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GEOLECTRICAL RESISTIVITY METHOD FOR DETECTING OCCURANCES OF SALTWATER INTRUSION

Nur Islami
Laboratorium Pendidikan Fisika, Jurusan PMIPA FKIP
Universitas Riau, Pekanbaru 28293
e-mail: nris74@yahoo.com

Abstrak

Lokasi kajian berada di kampong Tanjung Mas, Kelantan Utara–Malaysia. Wilayah Kelantan Utara dilapisi oleh batuan Sedimen Kuarter yang mana batuan Granit sebagai batuan dasarnya. Sistem pengairan adalah berbentuk jaringan dendritik dengan sungai utama mengalir ke Laut Cina Selatan. Survey resistivitas geolistrik dilakukan untuk mendeteksi kehadiran intrusi air garam dalam akuifer. Survey resistivitas geolistrik dibuat dengan 4 lintasan. Zona air payau yang memiliki harga resistivitas kurang dari 7 ohm.m, sangat jelas terlihat pada model inverse resistivitas dengan posisi kedalaman sekitar 22 m. Konsentrasi air payau dalam akuifer bagaimanapun juga berkurang akibat pengaruh bertambahnya jarak dari garis pantai dan juga berkurangnya jarak dari sungai.

Kata Kunci: resistivitas, sub permukaan, air payau

Introduction

Groundwater is an essential and vital resource in all countries. A number of factors can affect the quality of a groundwater reservoir, such as contamination by salt-water intrusion (Samsudin,. A.R., et al., 2007; Abdul et al., 2000; Harding 1991) or by toxic industrial chemical waste (Barker 1996). These pollutants pose common environmental problems that have created the need to find suitable methods for monitoring the extent of such environmental damage (Bernstone and Dahlin 1996). The geoelectrical imaging method has been widely used in environmental and geotechnical investigations for mapping complex geological structures (Griffiths and Barker 1993) as it can delineate the resistivity distribution of such structures. Geoelectrical imaging surveys aim to determine the physical properties on the plane delineated by injecting current along different paths and measuring the associated voltage drops. In this paper, the efficiency of the geoelectrical imaging method for the mapping of salt-water intrusion is examined.

Review of Geology and Hydrogeology in Study Area

Figure 1 show the location map of research area near Kampong Tanjung Mas, North Kelantan – Malaysia. The RSO West Malaysia and Kertau 1946 are used as coordinate system and datum in the map. The North Kelantan plain is covered with Quaternary sediments overlying granite bedrock. It is drained mainly by short rivers and streams which flow into the South China Sea. The central part of the plain is drained by the largest river in the region, the Kelantan River, and in the South East, it is drained by Pengkalan Datu River. The thickness of the Quaternary deposits varies from 25 m inland to about 200 m near the coast. The loose quaternary sediments consist of alternating layers of coarse gravels to silts or mixtures of the two (Saim 1999). There are two main aquifer. Shallow aquifer, mostly unconfined but occasionally confined or semi-confined, thickness normally 2-3 m and may reach up 17.5 m. This aquifer is first aquifer. Deep aquifer, mainly confined, its thickness usually more than 15 m, this deep aquifer comprises three different layers, separated from each other by permeable strata of clay. This aquifer refer to second, third and fourth aquifer (Pfeifer et al., 1986; Saim, 1999).

Review of Geoelectrical Resisitivity Theory

Geoelectrical resistivity is often first encountered in physics when discussing the resistance of an ideal cylinder of length *L* and cross-sectional area A of uniform composition. The resistivity ρ appears as the material-specific constant of proportionality in the expression for the total resistance of the cylinder,

$$R = \rho L/A \qquad (1)$$

The total resistance *R* may be obtained experimentally through Ohm's law, $R=V/I$, where *V* is the potential difference between the ends of the cylinder and *I* is the total current flowing through the cylinder. Edge effects are not considered. The resistivity of the material, an intrinsic property of the material, is then

