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# Integral Analysis of Field Work and Laboratory Electrical Resistivity Imaging for Saline Water Intrusion Prediction in Groundwater



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# Integral Analysis of Field Work and Laboratory Electrical Resistivity Imaging for Saline Water Intrusion Prediction in Groundwater

**M H Zawawi[1], M F Zahar[1], M M M Hashim[1], Z A M Hazreek[2] N M Zahari[1], and M A Kamaruddin[3]**
[1]Department of Civil Engineering, College of Engineering, Universiti Tenaga Nasional, Kajang, MALAYSIA
[2]Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn, Batu Pahat, Johor, MALAYSIA
[3]School of Technology Industry, Universiti Sains Malaysia, Pulau Pinang, MALAYSIA

E-mail: mhafiz@uniten.edu.my

**Abstract.** Saline water intrusion is a serious threat to the groundwater as many part of the world utilize groundwater as their main source of fresh water supply. The usage of high salinity level of water as drinking water can lead to a very serious health hazard towards human. Saline water intrusion is a process by which induced flow of seawater into freshwater aquifer along the coastal area. It might happen due to human action and/ or by natural event. The climate change and rise up of sea level may speed up the saline water intrusion process. The conventional method for distinguishing and checking saltwater interference to groundwater along the coast aquifers is to gather and test the groundwater from series of observation wells (borehole) with an end goal to give the important information about the hydrochemistry data to conclude whether the water in the well are safe to consume or not. An integrated approach of field and laboratory electrical resistivity investigation is proposed for indicating the contact region between saline and fresh groundwater. It was found that correlation for both soilbox produced almost identical curvilinear trends for 2% increment of seawater tested using sand sample. This project contributes towards predicting the saline water intrusion to the groundwater by non-destructive test that can replaced the conventional method of groundwater monitoring using series of boreholes in the coastal area

## 1. Introduction

Saltwater interruption is a serious ecological issue since 50% of the total world population uses groundwater aquifers for their water supply [1]. One of the components that corrupt the groundwater quality is by raising the salinity levels to surpassing the drinking water standard. It might happen because of human action and/or by natural event. Besides, the climate change and ocean level ascent speed up saltwater interruption [2]. Saline water is a water that have a huge amount of salt concentration (mostly NaCl) and usually known as seawater. The salt fixation are generally communicated in parts per thousand (permille, ‰) or parts per million (ppm). The United States Geological Survey characterizes saline water in three salinity classifications. Salt focus in marginally saline water is around 1,000 to 3,000 ppm (0.1–0.3%), in tolerably saline water 3,000 to 10,000 ppm (0.3–1%) and in profoundly saline water 10,000 to 35,000 ppm (1–3.5%). Electrical resistivity imaging method has commonly use to predict the depth of soil profile for determining the potential location of borehole for groundwater harvesting [3]. Generally, this method utilizing one-dimensional (1D) vertical's electrical resistivity reviews. Be that as it may, 1D vertical electrical resistivity reviews just model layered profile of the subsurface and don't give exhaustive data to translating the structure and degree of subsurface hydro-topographical elements [4]. In that capacity, the joining of two-dimensional (2D) geophysical methods for saline water intrusion assessment has been utilized to give more accurate elucidation of the subsurface hydro-geological aspect from which potential position for beneficial borehole location are recognized [5][6][7]. This study was conducted in Nenasi, Pekan, Pahang Darul Makmur, Malaysia. The objective of this studies is i) To determine the subsurface profile using Electrical Resistivity Imaging (ERI) method in Pekan, Pahang; ii) To assess the salt water intrusion to the ground at Pekan, Pahang; and iii) To establish the correction factor of resistivity value for different type of soil using soilbox and ERI.

## 2. Description of Study Area

The study area located in the District of Pekan, Pahang between Longitude 103˚20'0" E to 103˚30'0" and Latitude 3˚40'0" N to 3˚10'0" N (Figure 1). The area of study is parallel to the coastal and cover an area of 450km$^2$ between the towns of Pekan in the north and Nenasi in the south. Base on Geological Map of Peninsular Malaysia 1985, the study area underlain by quarternary sediment consist of marine and continental deposits such as clay, silt, sand and peat with minor gravel. This study area is situated in very high groundwater potential area. Four sampling locations were selected base on the existing of tube well in this area that can obtain groundwater samples. All these tubes well have their purpose of usage.


