AQUIFER CHARACTERIZATION AND GROUNDWATER POTENTIAL EVALUATION IN THE SEDIMENTARY ROCK FORMATION

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By

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I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Kajian ini telah dijalankan untuk mencirikan akuifer serta menilai potensi air bawah tanah di formasi batuan sedimen. Kaedah Keberintangan Elektik dan kaedah penggerudian telah digunakan untuk membangunkan sub-permukaan profil tanah bagi menentukan lokasi yang sesuai untuk pembinaan telaga tiub. Keputusan kerintangan menunjukkan hidrogeologi dan taburan ciri-ciri perbezaan antara kawasan kajian. Objektif utama kajian ini adalah untuk menghubung kait keputusan yang dihasilkan dengan menggunakan kaedah keberintangan elektrik bersama-sama dengan kaedah penggerudian bagi menentukan potensi ciri akuifer di kawasan kajian menggunakan hasil daripada ujian pengepaman. Kaedah keberintangan elektrik telah digunakan untuk membangunkan lapisan bawah permukaan tanah menggunakan pelbagai jenis tatasusunan iaitu Pole-Dipole, Wenner dan Schlumberger. Kajian ini telah dijalankan dengan menggunakan Sistem ABEM Terrameter LS 2 dan keputusannya dianalisis dengan perisian program penyongsangan kerintangan 2D (RES2DINV). Untuk kajian kerintangan pelbagai elektrod, kaji selidik ini dijalankan dengan sebaran elektrod maksimum 400m dan 800m dengan menggunakan dua jalur kajian keberintangan yang berbeza di zon yang disasarkan. Imej-imej yang telah dibentangkan dalam bentuk profil dua dimensi (2D) kerintangan memberikan pandangan yang jelas tentang pengagihan batuan pasir, kelodak dan syal serta potensi zon air bawah tanah. Penilaian potensi zon air bawah tanah yang dikenal pasti daripada hasil kerintangan telah disahkan dengan menggunakan ujian pam, ujian penyusutan dan ujian pemulihan. Gabungan antara ketiga-tiga tatasusunan dan korelasi antara log penggerudian dan ujian pengepaman boleh dipercayai dan berjaya dalam mengenal pasti zon berpotensi untuk mendapatkan air bawah tanah di kawasan kajian.

ABSTRACT

The study was carried out to characterize the aquifer and to evaluate ground water potential in the sedimentary rock formation. Electrical Resistivity method and drilling method was used to develop subsurface soil profile for the determination of suitable location for tube well construction. The resistivity results show hydrogeological and the distribution of inter distinctions features of the study area. The main objective of this study is to correlate the results obtain using the electrical resistivity method together with drilling method to determine the aquifer potential characteristic in the study area using the pumping test results. The electrical resistivity method was used to infer the subsurface soil layer using different types of arrays namely Pole-Dipole, Wenner and Schlumberger array. These surveys were conducted by using ABEM Terrameter LS System and the results were analysed using 2D resistivity inversion programme (RES2DINV) software. The survey alignments were conducted with maximum electrode spread of 400 m and 800 m by employing two different resistivity survey lines at the targeted zone. The images were presented in the form of two-dimensional (2D) resistivity profiles providing a clear view of the distribution of interbedded sandstone, siltstone and shale as well as potential groundwater zones. The evaluation of potential groundwater zones identified from resistivity results were confirmed by using pumping test, step drawdown test and recovery test. The combination between these three arrays and the correlation between the well log and pumping test is reliable and successful in identifying potentially favorable zones for obtaining groundwater in the study area.

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LIST OF ABBREVIATIONS

ERT	**E**lectrical **R**esistivity **T**omography
GPR	**G**round **P**enetrating **R**adar
GPS	**G**lobal **P**ositioning **S**ystem
IP	**I**nduced **P**olarization
MADA	**M**uda **A**griculture **D**evelopment **A**uthority
ReMi	**R**efraction **M**icrometer
RMS	**R**oot **M**ean **S**quare
SASW	**S**pectral **A**nalysis of **S**urface **W**aves
TEM	**T**ransient **E**lectromagnetic
VES	**V**ertical **E**lectric **S**ounding

NOMENCLATURES

A	Cross sectional area
I	Current
km	Kilometer
L	Length
m	Meter
m/s	Speed
R	Electrical resistance
V	Voltage
Ze	Median depth of investigation
ρ	Resistivity
Ωm	Ohm-Meter (resistivity)

CHAPTER 1

INTRODUCTION

1.1 Background of the study

The demand on water resources has been increasing rapidly and the issue of supplying adequate water to meet social needs is one of the most significant challenges. In Malaysia, the source of water for daily use comes from treated water from the reservoir. Due to the growth of population and expansion of industrial and agricultural, the demand for water has significantly increased manifold. The problems arise when the water is not sufficient to meet the demand or polluted. Large development in various sectors resulted in such impacts on high demand of clean water in some areas. In addition, climate change may be one of the contributors to the water supply problem. It changes the availability, quantity and quality of the water resources, which will have impact on the whole cycle of water supply. Nowadays, Malaysia and other Southeast Asian countries receive very high intensities of rainfall during monsoon season. In December 2014, the villagers in Kelantan and some parts of Terengganu faced water supply disruption after a water supply plant affected by the devastating floods (Ayob & Rahmat 2017). Tube wells were then built to supply clean water. This proved that groundwater can be an alternative source for water supply.

Besides, another factor that is often associated with the shortage of water is El Nino. El Nino is a natural phenomenon occurs in Pacific Ocean when warm waters of the western coast of South America replace the colder nutrient rich waters and cause impacts on the weather patterns such increase in temperature between 0.5°C and 2°C and reduce the amount of rainfall (Nampak et al. 2014).

This study will focus on groundwater potential in sedimentary rocks formation. Sedimentary rocks are formed from the consolidation of sediments. Among the type of sedimentary rock is shale. Shale constitute the thickest and most extensive aquitards in most sedimentary basins. Shale originates as mud laid down on ocean bottoms, in the gentle-water areas of deltas, or in the backswamp environments. Mud, from which shale is formed, can have porosities as high as 70-80% prior to burial. After consolidation, however, shale generally has a primary porosity of less than 20% and in some cases less than 5%. This type of sedimentary rock has higher groundwater potential compared to other type of rock such as igneous and metamorphic rock. A detail study about the type of rock and its potential for groundwater prospect is needed because the groundwater resources is very important for the future demand of water in Malaysia.

