MAPPING OF SALT-WATER INTRUSION BY GEOELECTRICAL IMAGING IN CAREY ISLAND

Samira Igroufa[1], Roslan Hashim[1], Samsudin bin Taib[2]

[1] *Department of Civil Engineering, Faculty of Engineering, University Malaya - Malaysia*
[2] *Department of Geology, Faculty of Science, University Malaya – Malaysia*
samiroufa@yahoo.com, roslan@um.edu.my,samsudin@um.edu.my

Abstract: Groundwater is an essential and vital resource in all countries. A number of factors can affect the quality of a groundwater aquifer, such as contamination by salt-water intrusion or by toxic industrial chemical waste. These pollutants pose common environmental problems that have created the need to find suitable methods for monitoring the extent of such environmental damage .The advent of fast computing technologies permitted a broad use of the electrical resistivity tomography for environmental purposes .This study aims to investigate the saltwater intrusion in the coastal alluvial aquifer at Carey Island, state of Selangor in Malaysia, by using electrical resistivity method. The purpose of this study is to map the subsurface salinity distribution. Two dimensional electrical resistivity survey was conducted using wenner electrode configuration. The data processing was made by Geoplot3 Res2dinv inversion program and the obtained results were analyzed and correlated with the available boreholes data and as a result, the ground water potential map was created using GIS. The resistivity images yielded useful information about the geometry of saltwater body. The saltwater intrusion was detected at shallow depth around 10m and extending down to more than 40m.The resistivity data were consistent and showed good correlation with the borehole lithologic cross sections, proving the efficiency of combining the two methods in solving environmental problems.

Keywords: Coastal environment, electrical resistivity imaging, saltwater intrusion.

INTRODUCTION

Freshwater quality and availability is one of the most critical environmental and sustainability issues of the twenty-first century. Of all sources of freshwater on the Earth, groundwater constitutes over 90% of the world's readily available freshwater resources with remaining 10% in lakes, reservoirs, rivers and wetlands. The quality and availability of these fresh groundwater resources in coastal areas are threatened by seawater intrusion from the seaside. Seawater intrusion is a natural process, by which seawater displaces and mixes with the fresh groundwater in coastal aquifers due to the density difference existing between waters of different salinities.

Contamination of groundwater due to saline intrusion into coastal aquifers has become a major concern for coastal communities which rely on groundwater as their principal source of drinking water. Therefore, understanding of saline intrusion is essential for the management of coastal water resources.

Saltwater intrusion in coastal aquifers has traditionally relied upon observation wells and collection of water samples. This approach may miss important hydrologic features related to saltwater intrusion in areas where access is difficult and wells are widely spaced.

Among geophysical exploration techniques, the electrical resistivity imaging method has been increasingly applied in geo-environmental investigations. This method provides information about resistivity distribution within the subsurface structures. It is commonly used by researchers for ground water exploration and seawater intrusion, and proved to be successful in detecting the fresh/salt-water interface in coastal aquifers (e.g. Abdul Nassir et. al., 2000, Abdul Rahim et. al., 2002, Al-Sayed et. al., 2007, Ekinci et. al., 2007, Ibrahim et. al., 2002, Mohsen et. al., 2006, Umar et. al., 2002, 2006 and Vincent et. al., 2002).

The electrical conductivity of an aquifer is controlled primarily by the amount of pore space of the aquifer (that is the aquifer porosity) and by the salinity of the water in the pore space. The increases in either the porosity or the concentration of dissolved ions result in an increase in the conductivity of the groundwater. Since seawater has a high concentration of dissolved ions, its presence in a coastal aquifer can be inferred from measurements of the spatial distribution of electrical conductivity (C. P. Kumar).

This study aims to map the subsurface salinity distribution in Carey Island due to salt water intrusion by using electrical resistivity method. Since understanding of saline intrusion is essential for the management of coastal water resources, hence the purpose and the importance of this study is not in preventing salt water intrusion but in revealing the present state of the saltwater intrusion and controlling it.

DESCRIPTION OF THE STUDY AREA

Carey Island is an island in the state of Selangor, Malaysia. It is a huge island separated from the Selangor coast by the Klang River, connected by a bridge from Chondoi and Teluk Panglima Garang near Banting. It is located to the south of Port Klang and north of Banting town between Latitudes N 2° 48'14 49'' to N 2° 58'34'' and Longitudes E 101° 17' 10 48'' to E 101° 27' 3 20'' (Figure 1).

