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IMAGING OF WATERLOGGED AREAS USING THE SELF-POTENTIAL METHOD AT EL-OBOUR CITY, NORTHEAST OF CAIRO, EGYPT

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تصوير المناطق المغمورة بالماء باستخدام طريقة الجهد الذاتي في مدينة العبور ، شمال شرق القاهرة ، مصر

الخلاصة: إن طريقة الجهد الذاتي هي طريقة جيوفيزيائية تعتمد على التواجدات الطبيعية للمجالات الكهربائية على سطح الأرض. يعتبر مسح الجهد الذاتى مفيدًا جدًا لتحديد كمية المياه الجوفية وتصوير المناطق التي تغمرها المياه في مدينة العبور ، شمال القاهرة ، مصر. تعتبر المناطق التي تغمرها المياه في مدينة العبور شمال شرق القاهرة ظاهرة سائدة ينتج عنها تأثير بيئي خطير ناتج عن تسرب الأنابيب المدفونة من الداخل ومن الصرف الصحي وأنظمة الري داخل المدينة ذات الكثافة السكانية العالية في المناطق منخفضة الطوبوغرافيا.

أظهرت نتائج التفسير أن المنطقة الأكثر استقطابًا موجودة في الجزء الجنوبي الشرقي بسبب زيادة تأثير تراكمات المياه تحت التربة مع زيادة سلبية لقيم الجهد الذاتى للمسافات الأوسع بين الأقطاب (٢٠ م) المسؤولة عن التأثيرات القادمة من الأعماق المكافئة البعيدة.

ABSTRACT: *The self-potential method is a geophysical method based on the natural occurrences of electrical fields on the Earth's surface. Self-potential survey is very useful in localizing, quantifying groundwater flows and imaging of waterlogged areas in El-Obour City, NE of Cairo, Egypt. The waterlogged areas at El-Obour City are dominant phenomena with hazard environmental impact originated from seepages of buried domestic, sewage and irrigation pipeline systems within the heavily populated city in low topography areas.*

The results of interpretation have shown that the more polarizing area is found at the southeastern part due to increase the effect of subterraneous water accumulation with higher negativity of self-potential values for wider electrode spacing (20 m) that is responsible for effects coming from deeper equivalent depths.

INTRODUCTION

The present study lies at El-Obour City between latitudes 30°12 '20.34" N and 30° 12' 30.26" N and longitudes 31°27' 11.43"E and 31°27' 18.84" E as shown in Fig. (1). El-Obour City is located at about 35 km northeast of Cairo and it is bounded from south by Cairo-Ismailia highway and from north by Cairo Belbeis Desert Road.

The expected source of self-potential at El-Obour City is thought to be as a result of **accumulation of subterraneous** water within **sand dune layer** above the **clayey bedrock** in **low topography** areas forming **waterlogged areas**.

The waterlogged areas at El-Obour City are dominant phenomena with hazard environmental impact which are mainly originated as a result of heavy population. The subterraneous water accumulations were originally come from several seepages of buried domestic, sewage and irrigation pipeline systems within the city in low topography.

Self-potential method was used in the present study to image the waterlogged areas. Previous hydro-geophysical studies (El-Badrawy and Soliman, 1997; El-Mahmoudi et al., 2006; Kotb et al., 2009; Sultan and Santos, 2009, Farag et al., 2018) already focused on such a geomorphologic-hydrogeological relationship.

a): Location map of El-Obour study area

b) SP profiles location map

Fig. (1): a) Location map of El-Obour study area and b) SP profiles location map

SELF-POTENTIAL THEORY

The self-potential (SP) method has a wide range of applications in engineering and geotechnical investigations (Corwin, 1984 and Markiewicz, et al., 1984), Geothermal exploration (Corwin and Hoover, 1979; Fitterman and Corwin, 1982; and Anderson, 1984), cavity detection (Schiavone and Quarto, 1992), and in the exploration for minerals, particularly metallic sulfides (Yungul, 1950). The self-potential method is based on the measurement of naturally occurring potential differences generated mainly by electrochemical, electrokinetic, and thermoelectric sources (El-Araby, 2003).