Despite its importance, groundwater behaviour and properties is poorly understood and often undervalued. This may in part derive from the nature of groundwater which is complex and a hidden resource that is difficult to understand.

1.2 Problem Statement

The exploration of groundwater is a complex method. It is difficult to locate the groundwater potential zones in sedimentary rock formation due to the heterogeneity and anisotrophy of the rock mass. Rock masses are composed of various rock types, inter-bedding and intrusion of foreign material. The conventional method is to conduct wash boring which is an invasive method. It is done based on direct drilling by the principle of trial and error. It is a popular method due to the use of limited equipment. In wash boring method, an open hole is formed on the ground so that the soil sampling or rock drilling operation can be done below the hole. To avoid drilling wells in unfavourable locations, a reliable method is required for assessing formation parameters before drilling takes place. This may ensure that a prospective productive well is sited where the aquifer is of adequate thickness and probably good quality. However, this method is costly and is a time consuming process. It can only produce 1-dimensional projection of the hydrogeological profile of the location. Besides, the result obtain from this method can only show the depth of groundwater level at that particular location and not at the area of surrounding. The data also cannot show the exact location of aquifer which have large volume of groundwater.

Apart from the conventional method, the electrical resistivity method is another method that can be used in the exploration of groundwater potential. It is a non-invasive method which mean that the soil is not being disturbed while doing the survey. It is suitable method because it require less time and can produced 2-dimensional projection of the interested location and can cover a very large area. The result from this method will be used to identify and infer the different subsurface condition. However, although the values of the resistivity is known, we cannot determine the aquifer potential and yield volume. To confirm the result from resistivity survey, drilling and pumping test is required. The correlation, verification and comparison of predicted results from this methods cannot be achieved without this verification. Thus, a better understanding between the predicted results from the analysis and observation in the field is required.

1.3 Objectives

The aim of this study is to identify the suitable location for groundwater exploration and to investigate the aquifer system from which the groundwater will be extracted as an alternative sources for water supply.

The specific objectives are as listed below:

1. To determine the geo-electrical parameters of the aquifer present in the sedimentary rock formation using various electrical resistivity arrays measurements (Pole-Dipole, Wenner and Schlumberger array).

2. To correlate the electrical resistivity values obtained from the electrical resistivity measurements to the aquifer characteristic for the groundwater potential identification.

3. To verify the groundwater potential identification based on the electrical resistivity results with the well log and pumping test results.

1.4 Scope of Work

The scope of work focuses on creating the 2-D electrical survey consist of a few parameters. A survey alignments will be conducted using multiple arrays such as Pole-Dipole, Wenner and Schlumberger array. The data then will be analyze using RES2DINV software to produce 2-D electrical resistivity profile of subsurface condition of the site. Then, a suitable location for tube well drilling will be identified to compare the geological condition with the resistivity data. The depth for the well will be determine from the resistivity data that is most accurate. The geological formation gathered from the drilling will provide useful information to characterize the aquifer and to confirm the potential yield volume of groundwater with the pumping test result that will be conducted after the drilling.

1.5 Justification of the Research

The need for water in Malaysia is very demanding. At the moment, the most widely used source of water is from the surface water which consist of river and reservoir. In the northern part of peninsular Malaysia particularly in Kedah and Perlis state, water is very important because it is used for agricultural purposes such as paddy plantation. From agricultural point of view, the ground water can serve as an alternative to the dependencies of surface water. However, the study of groundwater in the northern region is commonly done using the conventional method of drilling which is invasive and can be costly. The need for an efficient and proper type of groundwater study is very important because it can provide more accurate data and much more reliable than the conventional method.

This study is carried out to develop a better understanding about the potential of ground water sources in the ground reservoir especially in the sedimentary rock type. By understanding the characteristic of the aquifer present in the area, the estimating of the yield potential of groundwater present can be made before commencing drilling. Furthermore, in determining the suitable location for ground water extraction a few assumptions and engineering judgements is needed. It is very important to understand geological and hydrogeological properties of earth materials when it comes to the groundwater potential study.

1.6 Dissertation Outline

This thesis consists of five chapters.

Chapter 1: Introduction to the overall scope of study. This chapter also include the problem statement, objective and justification of research.

Chapter 2: Introduction to literature review of the study. A list of step to understand the concept and theory before starting the research will be presented. The previous work from other researcher serve as basic knowledge for the study.

Chapter 3: This chapter discuss the overall methodology that has been applied in this study. All the description about the test that have been carried out to determine the geological and hydrogeological properties of the site also being discussed in this chapter.

Chapter 4: Involved data processing, analysis, interpretation and evaluation by using software application. Result of the electrical resistivity survey, are presented. The results obtained from different objective were analyzed and the results are properly discussed below in this chapter.

Chapter 5: Conclusion is made based on result obtained from the resistivity survey and tube well data. All the limitations of study and assumption that have made throughout the study are listed. The recommendations for further study of this topic is clearly listed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Groundwater as an alternative source

Geophysics involves the measurement of contrasts in the physical properties of materials beneath the surface of the earth and the attempt to deduce the nature and the distribution of the materials responsible for these observations at the surface. It involves the application of the principles of physics to the study of the earth. The geophysical methods which are seismic, gravity, magnetic, electrical resistivity, induced polarization, spontaneous polarization, electromagnetic and radar sensor used in the investigation of the shallow and/or deep features of the earth's crust vary in accordance with the physical properties of rocks such as rock density, conductivity (resistivity), susceptibility, and dielectric constant.

Each geophysical method have their own technical and economic importance, thus it is very important that site investigations should be properly planned.

2.2 Geophysical Method for Subsurface Characterization

In recent years, geophysical methods have been widely applied to search for groundwater potential area. Surface geophysical methods are generally non-invasive and can be employed quickly to collect subsurface data. When performed properly and utilized early in the site characterization process, the methods can provide valuable information for placing tube wells and borings. They can be used later in the investigation to confirm and improve site characterization. Measurements are taken at or near the surface and are classified by the physical property being measured.