**Figure 1.** Sampling location of groundwater located at Pahang Tua, Pekan, Tanjung Batu and Nenasi.

## 3. Methodology

This study consist of three phases which is field work resistivity imaging, laboratory soilbox experiments and data processing and analysis using statically analysis and utility of software. This field survey is conducted at and Nenasi, Pekan, Pahang Darul Makmur.The field resistivity data obtainments device for this imaging is the SAS 4000 ABEM Lund Imaging System, together with a relay switching unit (Electrode Selector ES 464), four 100-m multi-conductor cables, and steel rod electrodes. The utilized protocol for this project is Wenner – Schlumberger protocol [8]. The figured out resistivity value is not the genuine resistivity of the subsurface, but rather an "illusive" value, which is the resistivity of a homogeneous ground, which will give the same resistance result for the same electrode layout. The relationship between the "illusive" resistivity and the "genuine" resistivity is a perplexing relationship. To decide the genuine subsurface resistivity, a reversal of the deliberate evident resistivity values utilizing a PC program must be done. Resistivity meters normally give a resistance value, R = V/I, so in practice the apparent resistivity value is calculated by

$$pa = k\,R$$

The groundwater sample from the boreholes at survey area were taken to the laboratory for hydrochemistry analysis which is salinity test, Total Dissolve Solid test, and conductivity test. After completing the fieldwork resistivity imaging, laboratory soilbox was performed.

## 4. Result and Discussions

### *4.1 Field ERI*

Electrical resistivity imaging was processed at high tide and low tide condition at two different location in Pekan district which is Tanjung Batu, and Nenasi. Wenner-Schlumberger protocol was used for resistivity determination at all study location.

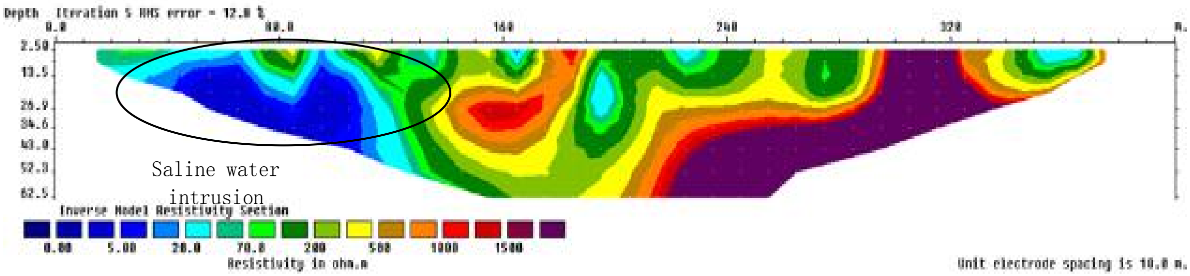


**Figure 2.** Nenasi resistivity profile during high tide.

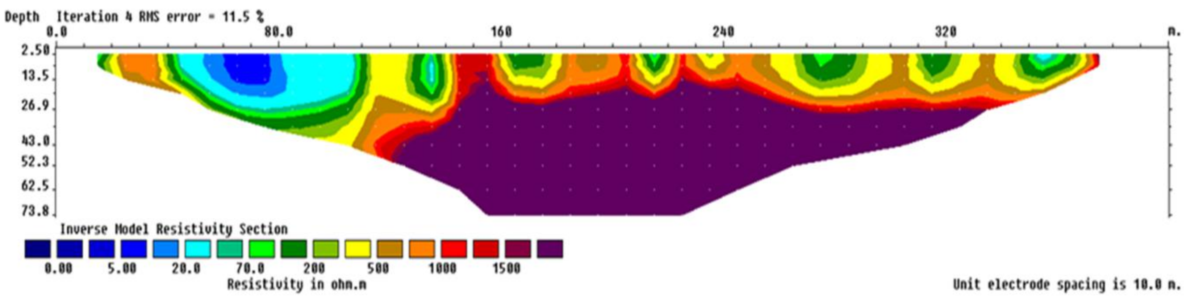


**Figure 3.** Nenasi resistivity profile during low tide.

The Electrical Resistivity Survey for high tide condition in Nenasi was carried out on March 3, 2016. From Figure 2, the RMS error for this survey is 12.8 %. This result is accepted because the RMS error from this survey is lower than ideal RMS error which is less than 15 %. The number of iteration for high tide condition is 5. From the high tide Electrical Resistivity profile (Figure 2), the dark blue area indicates the saline water intrusion in that area. The resistance value for that particular area is in the range of 1 Ohm-m to 10 Ohm-m. The surface distance for the saline water intrusion area can be found from 30 m to 110 m. The depth of that particular area can be found from surface down to 50 m deep.

For the low tide condition survey, the survey was carried out on the afternoon of that day. The RMS error for this survey is 10 %. From the low tide electrical resistivity profile, less saline water intrusion area in low tide condition compared to high tide condition. This indicated that seawater seeping into freshwater aquifer during high tide condition.