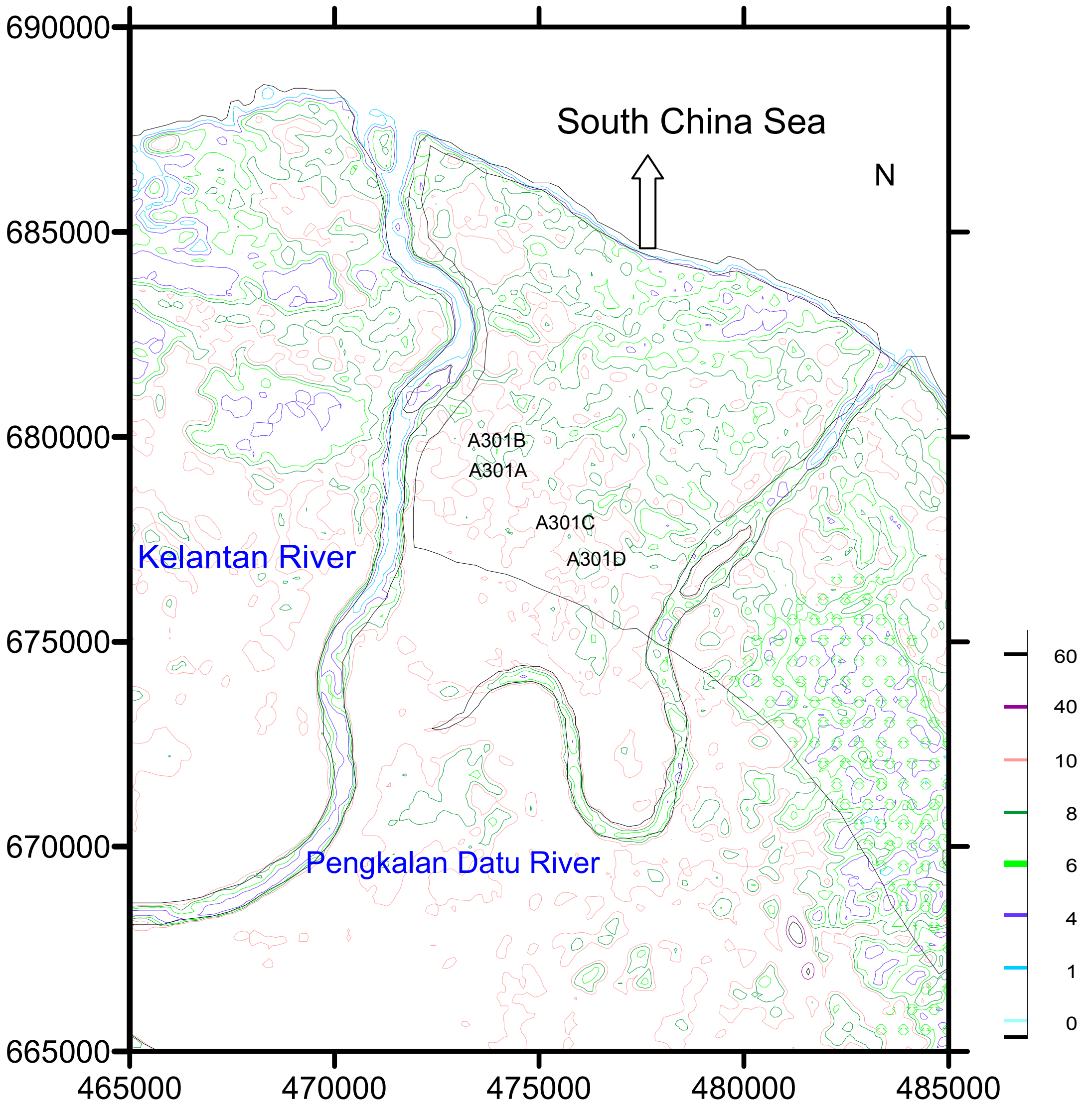


Figure 1. Site Survey Location Map Showing Centre of Geolectrical Resistivity Lines.