Carey Island represents part of the Selangor alluvial plain which is covered with alluvial quaternary deposits of Beruas, Gula and Simpang formations. The Beruas formation is formed by peat and clayey materials as well as silt and sands, whereas the Gula formation consists of clay, silt, sand and gravels. The Simpang formation is comprised of gravel, sand, clay and silt, which overlies the Carboniferous shale of the Kenny Hill formation bed rock. (Umar et. al., 2006).

Coastal lowlands in the west of the peninsula Malaysia were recognized as area of high potential for groundwater production. They are generally covered with clay soil containing mostly saline water (Ibrahim et. al., .2002).

According to the lithological cross sections obtained from the water productions wells distributed in the area of Carey Island (Figure 2) the subsurface is composed of two aquifers that contain sand mixed with marine clay and silt (Doll, 1988).

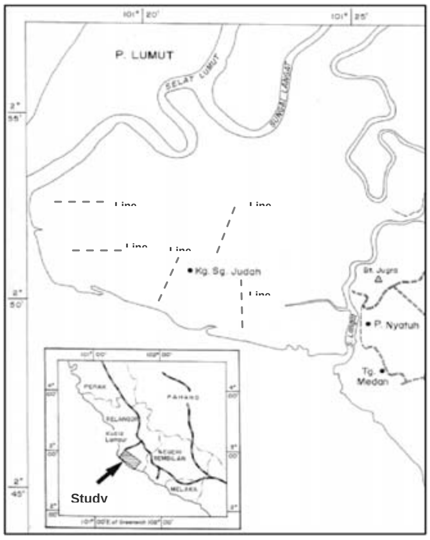
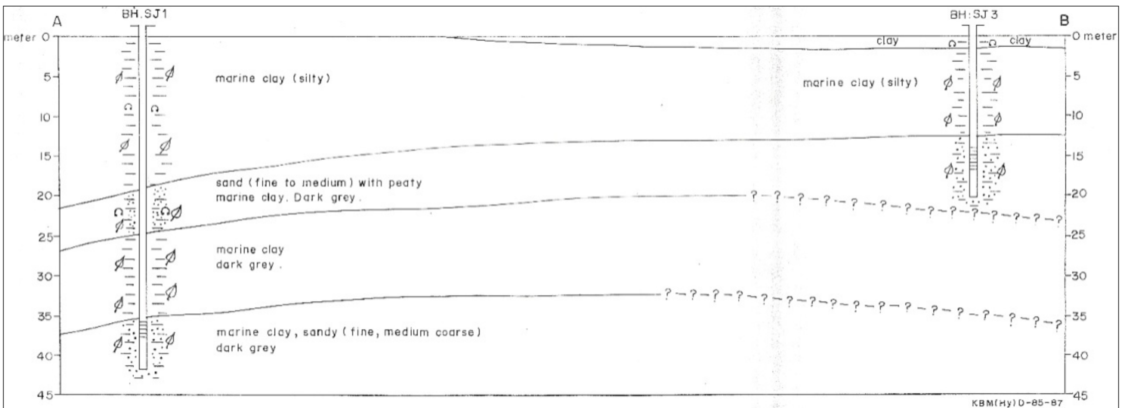


Figure1.location of the study area and the electrical resistivity profiles conducted



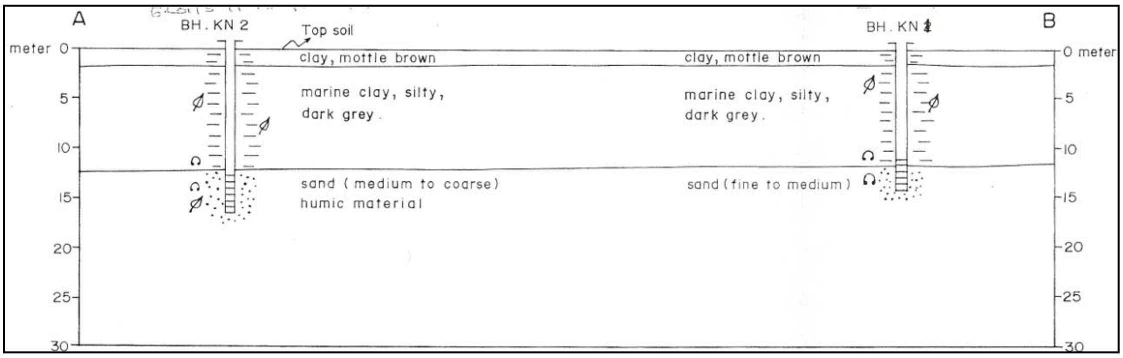


Figure2. Lithologic cross section of four boreholes located near the survey site (Doll, 1988)

DATA ACQUISITION AND PROCESSING

The measured apparent resistivity showed some negative values that were removed and than filled up using the nearest neighbor method this method is effective for filling in the holes in the data and than treated with low pass filter which blocks out higher frequencies and reduces noise using surfer 8.