Self-potential (SP) method is rapid, non-destructive, relatively inexpensive, and can vastly improve the characterization of the shallow subsurface. Self-potential method consists of measuring the natural electric field within the subsurface with non-polarizable electrodes. These electrical potentials are mainly related to groundwater flow through the electrokinetic effect. The electrokinetic effect corresponds to the generation of an electrical field associated to groundwater flow in a porous media. 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 electrokinetic coupling coefficient related to the electrical field difference versus the hydraulic pressure difference (Revil, et al. 1999).

The self-potential method is one of the simplest and oldest among all geophysical techniques used to locate and delineate sources associated with fluids, heat and ions flows. The method is based upon measuring the natural potential developed in the earth by electrochemical actions between minerals and subsurface fluids or by electrokinetic processes involving the flow of ionic fluids.

Streaming potentials or electrokinetic potentials are caused by the motion of ions with the flow of a liquid. In a system consisting of two separate phases such as liquid and a solid medium, there has to be a total balance of charge, that is, the system has to be electroneutral.

This means that the net charge within the liquid and the charge on the surface of the solid medium have to be equal in magnitude and of opposite signs. At the interface of the two phases there is an aggregation of excess charge (excess ions and/or electrons) on each side, which constitutes an electrical double layer. The electrical double layer, which is crucial for the generation of streaming potentials, can be described by models of various complexities (Fagerlund and Heinson, 2003).

Idris, et al. (2015) states that self-potential methods measure naturally occurring electrical potentials in the earth. One source of these self-potentials is the “streaming potential” (or electro kinetic potential) which arises from the flow of fluid (e.g. groundwater) through a porous medium. For this reason self-potential is used in groundwater investigations and in geotechnical engineering application for seepage studies. Self-potential surveys are conducted by measuring electrical potential differences between pairs of electrodes that contact the surface of the earth (or water, in water covered area) at a number of survey stations in the area of interest. These stations may be along profiles or spaced so as to obtain an aerial coverage. The self-potential geophysical method is simple, a high quality non-polarizing electrodes combined with a precision millivolmeter is used to record the voltages, resulting from natural electrical current flow in the earth, at the earth surface.

METHODOLOGY

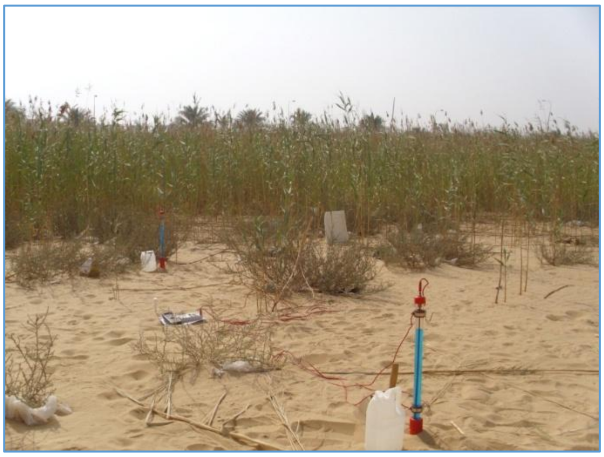
1. Field Equipments of Self Potential Geophysical Survey

Self-potential field survey was conducted by measuring electrical potential differences between pairs of electrodes that contact the surface of the earth at a number of survey stations in the area of interest.

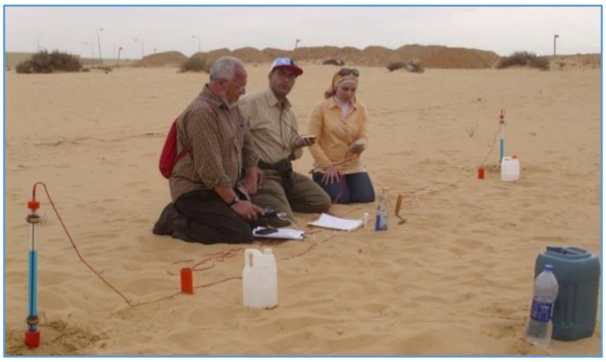
The required equipment simply includes two potential electrodes, wire, and a high-input impedance voltmeter (>10 mega ohms). The electrodes in contact with the ground surface should be the non-polarizing type (porous pots). Porous pots are metal electrodes suspended in a supersaturated solution of their own salts (such as a copper electrode suspended in copper-copper sulfates) within a porous container (Fig. 2). The non-polarizable electrodes are placed in holes about 25cm deep into the ground, which made at each station along each profile to reduce the source of noise from the topsoil. Watering of these holes could improve contact consistency. The wire used in SP survey was strong, hard, and of low resistance. An inexpensive, high-input-impedance voltmeter is used to read the potential in the millivolt range. The resolution of the voltmeter should be less than 0.5mV.

