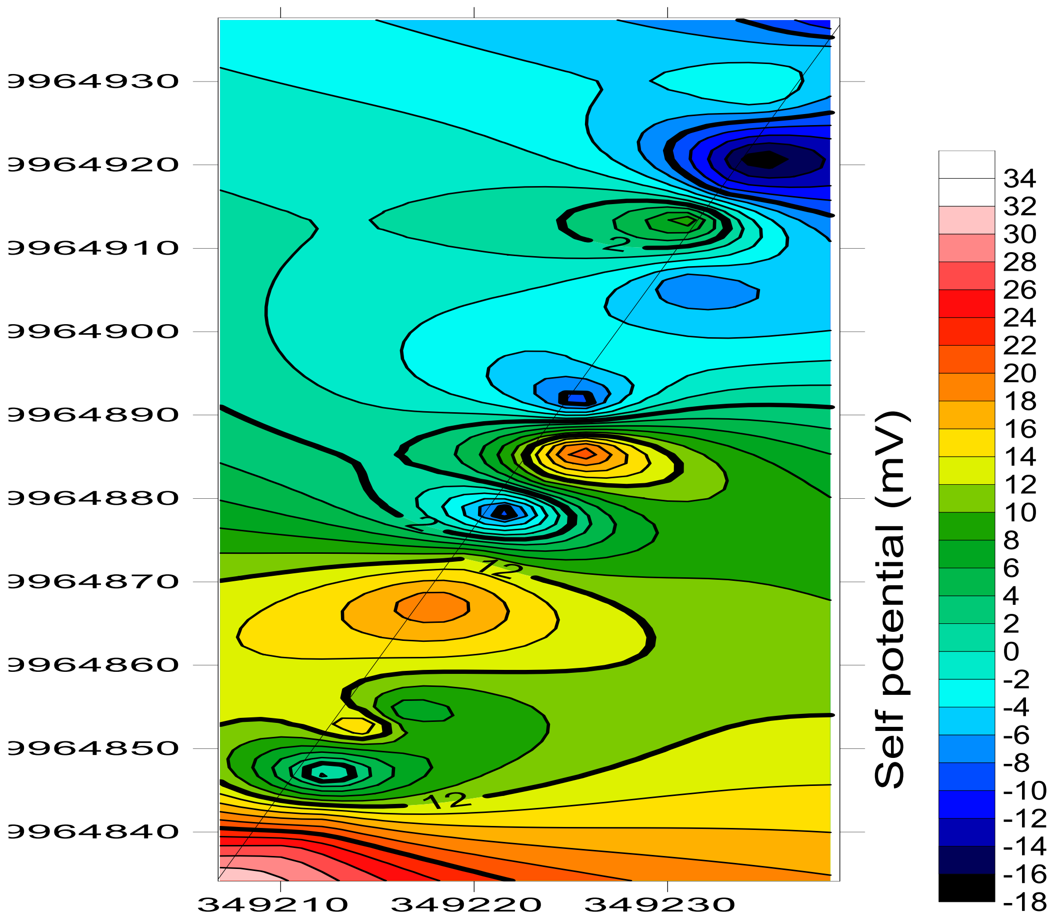


Figure 4 Self-potential anomalies

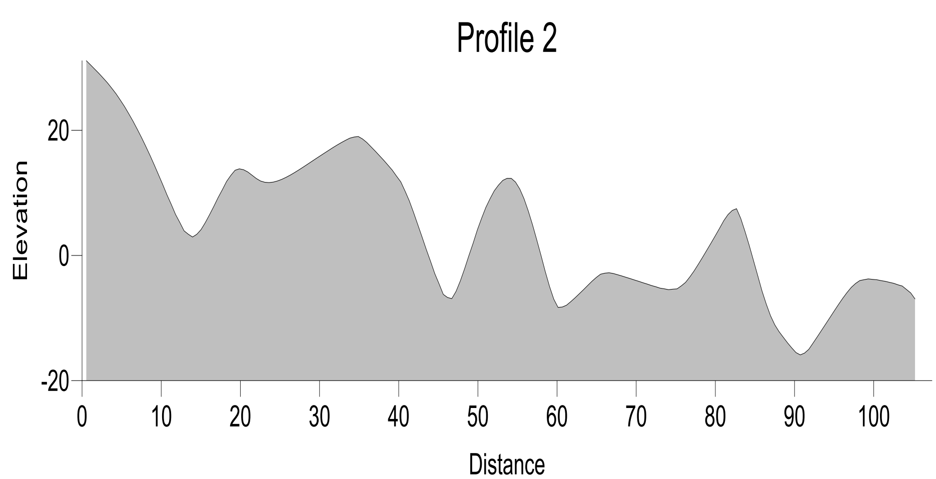
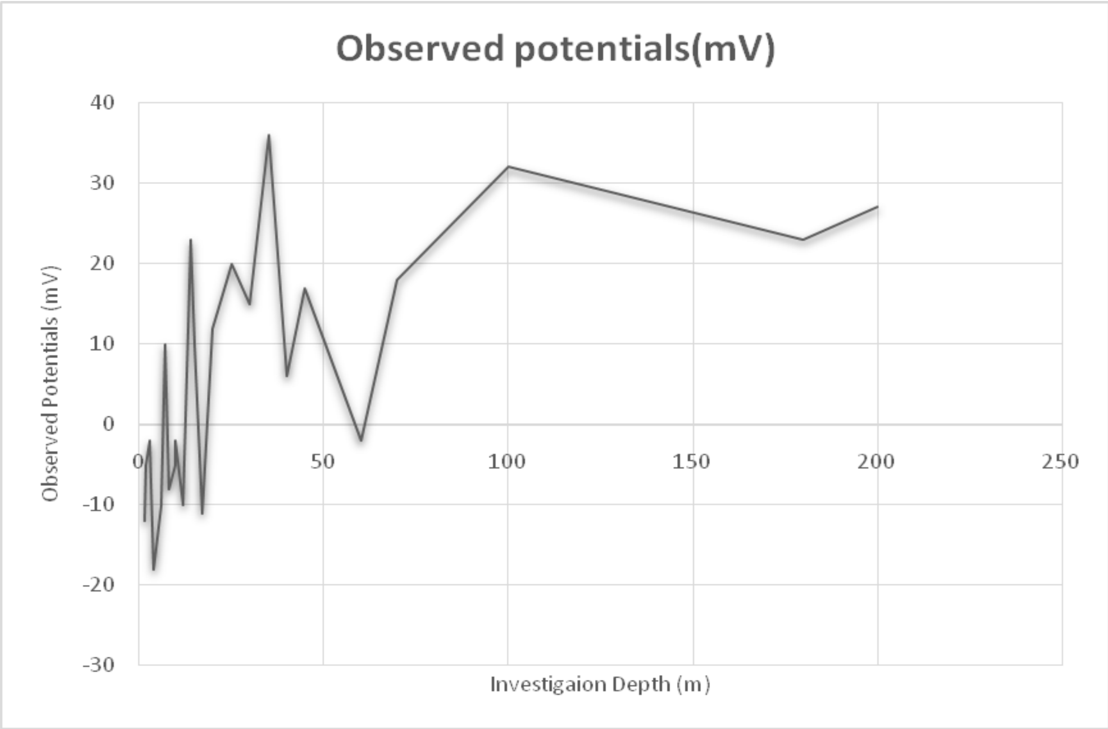


Figure 5 Self-potential anomalies profile

Figure 3 represents a graph of observed potentials (y-axis) in millivolts against depth of investigation (x-axis) in meters. Figure 4 represents self-potential anomalies signature. Based on the information from the graph, the self-potentials from 0m to around 30m shifts from positive to negative repeatedly. This behavior is as a result of near surface effects as a result of other factors other than groundwater flow. At a depth of 35m there is a sharp increase in the observed potential, which could be as a result of fluid flow majorly from seepage and percolation. Its short wavelength is an indication of its high fluctuation as the seasons change, therefore not recommended for drilling. This water cannot be relied on because it might not be available during dry season. At a depth of 100m to 180m there is a steady high self potential, this provides the best region for borehole drilling. Borehole depth at around 110m-150m would therefore be recommended.

Discussion and Conclusion

Self-potential anomalies measured at the site were assumed to be due primarily to streaming potentials created by groundwater flow. The magnitude of self-potential anomalies and self-potential changes is related to groundwater flow rates along with a host of other of other factors that makes the interpretation difficult. Direction of flow is indicated by the concentration of self-potential gradients.



Based on the information from the graph above, maximum depth of underground water site is around 180 meters. This is because, accumulation of water is highly dependent on pressure gradient and water levels, water flow towards and accumulate at locations of lowest pressure gradient. Consequently, more water will be found at locations 100-180 meters as it have deeper depth counting lower pressure gradient. The results show that a borehole depth ranging from 110 meters to 150 meters depth could be recommended at this location.

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