The data were processed using the 2D inversion algorithm of Loke and Barker (1996) RES2DINV which employs a least square optimization technique to invert two dimensionally measured apparent resistivity pseudo sections to define the true resistivity distribution in the subsurface .The technique adjusts the 2D resistivity model by reducing the difference between the calculated and the measured apparent resistivity values in each iteration until an acceptable RMS misfit is generated.

The results in this study were obtained by including smoothness of model resistivity and by using the finite element method since no existence of topographical changes in the study area.

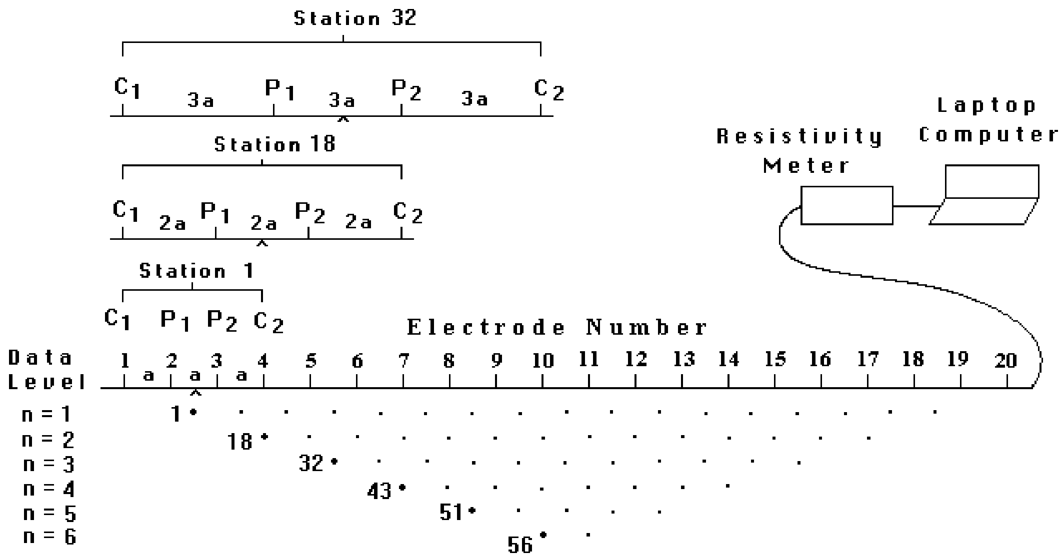


Figure3 The arrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build up a pseudosection

RESULTS AND DISCUSSION

The five geoelectrical sections were obtained up to penetration depth of about 66m.and for a total length of 400m and they are all perpendicular to the shore line.

The resistivity line1 runs in S-N direction (Figure 4.a), there are three distinct resistivity zones along this profile. The first one is observed as a top layer of low resistivity (less than 1.2 Ωm) it has approximately a 31m vertical extension which corresponds to silty marine clay based on the lithologic cross section and which could be interpreted as saline water. This clay layer is underlying by a layer of higher resistivity (2 - 4 Ωm) with a depth of more than 50m.This second layer corresponds to the sandy aquifer mixed with peaty marine clay. Underlying this aquifer is a higher resistivity zone (30 - 70 Ωm) which represents the Kenny hill formation bed rock.

The resistivity line 2 runs in W-E direction (Figure 4.b). The high resistivity zone on the top corresponds to the road embankment material, because the survey line was laid out on the road shoulder. The region of low resistivity values (0.05-3 Ωm) at the right side of the profile corresponds to the saline water, and it extends from depth 9m to more than 40m. The zone within the range of (19-50 Ωm) in the inverse resistivity model section represents the bed rock. This low resistivity of the bed rock is probably due to the very wet marine deposits overlying the bed rock, which had decreased the resistivity contrast, since half the total voltage signal received at the surface is contributed by the layer above the depth of investigation (Edwards 1977).

The traverse of line3 runs in S-N direction (Figure 4.c). Three different resistivity zones can be distinguished. The first zone with very low resistivity values (0.2-2 Ωm) represents the saline water. Underlying it is the sandy aquifer with resistivity ranging between (5 - 17 Ωm). The higher resistivity values (50-552 Ωm) are concentrated at the bottom of the profile from depth around 20m and which represents the bed rock.