The SP survey was conducted along 5 profiles trending E-W with 200 m profile length and 100 m profile spacing. The inter-station spacings within each profile were repeatedly 5, 10 and 20 m apart.

a) Porous pot electrode



b) Porous pots inside grass and vegetations

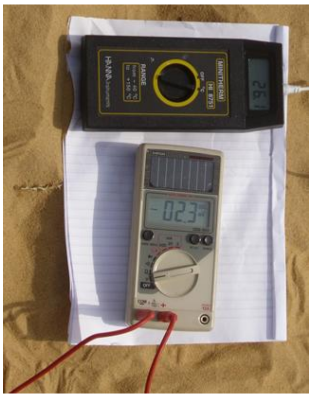


c) SP profile spacing between electrodes

Fig. (2): Equipments of self-potential.

One station was selected as a base station and all potentials were referenced to that point. The base station is located at a calm high topography area. The base station has been re-occupied each one-hour during the field measurements.

Field measurements were taken along each profile using a Digital Multimeter Model CDS-820 (Sanwa DMT Instrument, Japan) high input impedance voltmeter, with accuracy reaching 0.01 mV (Fig. 3).



High input impedance voltmeter

Fig. (3): Digital Multimeter Model CDS-820 (Sanwa DMT Instrument, Japan).

2. Self-Potential Data Interpretation

The SP survey was conducted along 5 profiles (profile I, profile II, profile III, profile IV and profile V) 200 m long for each, and the inter-station spacings between electrodes within each profile were repeatedly 5, 10 and 20 m apart as shown in SP values (mVolts) versus distances curves (Fig. 4). In general, SP curves exhibit negative values for all electrode spacings within each profile that is a result of the presence of polarizable water body. It is very remarkable from SP curves for all electrode spacings (5, 10, 20 m) that there is a sharp decrease in SP values towards the eastern side of the study area confirming the presence of waterlogged areas in this part with highly negative values (hot colors) reaching -200 mV particularly for wider electrode spacings (20 m).