related to experimentally measured extrinsic parameters by

$$\rho = (V/I)(A/L) = R_{app}K \quad (2)$$

In the second equation, the resistivity is given by the product of the apparent resistance R_{app}=V/I and a geometric factor K=A/L that carries information about geometry of the cylinder. This type of product of an apparent resistance and a geometry factor will appear again when the resistivity of the ground is determined. For the Wenner array which separated by equal intervals, denoted *a*, the apparent resistivity is given by (Telford et al., 1990):

$$R_{app} = 2\pi a(\Delta V/I) \quad (3)$$

Methodology

In this study, geoelectrical resistivity surveys were made up of 4 lines. The 2D electrical resistivity imaging surveys were performed at the proposed sites using the ABEM SAS1000 resistivity meter and multicore cable to which electrodes were connected at takeouts moulded on at predetermined equal intervals. A computer-controlled system was then used to select the active electrodes for each electrode set-up automatically. This computer-controlled system was included in the instrument ABEM SAS1000 which was used in the survey. Processing of the data was achieved by a tomographic inversion scheme using the software RES2DINV (Loke, 2007). In this scheme, true resistivity distribution in the subsurface is obtained by a linearized least-squares inversion of apparent resistivity pseudosections acquired along profiles.

Results and Discussion

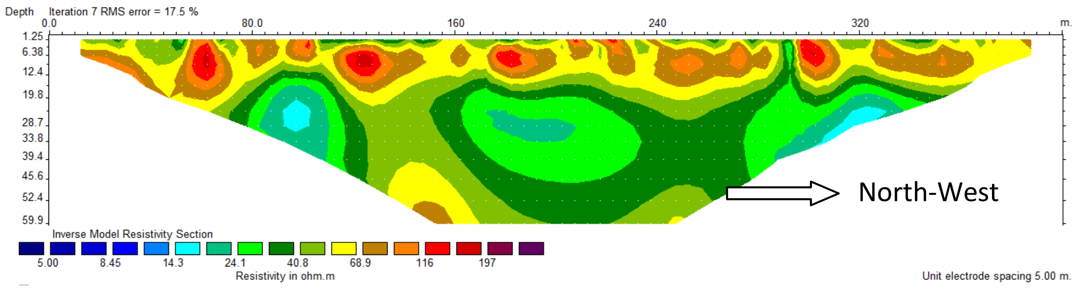
Entire survey lines of A301A, A301B, A301C and A301D were conducted in the surrounding area of the Tanjung Mas pumping well station. These lines consist of four wheel cable that required 61 electrodes. The total length of these set up equipment was 400 meter except A301B (240 m length) due to the lack in space.

Wenner inverse model of line A301A and A301B can be found in Figure 2. The line of A301B is the nearest survey done to the Kelantan River for the whole of the surveys in Area 3. In the Wenner inverse model of A301A, the minimum values of true subsurface resistivity is 16.1 ohm.m that correspond to fresh water. This can be seen in the interval depth from 20 – 28 meter deep. More compacted material which alternates to softer material is revealed on the top. It can be explained by the occurrence of relative high and low resistivity values respectively. In the area with a depth of around 7 meter and 50 meter, the highest resistivity values are to be found. That means more compacted and less porous material such as clay material can be defined in that area. This can be clarified with the occurrence of clay material based on the interpreted gamma ray data in Tanjung Mas well located around 1.3 km from the line.

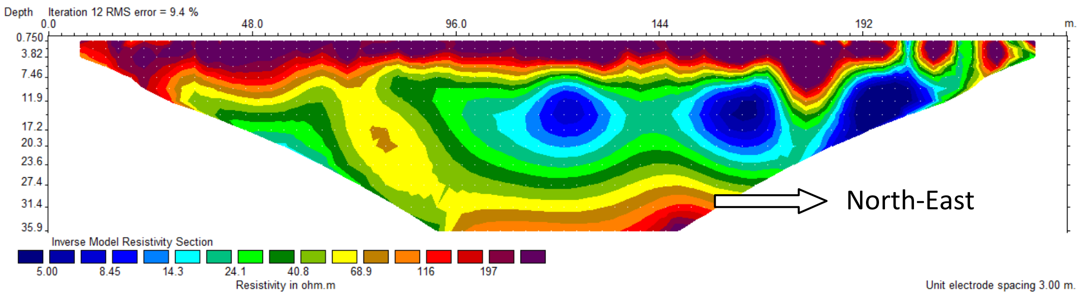
In the Wenner inverse model of line A301B (Figure 2.), the boundary between brackish and fresh water is very clear, occuring in the centre of the line survey. This is indicated by the presence of a resistivity value of less than 7 ohm.m with a depth of around 18 m deep at the right side of the survey line, and the value of more than 10 ohm.m at the same depth at the left side. However, the left side is closer to the Kelantan River, and the right side is to the sea ward.

