Groundwater Detection in Alluvium Using 2-D Electrical Resistivity Tomography (ERT)

Rosli Saad
Senior Lecturer (Dr.), Geophysics Section, School of Physics, Universiti Sains Malaysia, Penang, Malaysia;
e-mail: rosli@usm.my

Prof. (Dr.) **M.N.M. Nawawi**
Geophysics Section, School of Physics, 11800 Universiti Sains Malaysia, Penang, Malaysia; e-mail:mnawawi@usm.my

Edy Tonnizam Mohamad
Senior Lecturer (Dr.), Department of Geotechnics and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Johor
e-mail: edy@utm.my

ABSTRACT

2-D electrical resistivity tomography (ERT) has been extensively used for many years for groundwater exploration. The technique is employed together with drilling for determination of resistivity value of alluvium and the effect of groundwater. The study was conducted in areas which have a geology record of thick alluvium. The result show that groundwater will lower the resistivity value and silt also will bring down the resistivity value lower then groundwater effect. Groundwater reservoirs are found in saturated sand, saturated sandy clay and saturated silt, clay and sand.

KEYWORDS: Electrical resistivity tomography; Alluvium; Resistivity value; Saturated; Groundwater.

INTRODUCTION

The role of geophysical methods in Groundwater Exploration is vital. The aim is to understand the hidden subsurface hydrogeological conditions adequately and accurately. The basis of any geophysical method is measuring a contrast between physical properties of the target and the environs. The better the contrast or anomaly, the better the geophysical response and hence the identification. So, the efficacy of any geophysical technique lies in its ability to sense and resolve the hidden subsurface hydrogeological heterogeneities or variation. Hence for groundwater exploration, a judicious application or integration of techniques is most essential for success in exploration, technologically as well as economically. Generally, alluvium sediments consist of clay, silt, sand and gravels. Groundwater is the water that lies beneath the ground surface, filling the pore spaces between grains in bodies of sediment and clastic sedimentary rock and filling cracks and crevices in all types of rock (Plummer et al., 1999). Little is known about the moisture capacity and the status of the regolith (unsaturated zone) or how this has changed as a result of changes in the soil water balance. To examine the moisture status of the regolith, 2-D electrical resistivity tomography (ERT) and soil coring was applied to transect in the central alluvium. Soil resistivity is related to soil water content, salinity and clay (content and type). Data can be interpreted qualitatively with the aid of lithology from bore logs and measures of salt and clay content. Contrasts in regolith under native vegetation and under irrigated agriculture were examined, to assess the impacts from various land uses (19th World Congress of Soil Science, 2010). Studies have showed that groundwater could be explored using electrical resistivity methods (Olorunfemi and Fasoyi, 1993; Olasehinde, 1999; Alile et al., 2008). Therefore, the use of such techniques for groundwater exploration has earned an important place in recent years despite some interpretive limitation (Dogara et al., 1998; Singh et al., 2006). It is therefore expected that the results obtained from this study would produce detailed groundwater condition and areas within the observatory can be recommended for the location of deep tube wells (Nmankwo, 2011). The objective of the geophysical surveys was to delineate the nature of alluvium using 2-D electrical resistivity tomography (ERT) method for groundwater reservoir.

2-D ELECTRICAL RESISTIVITY TOMOGRAPHY

2-D electrical resistivity tomography (ERT) is now mainly carried out with a multi-electrode resistivity meter system (Figure 1). Such surveys use a number (usually 25 to 100) of electrodes laid out in a straight line with a constant spacing. A computer-controlled system is then used to automatically select the active electrodes for each measure (Griffith and Barker, 1993).