There are many different methods and varying setups or configurations for the different methods. The methods commonly used for geophysical surveys include:

i. Electrical methods such as Vertical Electric Sounding (VES), 2D Electrical Imaging.
ii. Magnetic method, including aeromagnetic surveys and magnetometers.
iii. Electromagnetic method such as frequency domain electromagnetic prospecting, time domain electromagnetic prospecting and Ground Penetrating Radar (GPR).
iv. Seismic method which include seismic refraction, seismic reflection, refraction micrometer (ReMi) technique and spectral analysis of surface waves (SASW).
v. Gravity method, including gravimetry and gravity gradiometry.

2.2.1 Electrical Resistivity Method

One of the commonly used geophysical methods in engineering investigations is the electrical resistivity method (Ariyo & Adeyemi 2009). Electrical resistivity surveying methods have been widely used to determine the thickness and resistivity of layered media for the purpose of assessing groundwater potential and siting boreholes in fractured aquifers. Traditionally, this has been done using one-dimensional (1D) vertical electrical sounding (VES) surveys.

The electrical resistivity method can be used for investigating subsurface layer properties and groundwater potential (Samsuddin 2013). The resistivity imaging surveys carried out is used to measure and maps the resistivity of subsurface materials. The resistivity distribution of the ground is sometimes related to some physical conditions such as lithology, porosity, degree of water saturation and presence of voids in the rocks (Anomohanran, 2013). From the result of the resistivity survey, the identification of the area with high potential of groundwater can be made. Electrical imaging is an appropriate survey technique for areas with geological condition of which the use of resistivity sounding and other techniques are unsuitable to provide detailed subsurface information (Asry et al., 2012). Electrical resistivity methods are particularly suitable for groundwater studies because hydrogeological properties, such as porosity and permeability, can be correlated to the electrical resistivity values (Muchingami et al., 2012).

The main principle is that electrical current is induced into the earth which generates a signal that is monitored at the surface. Geo-electrical resistivity techniques are increasingly being applied in addressing a wide range of hydrological, environmental, and geotechnical problems. This is due to their effectiveness in near-surface characterization (Aizebeokhai et al., 2016). The basic principle behind the non-destructive geophysical methods is to gather data in the medium under investigation without destroying the subsurface (Jakalia et al., 2015). Understanding how electrical resistivity (or conductivity) relates to the actual geologic properties of the earth is important. Electrical conductivity (or resistivity) is a bulk property of material describing how well that material allows electric currents to flow through it. Resistance is the measured voltage divided by the current. This is also known as Ohm's Law. Resistance will change if the volume of material changes. Resistivity is the resistance per unit volume. Resistivity is defined as the voltage measured across a unit cube's length. This results in units of $\Omega m^2/m$ or Ωm. The greek symbol rho (ρ), is often used to represent resistivity.

Conductivity, often represented using sigma (σ), is the inverse of resistivity. Higher value of conductivity will give low value of resistivity. The electrical conductivity of Earth's materials varies over many orders of magnitude. It depends upon many factors, which is rock type, porosity, connectivity of pores and nature of the fluid. Sedimentary rocks, which are usually more porous and have higher water content, normally have lower resistivity values compared to igneous and metamorphic rocks. The resistivity values range from 10 to about 10000 Ωm, with most values below 1000 Ωm (Collins et al., 2013). The resistivity values are largely dependent on the porosity of the rocks, and the salinity of the contained water. A very rough indication of the range of conductivity for rocks and minerals is in the following figure.

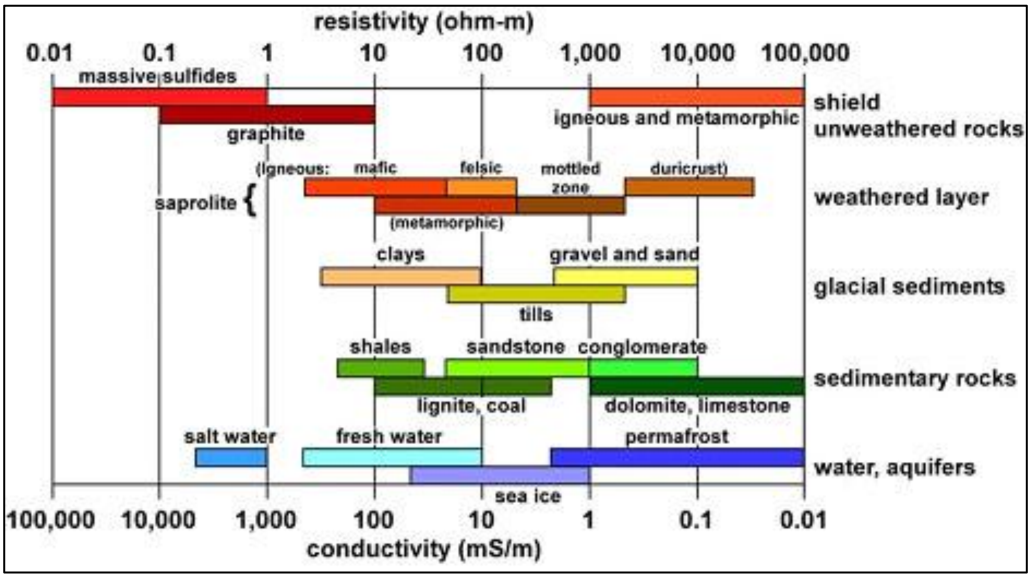

Figure 2.1: Range of conductivity for rocks and minerals

2.2.2 Transient Electromagnetic or Time-Domain EM (TEM) Method

The TEM method uses a magnetic field to induce currents in the earth. In the central loop TEM sounding method (referred to as TEM only from now on), constant magnetic field is built up by transmitting current through a big loop. The current is suddenly turned off. The decaying magnetic field induces secondary currents and a secondary magnetic field, decaying with time. This decay rate of the secondary field is monitored by measuring the voltage induced in a receiver coil (or a small loop) in the centre of the transmitting loop. Current distribution and the decay rate, recorded as a function of time, depend on the resistivity distribution of the earth, and can be interpreted in terms of the subsurface resistivity structures. Other methods may be based on a grounded dipole to create the primary magnetic field. The TEM method is a fairly recent addition to the resistivity methods used in geothermal exploration, developed in the late 1980s (Tecla and Salvador 2009).