Figure 3 shows Wenner inverse model of line A301C. It can be seen that the minimum values of true subsurface resistivity is 5.51 ohm.m which corresponds to brackish water in the interval depth of 18 – 26 meter. Occurrence of relative high and low resistivity values on the top correspond to more compacted material which alternates to softer material. At around the 265 m mark, very soft material is exhibited. It is very possible for water to infiltrate from the surface to the next aquifer by this path.

Wenner inverse model of line A301D can be seen in Figure 3. In the model, from the surface to a depth of 4 meter lower resistivity value (around 30 ohm.m) can be found corresponding to the possibility of the top aquifer. At the next depth (4-10 m), more values of resistivity are revealed. This correlates to less porous material. In the second aquifer, it can be interpreted that freshwater is occupying this zone. This is indicated by the lowest resistivity values in the zone of 8.37 ohm.m. However, the dominant resistivity values is around 30 ohm.m.

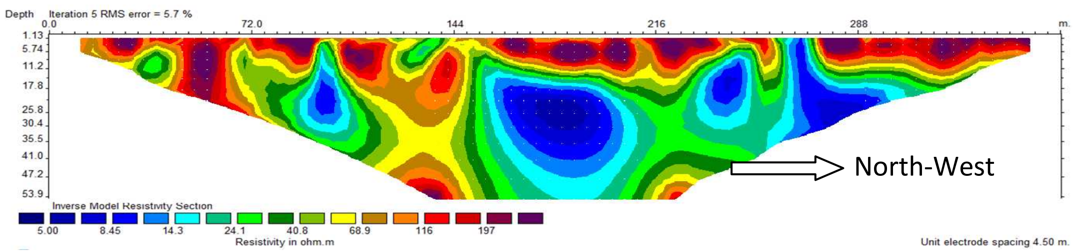


Line A301A



Line A301B

Figure 2. Wenner Inverse Model o Line A301A (Top) and Line A301B (Bottom)



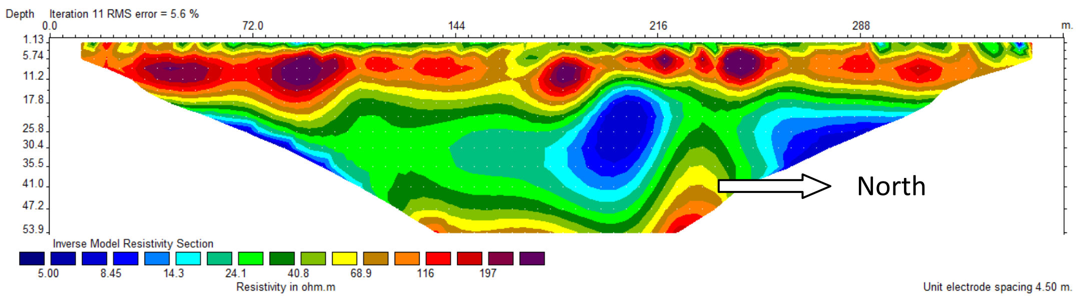


Figure 3. Wenner Inverse Model of Line A301C (Top) and Line A301D (Bottom)

Conclusion

The inverse model sections have shown the usefulness of geoelectrical imaging for groundwater investigations in coastal areas. It has proved to be a useful tool for delineating the boundary between fresh water and salt water because of its inherent capability to detect the changes in pore-water electrical conductivity. The fresh-water/ saline-water boundary is almost two-dimensional and is a good target for 2D electrical imaging surveys. The zone of brackish water which has a resistivity value less than 7 ohm.m is very clearly seen in the Wenner inverse model with position around 22 m depth.

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