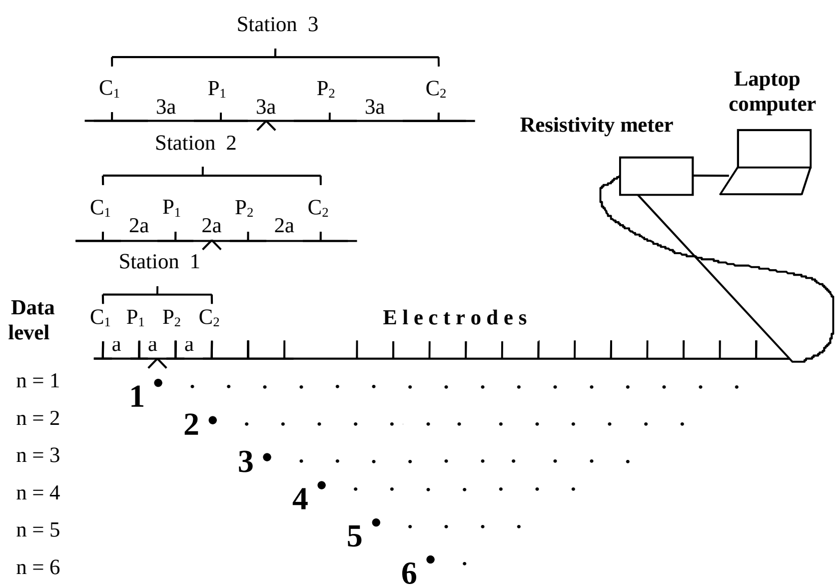


Figure 1: The arrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build up a pseudosection.

The resistivity method basically measures the resistivity distribution of the subsurface materials. Table 1 and 2 shows the resistivity value of some typical rocks, soil materials and water (Keller and Frischknecht 1996). Igneous and metamorphic rocks typically have high resistivity values. The resistivity of these rocks is mainly dependent on the degree of fracturing. Since the water table in Malaysia is generally shallow, the fractures are commonly filled with ground water. The greater the fracturing, the lower is the resistivity value of the rock. As an example, the resistivity of granite varies from 5000 Ωm in wet condition to 10,000 Ωm when it is dry. When these rocks are saturated with ground water, the resistivity values are low to moderate, from a few Ωm to a less than a hundred Ωm. Soils above the water table are drier and have a higher resistivity value of several hundred to several thousand Ωm, while soils below the water table generally have resistivity values of less than 100 Ωm. Also clay has a significantly lower resistivity than sand.

Table 1: Resistivity values of common rocks and soil materials in survey area.

Material	**Resistivity (Ωm)**
Alluvium	10 to 800
Sand	60 to1000
Clay	1 to 100
Groundwater (fresh)	10 to 100
Sandstone	8 - 4 x 10^3
Shale	20 - 2 x 10^3
Limestone	50 – 4 x 10^3
Granite	5000 to 1,000,000

Table 2: Resistivity values of some types of waters.

Type of water	**Resistivity (Ωm)**
Precipitation	30 - 1000
Surface water, in areas of igneous rock	30 – 500
Surface water, in areas of sedimentary rock	10 - 100
Groundwater , in areas of igneous rock	30 - 150
Groundwater , in areas of sedimentary rock	> 1
Sea water	≈ 0.2
Drinking water (max. salt content 0.25%)	> 1.8
Water for irrigation and stock watering (max. salt content 0.25%)	> 0.65

Direct-current (DC) resistivity method is used to determine the electrical resistivity structure of the subsurface. Resistivity is defined as a measure of the opposition to the flow of electric current in a material. The resistivity of a soil or rock is dependent on several factors that include amount of interconnected pore water, porosity, amount of total dissolved solid such as salts and mineral composition (clays). The 2-D DC resistivity method is describe by Zohdy and others (1974), Sumner (1976), Reynolds (1997) and Rubin and Hubbard (2006).

STUDY AREA

The study was conducted in Malaysia. Selangor and Pahang areas were chosen since they have geology record of thick alluvium (Figure 2). One study line of 200m length was located at Selangor study area near Universiti Selangor. 3 study lines were located at Pahang study area of which 2 lines of 400m length were at Permatang Lawang and 1 line of 300m length was at Inderapura.