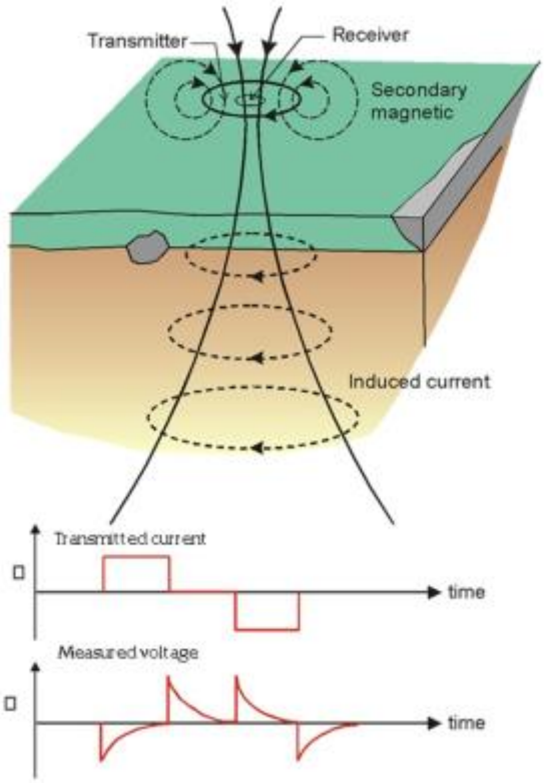

Figure 2.2: The principles behind TEM method

From Figure 2.3, it shows the actual lay-out for a TEM sounding. When the current in the big loop is turned off and the primary magnetic field decays, secondary currents are induced that gradually migrate to deeper levels. The secondary induced magnetic field is monitored by the receiver loop and a receiver in the centre of the survey. Readings are done from the turn-off at fixed intervals during the decay of the secondary magnetic field as it approaches zero, the last ones reaching the deepest structures. The measured resistivity in the subsurface is, similarly to the Schlumberger soundings, expressed as apparent resistivity ρ_a and is an expression for the average resistivity of the structures below the centre of the sounding. It is a function of several variables, including:

I. Measured voltage
II. Time elapsed from turn off
III. Area of loops/coils
IV. Number of windings in loops/coils
V. Magnetic permeability

2.2.3 Induce Polarization (IP) Method

This method require measuring instruments that are more sensitive than the normal resistivity method, as well has significantly higher currents. The time domain IP technique works by energizing the ground surface with an alternating square wave pulse via a pair of current electrodes. To date, majority of the surveys including the IP/Resistivity measurements are made on a regular grid of stations along survey lines.

When the transmitter (Tx) pulse has been transmitted into the ground via the current electrodes, the IP effect is measured as a time diminishing voltage at the receiver electrodes. Under ideal circumstances, IP chargeability responses are a measure of the amount of disseminated metallic sulfides in the subsurface rocks.

However, there are other rock materials that can contributing to the rise of IP effects, including some graphitic rocks, clays and some metamorphic rocks, that from a geological point of view, IP responses cannot be interpreted. Because of the non-uniqueness of geophysical measurements it is always crucial to import other sets of data to help with the interpretation.

Besides, from the IP measurements the apparent (bulk) resistivity of the ground is calculated from the input current and the measured primary voltage. IP/Resistivity measurements are generally considered to be repeatable within about five percent However, they will exceed that if field conditions change due to variable water content or variable electrode contact. The IP effect is a measure of the amount of IP polarizable materials in the IP/Resistivity measurements are influenced, to a large degree, by the rock materials nearest the surface (or, more precisely, nearest the measuring electrodes), and the interpretation of the traditional pseudosection presentation of IP data in the past have often been uncertain. This is because stronger responses that are located near surface could hide a weaker one that is located at deeper depth.

The IP surveys are common in mineral exploration surveys because it can assist to detect conductive minerals of very low concentrations that might otherwise be missed by resistivity or EM surveys.

2.2.4 Summary of Geophysical Method

Using geophysical methods to assess and monitor geotechnical properties would be extremely useful as they are non-invasive, cheaper to perform than drilling many sampling wells and faster in operation. The studies reviewed show that geophysical methods are applicable to hydrological investigation and the delineation of geologic structures and materials (Lateef, 2012). The incorporation of two-dimensional (2D) geophysical techniques for groundwater prospecting has often been used to provide a more detailed interpretation of the subsurface hydrogeological features from which potential sites for successful borehole location are identified. 2D electrical resistivity surveys can provide a more detailed subsurface structure and may assist in identifying the configuration of possible fractures which could conduct groundwater into the shallow subsurface of study area. Geo-electric parameters such as electrical resistivity, can be correlated to the intrinsic hydrogeological characteristic of the rock mass and verified with the well log and the pumping test result.

2.3 Characteristic of an aquifer

Groundwater potential study also has led to the need for accurate investigation and description of aquifers. Groundwater is stored in the open spaces and fractures within geologic materials such as soil, sand, and rock that occur under the land surface. Aquifers are the geologic layers that are filled with water and that can transmit enough water to supply a well. A hydrogeological characterization of a sedimentary rock formation can be achieved by estimating a set of aquifer's parameters, such as aquifer thickness and extent and also its hydraulic conductivity (Kanta et al., 2013). Aquifers differ in properties, because these properties are function of rock types constituting them. Different rock materials constitute the basement complex and sedimentary aquifers as stated by (Mogaji et al., 2011). In hard rock terrain, aquifers are fractured rocks and weathered in-situ materials, while the sedimentary aquifers consist of sands and sandstones. (Rinaldi et al., 2006) also mentioned that the existence of fracture zone in a geologic medium can assist in creating groundwater conduit medium and aids groundwater accumulation.

2.4 Geological Influence on Groundwater Characterization

Groundwater concerned with plates and bound syncline of platforms or large intermountain areas can be attributed to this type. Dominating thickness of sedimentary deposits changes in these conditions within 1-4 km, reaching in some structures 10-12 km or above. To a great extent, sedimentary deposits of these structures maintain primary sedimentary porosity that determines their storage and permeability. Formation of rocks with dominance of fractured porosity is typical mainly of sedimentary carbonate and clay-carbonate and of deep (3-4 km and above) parts of structures, where due to high temperature and pressure the processes of lithification of sedimentary rocks (the sandstone, argillite, siltstone and others) take place.