The profile 4 runs in SW-NE direction (Figure 4.d) and it displays very similar features as those obtained in line1, with different resistivity values and vertical extensions. The high resistivity zones at the top of the profile refers to marine clay and underlying it, is the sandy aquifer that extends from depth of 8m to more than 40m down, while the bed rock is detected at shallower depth of 30m and with higher resistivity values of (52-125 Ωm)
The profile 5 (Figure 4.e) displays very similar results with the profile 2 (Figure 4.b) The only difference is that the zone that corresponds to he saline water (0.01 - 3 Ωm) in the right side of the profile

extends from depth 9m to 31m and the resistivity of the bed rock is (24 Ωm) which is lower compared to the one in the profile2.

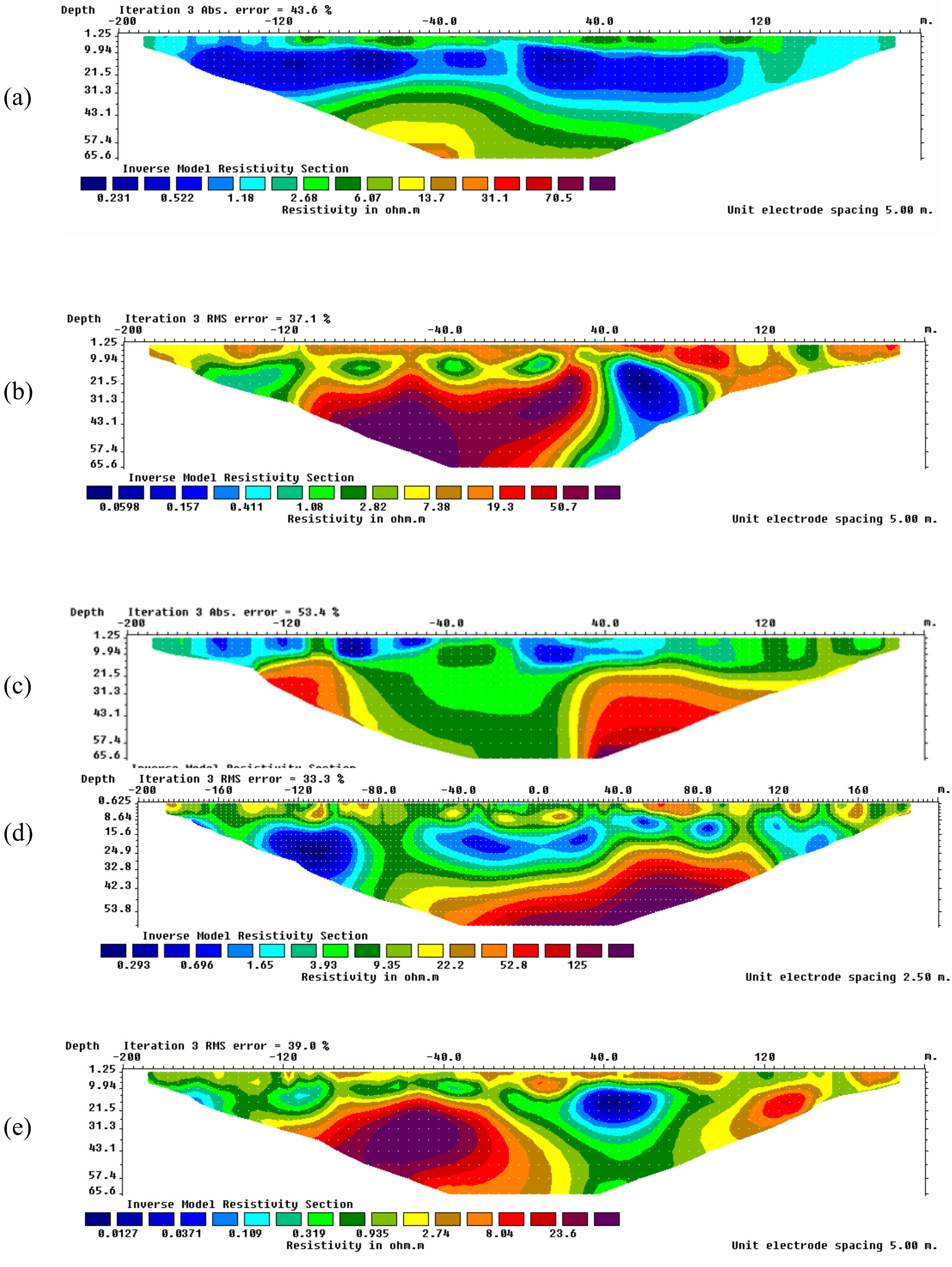


Figure4.Electrical resistivity images along the lines 1(a), 2(b), 3(c), 4(d), 5(e).