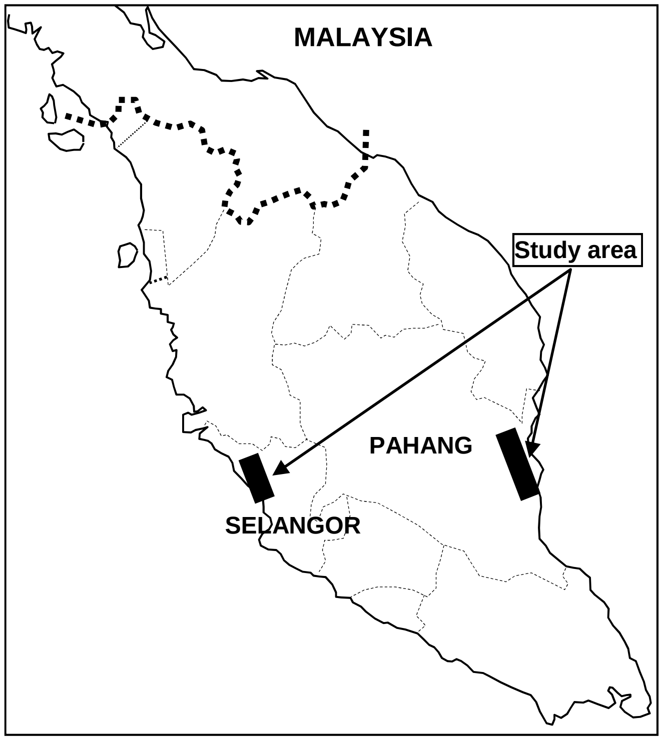


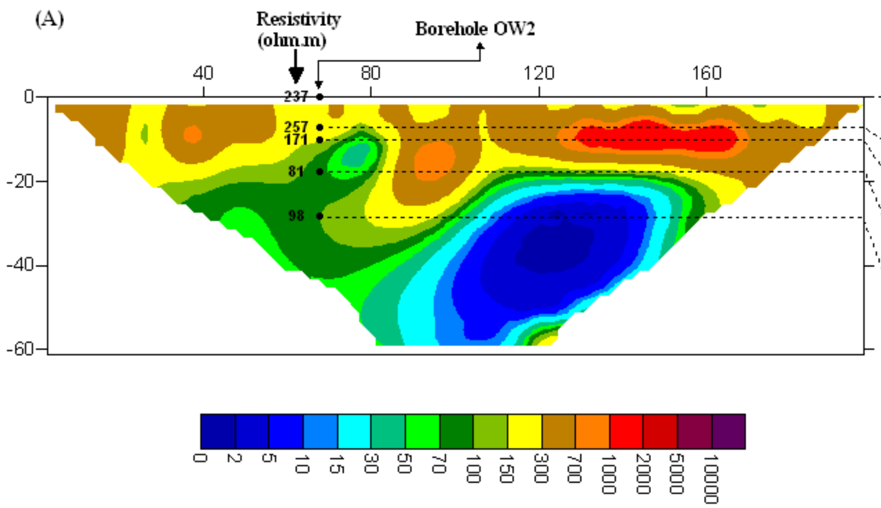
Figure 2: The study areas with thick alluvium geology record.

METHODOLOGY

2-D electrical resistivity tomography (ERT) surveys were conducted in Selangor and Pahang areas. By using ABEM SAS4000 system, the surveys used Pole-dipole array with 5m electrode spacing, 2mA minimum and 20mA maximum current. The raw data was processed and interpreted using RES2DINV software on an inexpensive microcomputer. Boring was performed on every survey line for correlation with the 2-D ERT result.