Due to conditions of sedimentation and relatively low tectonic dislocation, hydrogeologic formations of sedimentary deposits typically have layered structure of heterogeneity with aquifer-aquitard consecution. Sand, sandstone, fractured or karstic limestone and dolomite are usually the main types of water-bearing rocks. Typically low permeability rocks such as loam clays, carbonate-clayey rocks, gypsum-anhydride and salt (at their occurrence outside of upper zone of intensive leaching). The rocks, which are usually considered as water-bearing aquifers, have characteristic hydraulic conductivity 10^{-6}-10^{-4} m/s or more. Typical low permeable rocks for example, aquitards have hydraulic conductivity of the order of 10^{-7} m/s or less. The so-called confined aquifers, which are confined by aquitards at the top and the bottom (except when the upper aquifer has free groundwater level) are related to the cross-section of sedimentary rocks of this type.

2.4.1 Geological condition of Northern Malaysia

The part of the Western Belt in northwest Malaya comprising of Kedah, Perlis and north Perak on the whole has a unique geological formation. The Kubang Pasu Formation is overlain conformably by the Chuping limestone. The oldest strata are those of the Jerai Formation which is believed to be comparable to the Machinchang Formation in Langkawi. It is made up of a lower schist series and an upper arenaceous series. In the Muda Dam area of eastern Kedah, this formation is called the Semanggol Formation underlies a sequence of probable post-Triassic redbeds unconformably. The contacts between the Semanggol and older formations are interpreted to be faults. In addition isolated occurrences of Triassic limestones are also known in north Kedah. The Tertiary rocks in the whole of the Western Belt are presented by small basinal rocks of shale and other clastics with coal bands (Khoo & Tan 1983). The details about the geological map is shown in Figure 2.4.

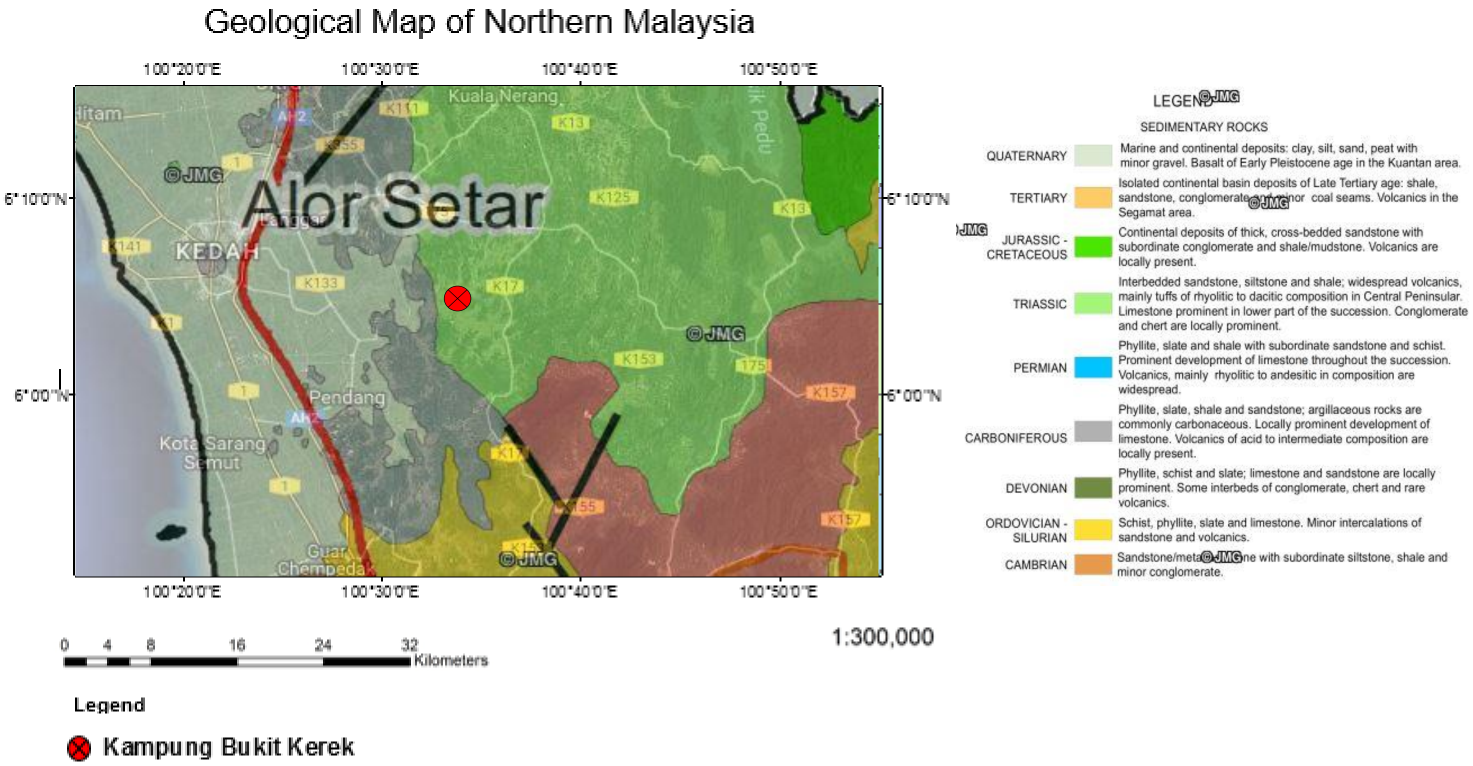

Figure 2.3: Geological Map of Peninsular Malaysia (Jabatan Mineral dan Geosains Malaysia, 2012)

CHAPTER 3

METHODOLOGY

3.1 Method Approach Overview

This chapter discuss about the field experiment that is used to interpret the subsurface condition of chosen location and the method for verification. The study will show the resistivity of the sub-surface geologic boundaries from their conductivities and use the same method to determine the geo-electrical parameters and establish the geo-electric sections. The summary of the method of the research schematic outline is shown in the Figure 3.1. The most important component of the study involved the method of investigation and followed by the method of analysis. In the investigation method, field investigation is used which can be divide into two part which are engineering geology and geophysical method.