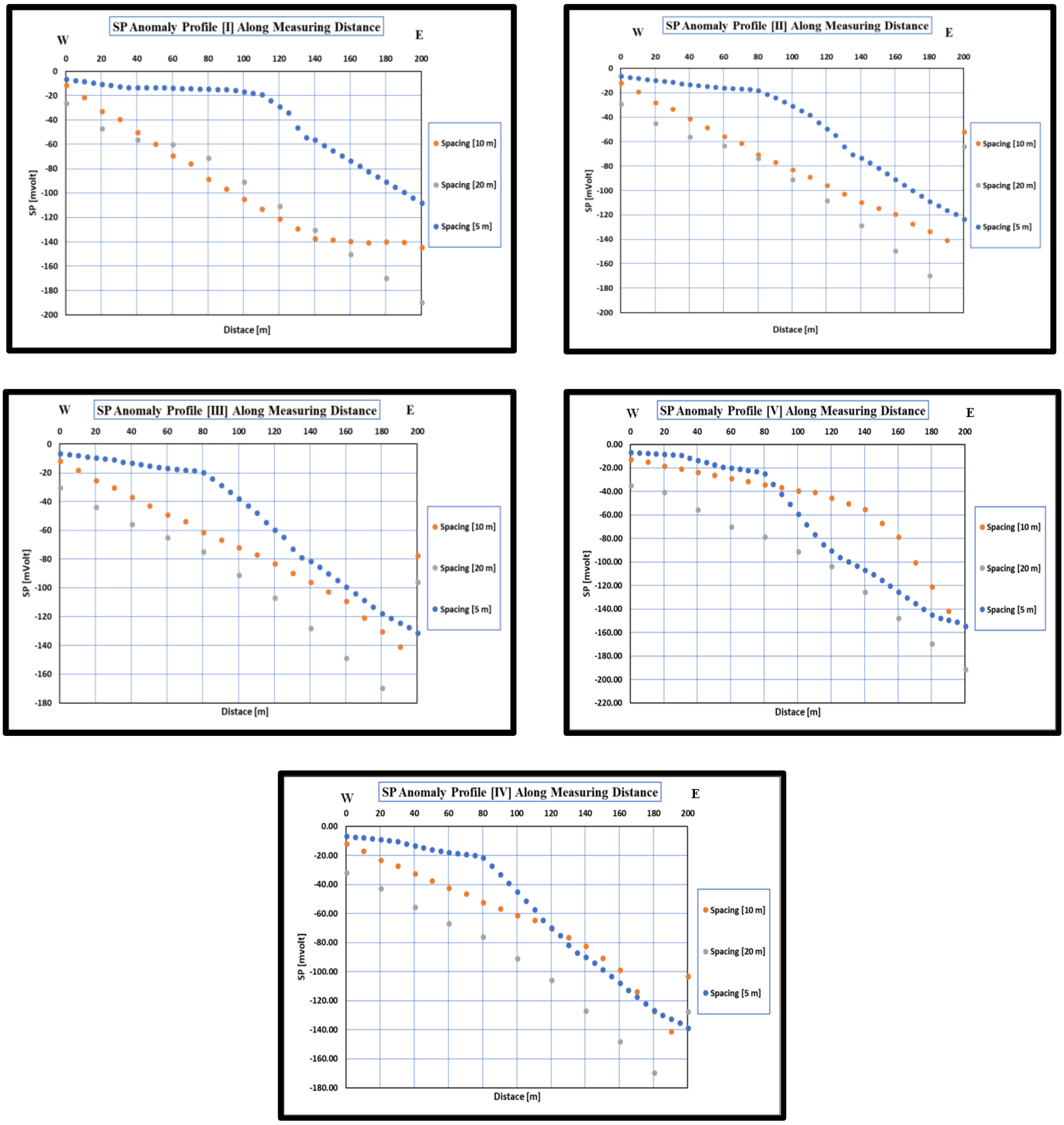


Fig. (4): SP versus distance curves for all electrode spacings within five studied profiles.

The results of interpretation of self-potential survey were presented as a vertical SP cross sections of the superimposed three electrode spacings (5, 10, and 20 m) for each profile as shown in Fig. 5. The encountered SP anomalies in profile I was very limited to eastern side with small contour intensity and sharpness; this may indicate that the earth model below profile I is less affected by the SP source with SP values in the range of (-0.2 – -5.8 mV/m) reaching an equivalent depth up to 20 m. The second profile II shows a range of SP values from -8.0 to 4.2 mV/m with higher negative anomalies due to increase the effect of SP source from waterlogged areas. SP values in profile III are ranged from -4.5 to 2.0 mV/m and from -5.2 to – 0.8 mV/m for profile IV, while they are remarkably increased at profile V till reach -8.0 to -0.5 mV/m.

It can be generally observed that the more polarizing area is found at the southeastern part of El-Obour City study area due to the increase effect of subterraneous water accumulations.

The results of SP were constructed in SP maps for each electrode spacing (5, 10 and 20 m) as shown in Fig. 6, which act as a high-cut filter, so that the only long-wavelength anomalies remain. The structure to be detected is generally 3D, therefore it is better to interpret a contour map rather than profile vertical cross-section