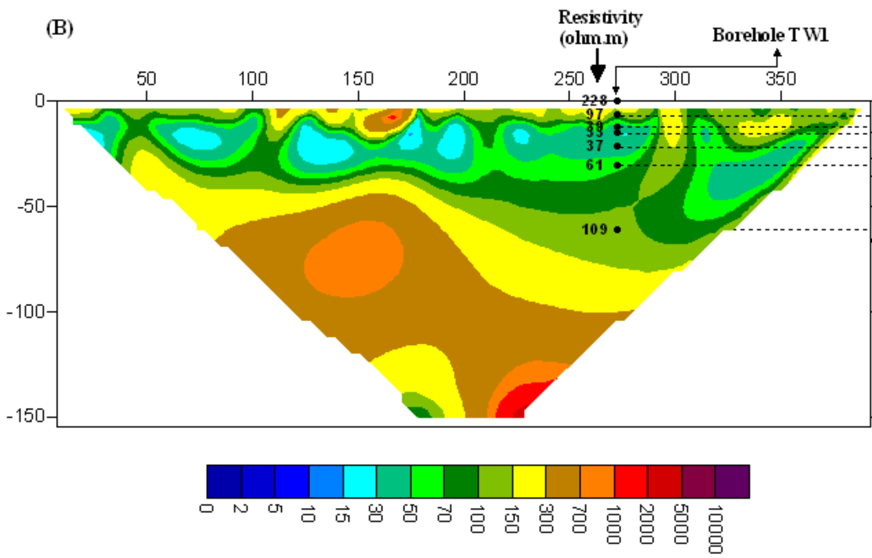
RESULTS

Figure 3 show resistivity section of all study areas with resistivity values <800 Ωm which indicate an alluvium overburden (Table 1). Drilling record for every study line shows the lithology of every study areas. The result shows fine to coarse sand with resistivity value of 81-257 Ωm while saturated sand with resistivity value of 45-75 Ωm, and silty sand with resistivity value of 29-57 Ωm. Clay shows resistivity value of 37-88 Ωm, silty clay, 20-69 Ωm while sandy clay, 57-109 Ωm and saturated sandy clay, 37-39 Ωm. Silty clay with sand shows resistivity value of 20-97 Ωm, while saturated silty clay with sand is 31-45 Ωm (Table 3).



Borehole OW2

Depth (m)	Description	Depth of aquifer & flow rate
0- 7.0	Light grey to coarse Sandy CLAY	
7.0-10.0	Medium to coarse SAND	
10.0-17.0	Fine to Medium SAND with decayed wood	
17.0-28.0	Yellow to light brown Sandy CLAY	



Borehole TW1

Depth (m)	Description	Depth of aquifer & flow rate
0- 6.0	Peat soil & brown dense, humic Clay and fine Sand	Cased hole
6.0-12.0	Marine & continental deposit Clay, Silt and Sand	
12.0-15.0	Very coarse, stiff Clay with traces of Sand	Yield >10.8m^3/h
15.0-21.0	Grey, dense, stiff Clay with traces of sand	
21.0-30.0	Grey, dense Clay	No aquifer
30.0-60.0	Marine alluvium of white stiff Clay with coarse Sand interbedded along the depth to 60.0m	Backfilled with Clay and drill cutting

Figure 3*a*: Resistivity section of study line at study areas with drilling record. (*a*) Selangor. *Figure* 3 *continues on the next page*