The next part of the study is the method of analysis. In this part, the main components involved are data processing and result characterization. The processing steps include the description of the subsurface profile. The geophysical method involved the process of generating the resistivity models by using computer software. The result of the analysis will be followed by result characterization help by the correlation between borehole logging data.

The final step in the study is to fulfill the engineering requirement by conducting result assessment.

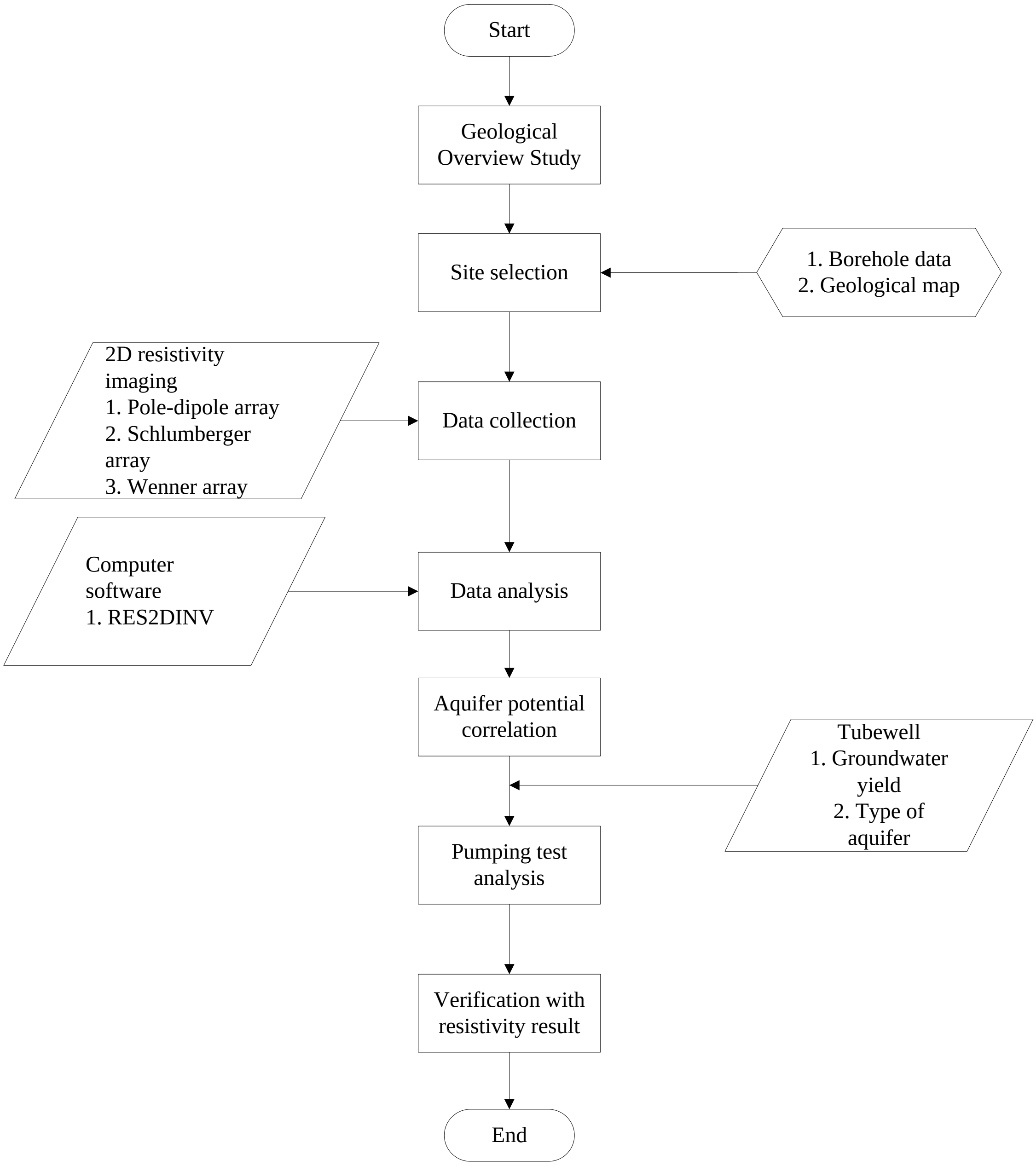

Figure 3.1: Flowchart of Methodology

3.2 Site Selection

The site chosen for this research is the northern region of peninsular Malaysia which is Kampung Bukit Kerek in Kedah. It is located in the Pendang district (coordinates: 6° 3′ 0″–6° 4′ 30″ N, 100° 34′ 30″–100° 36′ 0″ E). Pendang District spans over an area of 629 km^2 with a population of 112,000 people. The town is about 20 km from state capital Alor Setar and it is a district and a parliamentary constituency in Kedah, Malaysia. The district is primarily covered with paddy fields with agriculture being its main economic activity. This study area is a sparsely populated rural region with underdeveloped infrastructures.

Water supply for irrigation and domestic use in Kedah and Perlis is mainly supplied from surface waters from the Muda, Pedu (Kedah) and Timah Tasoh (Perlis) dams. The climate change in Malaysia especially during the drought season can affect the water level at the reservoir drastically (Issa et al. n.d.). If groundwater can be a viable alternative source of supply for multi-purpose usage, it can be better exploited if potential areas with abundant groundwater can be identified. In the future with the increase of human population, water demand will continue to increase thus, groundwater is considered as a viable option to the surface water supply that is commonly used now (Lateef, 2012). Based on experiment data for the resistivity survey, the geoelectrical parameters of the aquifer present in the sedimentary rock formation can be analyze using RES2DINV software for further analysis. Then, the electrical resistivity values is correlated with the hydrogeological characteristic of the soil for the aquifer potential study.

3.2.1 Justification for Site Selection

With the limited availability of surface water, the utilization of ground water as a supplementary irrigation in agricultural cultivation such as paddy plantation becomes an inevitable alternative. Utilization of groundwater for irrigation, known as ground water irrigation network is not very common in Malaysia in contrast to surface irrigation system that only utilizes gravity to drain water into rice fields. Depending on their potential, ground water is not only used for seasonal supplementary crop irrigation but can also serve as an irrigation solution for annual crops. Because the location of the study area is largely composed of paddy plantation area, it is a suitable location for groundwater exploration. A previous study by Muda Agriculture Development Authority (MADA) also shown that the location has high potential of groundwater source that can be used for agricultural purposes. The map of the study area is shown below in Figure 3.2. From the map, the study area is composed of interbedded sandstone, siltstone and shale.