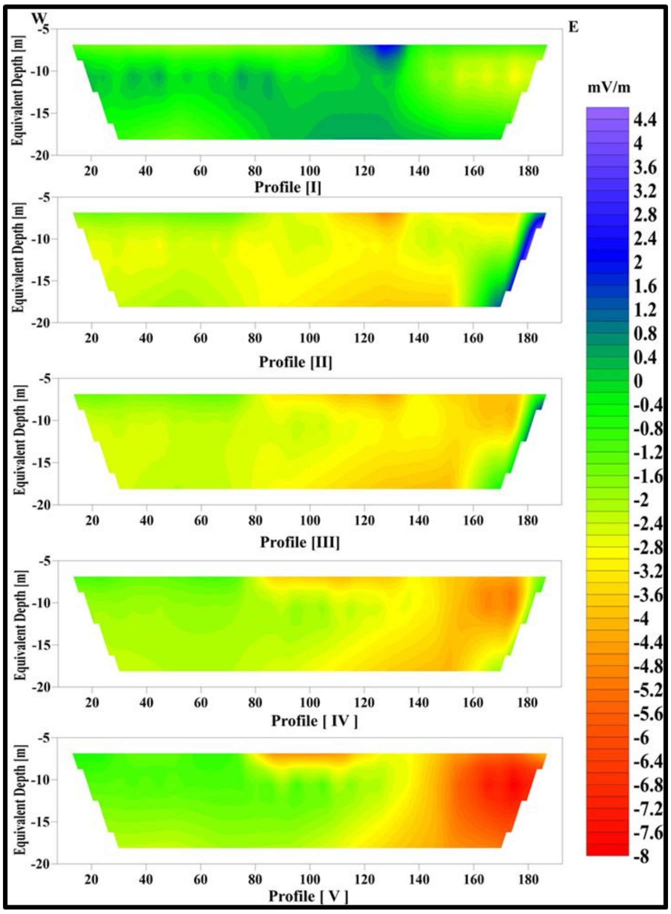


Fig. (5): Vertical SP cross sections of the superimposed three electrode spacings (5, 10, and 20 m) for all studied five profiles.

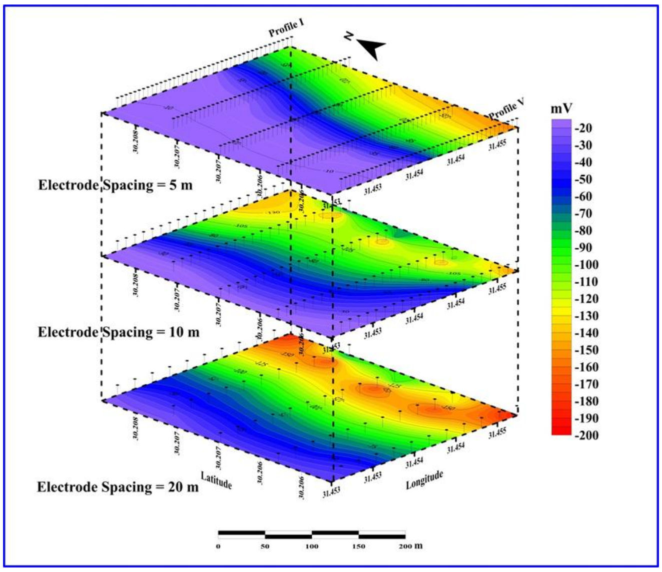


Fig. (6): SP maps collecting all five profiles for electrode spacings (5, 10 and 20 m).

The constructed SP maps of the study area show a wide range of amplitudes varies from -20 to – 200 mV with higher negative values at the southeastern part for the electrode spacing 5 m that represents shallower equivalent depth, while the effect of SP source is remarkably increased at the whole eastern half of the investigated area for electrode spacing 20 m of deeper equivalent depth.

SUMMARY AND CONCLUSIONS

The self-potential is a rapid, non-destructive and inexpensive method based on measuring the natural electric field within the subsurface with non-polarizable electrodes on the Earth's surface. These electrical potentials are mainly related to groundwater flow through the electrokinetic effect.

Self-potential survey was very useful for detecting and imaging of waterlogged areas in El-Obour City, NE of Cairo. The waterlogged areas are a result of seepages of buried domestic, sewage and irrigation pipeline systems within the sand layer above clayey bedrock in low topography areas in the heavily populated city.

The southeastern part exhibited the more polarizing area due to the increase of the effect of subterraneous water accumulation with higher negativity (hot colors) of self-potential values for wider electrode spacing (20 m) that is responsible for SP effects coming from northwestern areas and accumulated in deeper equivalent depths.

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