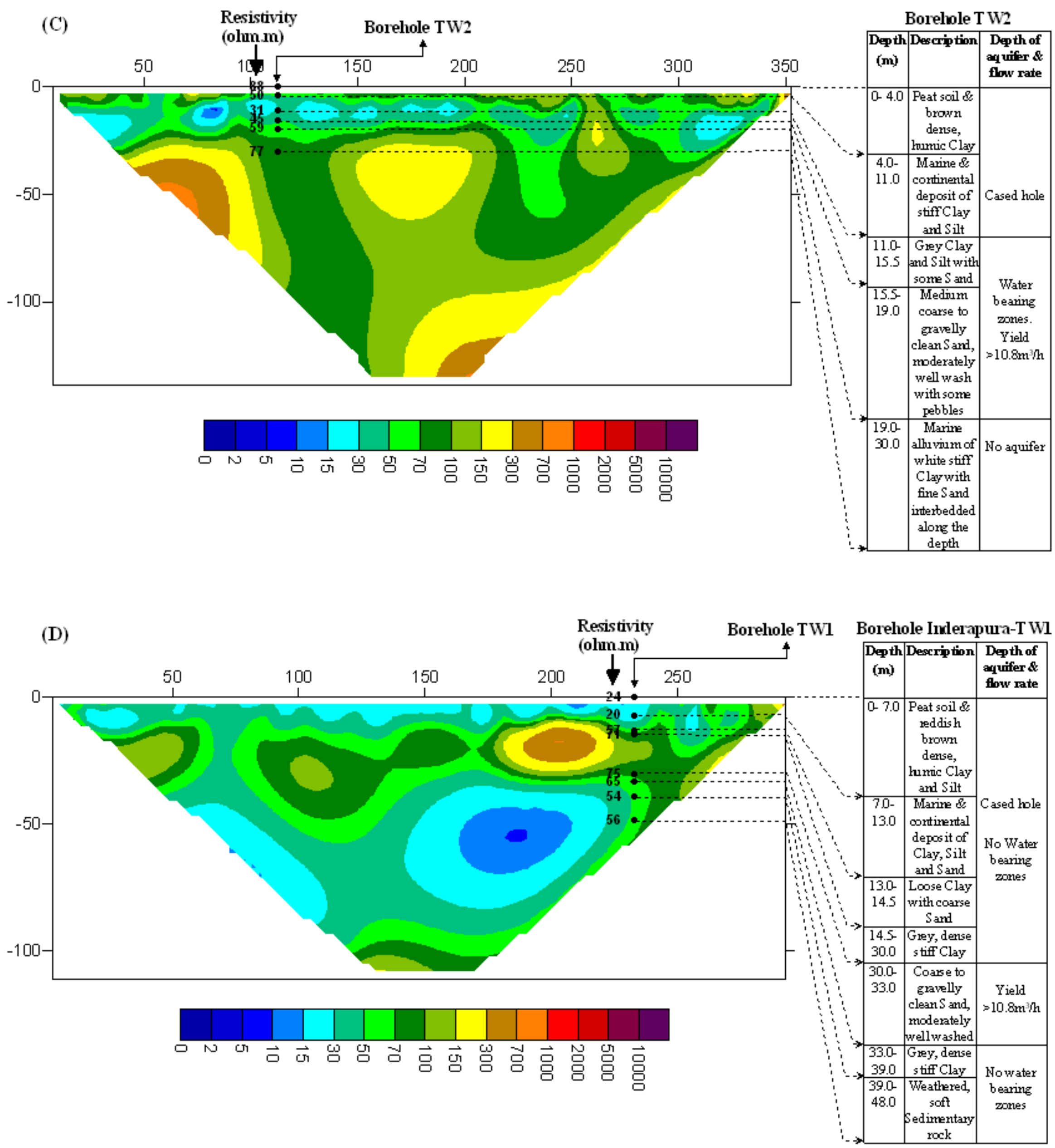


Figure 3: Resistivity section of study line at study areas with drilling record. (*a*) Selangor, (*b*) Permatang Lawang, Line1, (*c*) Permatang Lawang, L2 and (*d*) Inderapura.

Table 3: Resistivity values of alluvium at study areas.

Material	Resistivity (ohm-m)	Remark
Coarse Sand	237 - 257	
Silty Sand	29 - 57	
Coarse Sand	65 to 75	Water pumping rate, >10.8m^3/h)
Medium to coarse Sand	171 - 257	
Medium to Coarse Sand and pebbles	45 – 59	Water pumping rate, >10.8m^3/h)
Fine to medium Sand	81 – 171	
Sandy Clay	81 - 98, 97, 57-71	
Silty Clay	57 - 69, 31-50, 20-24	
Clay, silt and Sand	39 – 97, 20 - 57	
Clay, silt and Sand	31 – 45	Water pumping rate, >10.8m^3/h)
Stiff Clay	37-61, 50 - 88, 71-75, 54 - 65	
Stiff Clay with traces of Sand	37-39	Water pumping rate, >10.8m^3/h)
Stiff Clay with coarse Sand	61-109	
Stiff Clay with fine Sand	59 – 77	
Soft Sedimentary rock	54-56	

DISCUSSION

The resistivity value of sand is 81-257 Ωm, saturated sand is 45-75 Ωm, and silty sand is 29-57 Ωm. Meanwhile clay resistivity value is 37-88 Ωm, silty clay is 20-69 Ωm, sandy clay is 57-109 Ωm, and saturated sandy clay is 37-39 Ωm. Silty clay with sand shows resistivity value of 20-97 Ωm, while saturated silty clay with sand is 31-45 Ωm. Groundwater will lower the resistivity value and silt also will bring down the resistivity value lower then groundwater effect. Groundwater reservoirs are found in saturated sand, saturated sandy clay and saturated silt, clay and sand (Table 4).

Table 4: Resistivity values of alluvium and groundwater.

Material	Resistivity (ohm-m)	Remark
SAND	81 - 257	
Saturated SAND	45 - 75	Water pumping rate, >10.8m^3/h)
Silty Sand	29 - 57	
Clay	37 - 88	
Silty Clay	20 - 69	
Sandy Clay	57 - 109	
Saturated sandy Clay	37 - 39	Water pumping rate, >10.8m^3/h)
Silty Clay with Sand	20 - 97	
Saturated Silty Clay with Sand	31 - 45	Water pumping rate, >10.8m^3/h)
Soft Sedimentary rock	54-56	

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