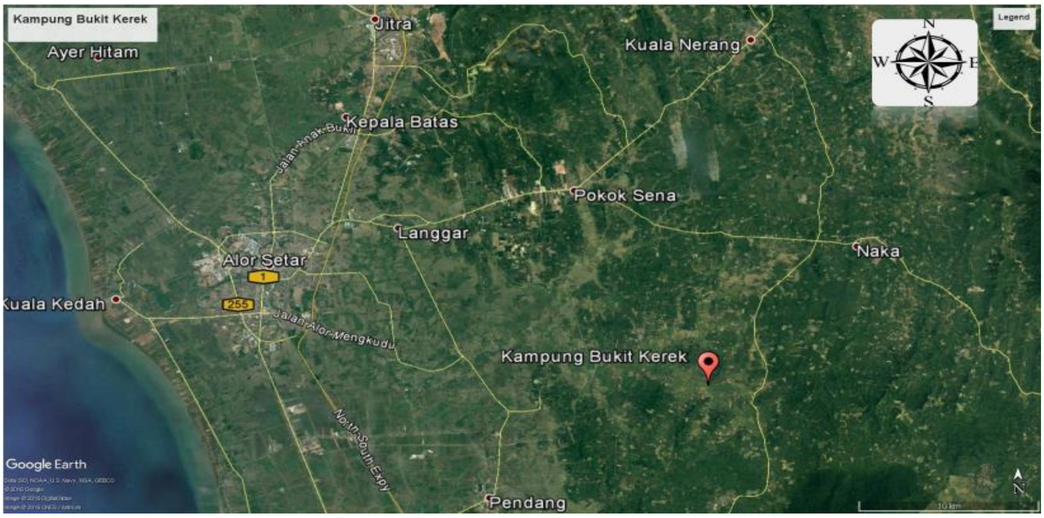

Figure 3.2: Location of the study area (Google Earth Imagery, 2015)

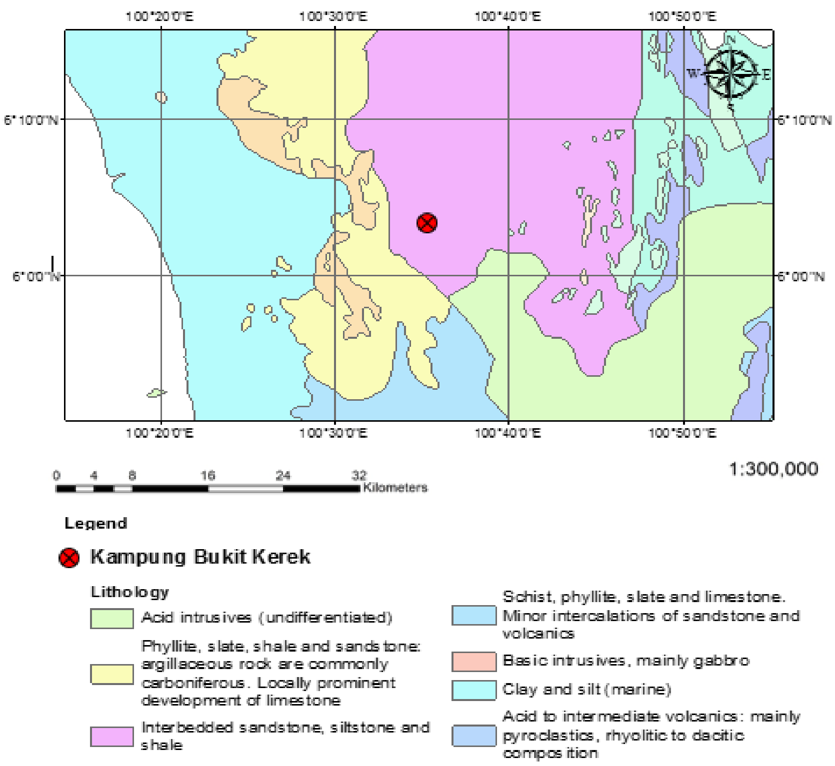

Figure 3.3: Geological condition of the study area at Kampung Bukit Kerek, Pendang Kedah (Jabatan Mineral dan Geosains Malaysia, 2012)