CONCLUSION

The conducted electrical resistivity tomography at the coastal alluvium in Carey Island helped successfully to map the subsurface salinity of the study area. The presence of a low resistivity zone (less than 3 Ωm) in the tomograms is the main characteristic of the resistivity survey. This is considered to be associated to the seawater intrusion from the Strait of Malacca. The saltwater was detected at shallow depth around 10m and extending down to more than 40m (line 2 and line 4).

The lithologic cross section made near to line1 and line 4 gave good correlation with the resistivity data which proves the efficiency of combining the two methods in solving environmental problems.

ACKNOWLEDGEMENT

We, the authors would like to thank the university Malaya for the grant offered to achieve this research work.

REFERENCES

Abdul Nassir S. S., Loke M. H., Lee C. Y. and Nawawi M. N. M., (2000). "Salt-water intrusion mapping by geoelectrical imaging surveys". European Association of Geoscientists & Engineers, Geophysical prospecting, 48, pp. 647-661.

Abdul Rahim S. and Abdul Ghani R., (2002). "An integrated approach for managing saltwater intrusion in coastal area". Proceedings of the regional symposium on environment and natural resources, Malaysia, Vol. 1, pp. 436-444.

Al-Sayed E. A. and El Qady G. (2007). "Evaluation of sea water intrusion using the electrical resistivity and transient electromagnetic survey: Case study at fan of wadi feiran, Egypt." EGM 2007 international workshop, Capri, Italy.

Doll S. N. (1988). "Penyiasatan menentukan sumber air tanah untuk kegunaan pam-tanagan di luar Bandar daerah Kuala Langat, Selangor". Geological survey report No. GPH1 / 1988. Geological survey department, Malaysia.

Edwards L.S., (1977). "A modified pseudosection for resistivity and induced-polarization." Geophysics 42, pp. 1020-1036.

Ekinci Y. L., Demirci A. and Ertekin C., (2007). "Investigation of the layered seawater-freshwater interface: A study from Kalekoy-Gokceada, Turkey. International earthquake symposium Kocaeli 2007. pp. 225-229.

Ibrahim A. N., Harith Z .Z. T., Nawawi M. N. M. and Ayub M. S., (2002). "Mapping of groundwater aquifer using integrated geophysical methods." Proceedings of the Regional Symposium on Environment and Natural Resources, Malaysia. Vol. 1, pp.177-187.

Kumar C. P., "Management of groundwater in salt water ingress coastal aquifers." Report by the national institute of hydrology, Roorkee - 247667 (Uttaranchal).

Loke M.H. and Barker R.D. (1996). "Rapid least-squares inversion of apparent resistivity pseudosection by a quasi-Newton method." Geophysical Prospecting, Vol. 44, pp. 131-152.

Mohsen S., Anvar K., Ahmed E., Abdel Azim I., Salim A., Johan P., Ampar S. and Salim A., (2006). "Geophysical Studies for Assessment of Seawater Intrusion in the Aquifers of Wadi Ham, UAE and Wadi Al Batinah, Oman". The fifth annual U.A.E. university research Conference, Vol. 15, pp. 15-24.

Stewart, M.T. (1999). “Geophysical Investigations”. In. Bear, Jacob, and others, Eds., Seawater Intrusion in Coastal Aquifers - Concepts, Methods and Practices, Dordrecht, The Netherlands, Kluwer Academic Publishers, pp. 9-50.

Umar H., Abdul Rahim S., Edna Pilis M. and Siti Zalifah J., (2002). “Integrated geological investigation of saltwater intrusion: A case study in Kuala Selangor, Malaysia.” Proceedings of the Regional Symposium on Environment and Natural Resources, Malaysia. Vol. 1, pp. 402-412

Umar H., Rahman Y., Abdul Rahim S., Mohd S. A., (2006). “Electrical imaging of the groundwater aquifer at Banting, Selangor, Malaysia” Environmental Geology, Vol. 49, No. 8, pp. 1156-1162.

Vincent P., Esther B., Kevin O., Evert S., Koos G. and Michel G., (2002). “The use of CVES to map the subsurface salinity distribution: A case study from the Netherlands.” 17th Salt Water Intrusion Meeting, Delft, The Netherlands, pp. 283-290.