### *4.2 Laboratory Electrical Resistivity Experiment Using Sand Sample*

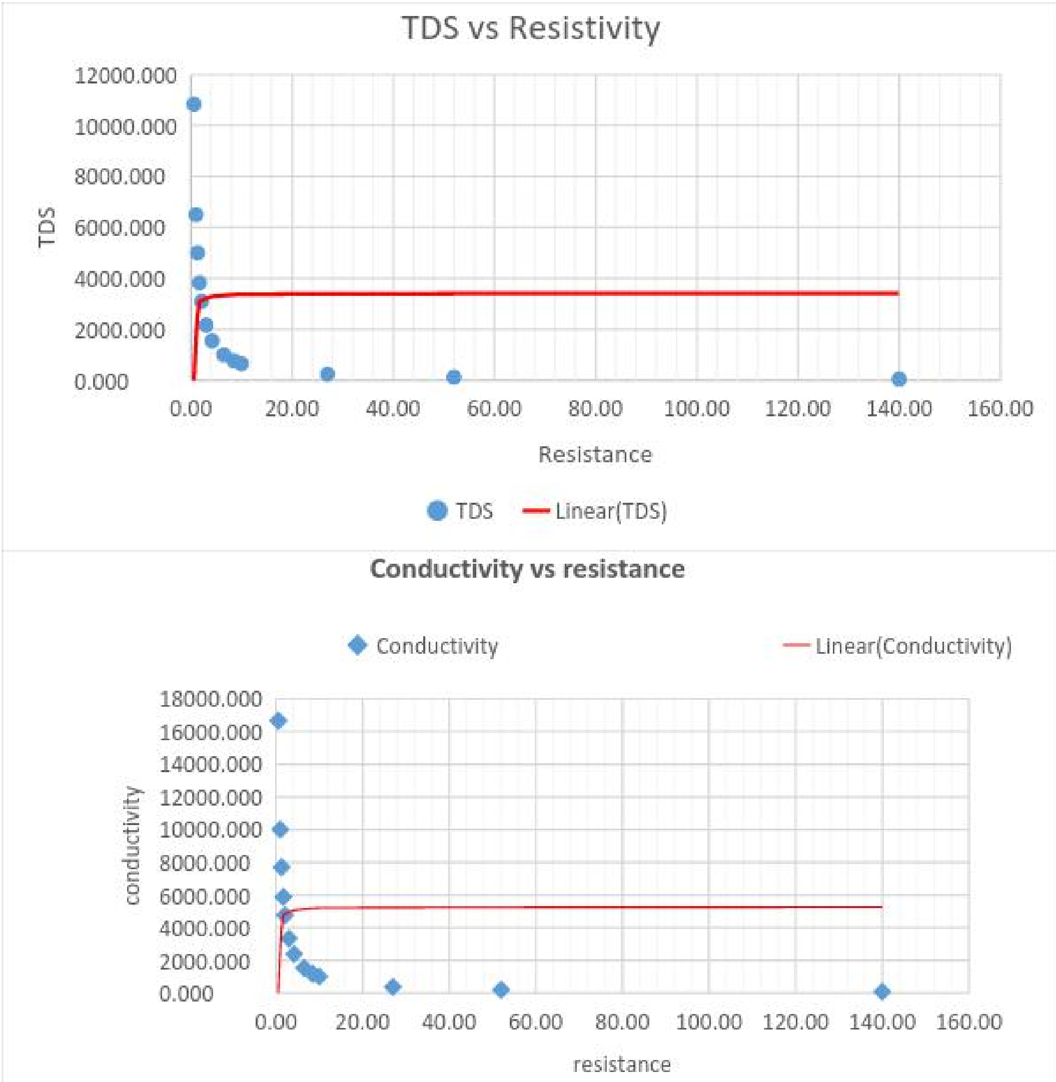


**Figure 4.** Conductivity vs resistance and Total Dissolve Solid vs resistance for sand sample.

It was found that correlation for both soilbox produced almost identical curvilinear trends for 2% increment of seawater tested using sand sample. According to Figure 4, the higher the moisture content of soil sample, the lower the soil resistivity value due to the presence of more seawater content in sample tested. When the seawater added continuously to the sand sample until it reach oversaturated condition, the increment of seawater in sand sample will resulting easier the current to flow in the soil sample, thus creating a lower soil resistance value. As the low saline moisture content soil producing low electrical conductivity which will increase the resistivity value due to current difficult to flow in dry and dense soil sample.

After all the field work and laboratory resistivity imaging experiment are conducted, the analysis were correlated to find the correction factors, c between field work and laboratory electrical resistivity experiment. It is determined by interpolate the resistivity value from laboratory resistivity experiment with field electrical resistivity value to determine lab value of TDS and conductivity. The TDS and conductivity value from field work analysis for both high tide and low tide condition were divided with laboratory values to determine its correction factor for type of soil at site survey. The correction factor for this study are as Table 1. The standard used for conductivity test was 111.3 mS/cm KCl Standard (1 D) part number S51M001 meanwhile for TDS, Hach Method 8163 used [9].

**Table 1.** TDS and Conductivity correction factor.

| | TDS Correction Factor | Conductivity correction factor |
|---|---|---|
| **High Tide** | **0.4** | **0.52** |
| **Low Tide** | **0.39** | **0.56** |
| **Mean Correction Factor** | **0.51** | **0.69** |

## 5. Conclusion

Laboratory work and analysis is one of the method to verify the fieldwork findings. It is shown by the resistivity value and percentages of saline moisture content produced The value of total dissolve solid, TDS, conductivity, and saline moisture content at field can be predicted from resistivity value from field electrical imaging survey by interpolating resistivity value from laboratory analysis and multiply its value with conversion factors.

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