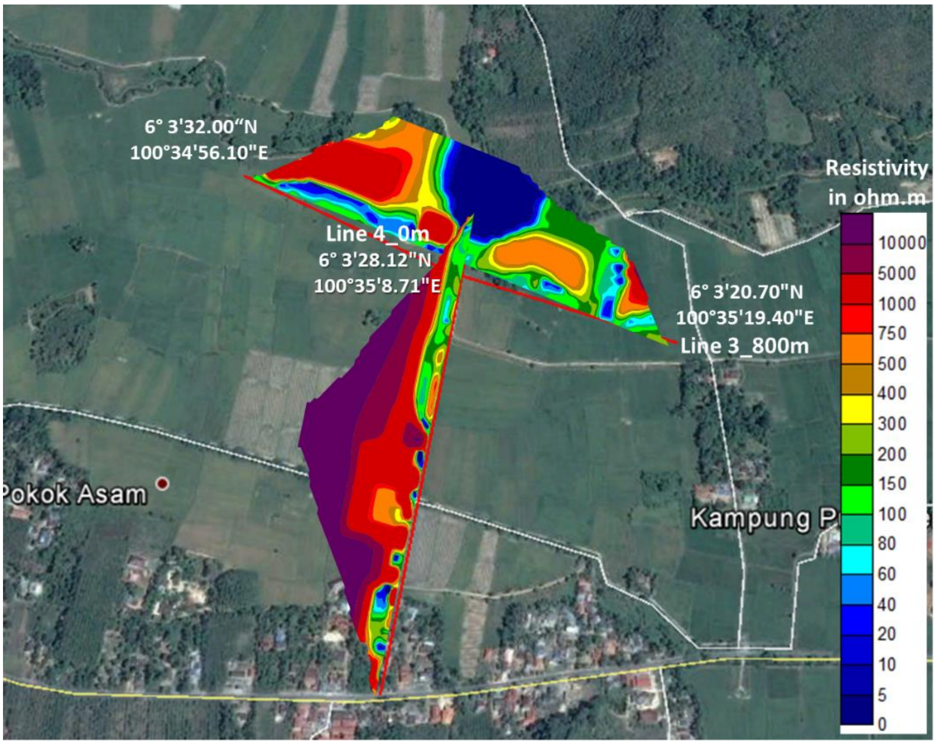

Figure 3.4: Previous electrical survey at Kampung Bukit Kerek, Pendang Kedah

3.3 Electrical Resistivity

Resistivity geophysical surveys measure variations in the electrical resistivity of the ground, by applying small electric currents across arrays of ground electrodes. The survey data is processed to produce graphic depth sections of the thickness and resistivity of subsurface electrical layers. The resistivity sections are correlated with ground interfaces such as soil and fill layers or soil-bedrock interfaces, to provide detailed information on subsurface ground conditions.

Resistivity imaging, also known as electrical resistivity tomography (ERT) is a particularly useful survey method in clayey ground, where techniques such as Ground Penetrating Radar (GPR) are less effective. The method can also help to identify transitional boundaries in subsurface layers that can be difficult to detect using other geophysical methods and is a useful tool for groundwater potential exploration. By utilizing this method, different subsurface condition can be map to characterize fracture zones & discontinuities in order to determine the zone that contain groundwater.

The purpose of this study is to identify the location of the sedimentary rock area that have groundwater potential and to map possible fractured aquifer system in the study area. The electrical resistivity results will then be verified with the pumping test carried out from the tube well construction.

3.3.1 Method of the Survey

The principle of resistivity is based on the four electrodes that are currents, C1 and C2 potentials, P1 and P2 due to study by Schlumberger brothers in 1920. Using this method, the center point of the electrode arrays remains fixed, but the electrode spacing is increased to gain detail information about the subsurface. There are multiple type of arrays used in resistivity survey and their geometric factors are based on change of spacing between electrodes as shown in Figure 3.4.

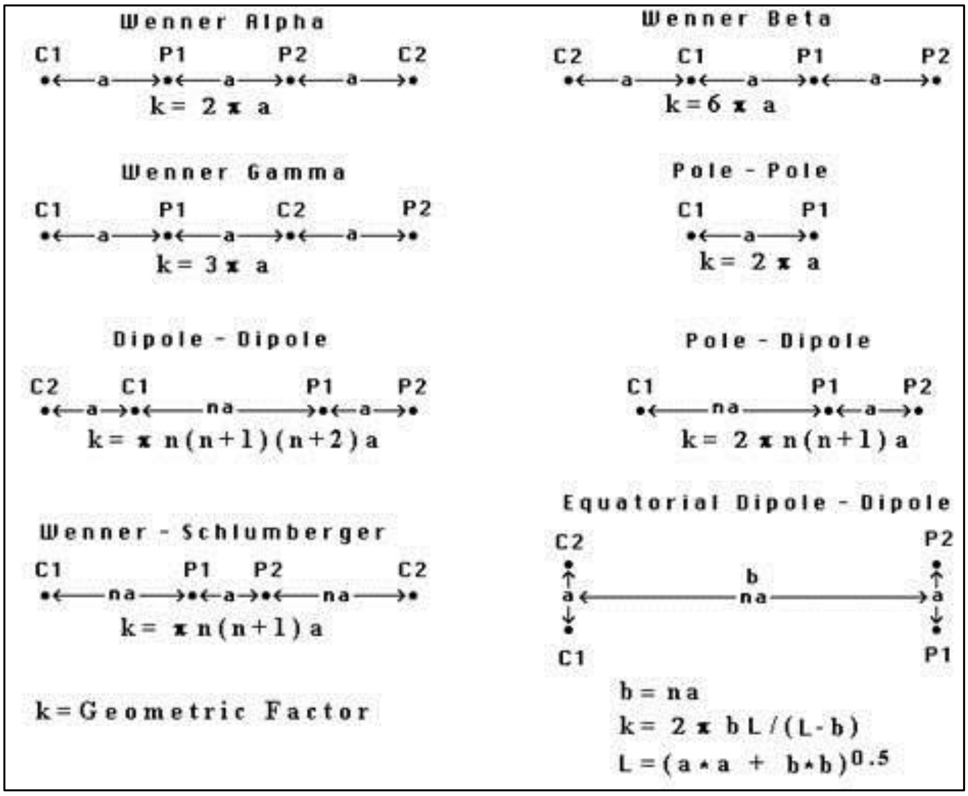

Figure 3.5: Common arrays used in resistivity survey (Loke 2012)

The apparent resistivity of the subsurface can be computed using the following formula.

$$\rho = 2\pi a R \tag{3.1}$$

Where: ρ = Apparent resistivity

a = Electrode spacing

R = Resistance

As a result of the developments of multielectrode resistivity equipment and data acquisition technique, the electrical resistivity imaging has become a standard tool in near-surface geophysical surveys. Electrical resistivity is measured in Ωm (ohm·m) and represented by ρ. This physical property represents how difficult it is to pass an electric current through a volume of material with a given length and cross sectional area (Loke 2012). The resistivity of a volume of material can be calculated by multiplying the electrical resistance with the cross sectional area and divided by the length.

$$\rho = R\ (A\ /\ L) \tag{3.2}$$

Where: ρ = Resistivity

R = Electrical resistance

A = Cross sectional area

L = length

Electrical imaging system is normally carried out with a multi-electrode resistivity meter system. In the survey, the number of electrodes used is typically from 25 to 100 laid out in a straight line with constant spacing. The active electrodes that is used for measurement is automatically select by the computer system (Griffith and Barker, 1993).

3.3.2 Electrode arrays

The selection of array for a field survey depends on the type of structure to be mapped, the sensitivity of the resistivity meter and the background noise level. In common practice, the arrays that are most commonly used for 2-D imaging surveys are the Wenner, diPole-Dipole, Wenner-Schlumberger, pole-pole and Pole-Dipole (Loke 1999). Among the characteristics of an array that should be considered are: