Validation of Groundwater Potential Zone Based on Imaging Profiles using Different Array and Lines of Survey Position

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Abstract. Two resistivity and induced polarization surveys were carried out in this study to validate the groundwater potential location. These 2D geo-electrical survey lines were perpendicular to each other and intersected at point E. The survey lines used a different array configuration; pole-dipole and Wenner-Schlumberger for AB and CD lines, respectively. The surveys were conducted using set of ABEM Terrameter SAS 400 which resulted a resistivity and induced polarization imaging profiles after an analysis in RES2DINV software. The results revealed that, both induced polarization profiles have a low chargeability values of between 0 – 10 ms at intersect point, E even though the resistivity values varied. Thus, the results have verified the location to be a highly potential groundwater reservoir. The reservoir may be found around 50 m depth below ground surface.

1. Introduction

Groundwater in Malaysia is an important resource that is yet to be exploited on a bigger scale to meet the increasing demand for various uses [1]. The utilisation of groundwater can help solve water shortage in areas where surface water is limited [2]. The capacity and limitation of groundwater in Malaysian aquifer should be determined in knowing the groundwater storage available in the aquifer. An increase of cropped area and population in Malaysia has contributes to a rapid increase of groundwater exploration for irrigation purposes [3,4]. The water shortage by caused of the drought season especially in several states including Perlis, Malaysia need this alternative resources. This resources of water have also been proven to be a reliable resource that farmers exploit to offset droughts and shortfalls in surface water irrigation supplies [5].

In Malaysia, farmers are normally use surface water as source of irrigation. Nevertheless, the study area has no nearby water body, thus fully depended on water pipes with huge cost. To reduce the dependency on pipe water, shallow groundwater resources can be assessed. Groundwater location should be studied to discover the potential aquifer area. Many methods have been proven to treasure groundwater and the most popular and non-destructive method is geophysical exploration.

As existing techniques and methods of geophysical exploration can be modified to adapt the environmental and engineering investigation, the development of the new one is no use [6]. Most cases of environmental and engineering interest are at shallow depth of subsurface, therefore near-surface study can be applied. The near-surface study techniques of geophysical investigation can be classified into several categories which includes 2D geo-electrical method. A 2D geo-electrical method compose of two surveys; resistivity and induced polarization. Many researchers [7, 8, 9] have used resistivity
and induced polarisation survey in their study and evidenced that this technique is reliable to detect groundwater based on the imaging result profile.

However, this type of survey has several electrode configurations that can be used for measuring an electric current. The electrode configuration or arrangement is called array. Each array has its own advantage and disadvantage based on four characteristics which are (i) the sensitivity of the array to vertical and horizontal changes in the subsurface resistivity, (ii) the depth of investigation, (iii) the horizontal data coverage and (iv) the signal strength [10]. Besides, the resolutions, depth of investigation and noise sensitivity of these arrays are distinctive and recognized [11, 12].

As different array has different conditions, the imaging profiles results will be slightly different from each other. This differentiation might lead to inaccurate interpretation. Therefore, this study was conducted to validate the potential zone of groundwater by using two different arrays and position of survey lines.

2. Materials and Methods

2.1. Study area

The study area is located at Institute of Sustainable Agrotechnology (INSAT), Universiti Malaysia Perlis, Perlis, Malaysia. The area lies between 6° 39′ 07″ to 6° 39′ 26″ North and 100° 15′ 34″ to 100° 16′ 03″ East. Besides 50 greenhouses of Harumanis mango tree, the study area was also built up with offices and laboratories. The average temperature is about 32°C at daytime and 24°C at night, with annual rainfall of 1869 mm. The study area formation is Kubang Pasu - Singa formation. This formation makes up of shale, siltstone and sandstone. In the north-eastern part of Perlis, Yap [13] divided the sequence of the Kubang Formation to three facies; Passage beds facies, Dominant sandstone facies, and Argilitary rock facies.

2.2. Survey Technique

In this study, two electrical resistivity and induced polarization surveys were carried out using ABEM Terrameter SAS4000 equipment set. The survey lines; namely AB and CD lines were overlapped at 190 m from each left-end as shown in Figure 1. The lines were intersected at point E as the location has a potential groundwater zone under the ground surface. Each survey line in study area has 400 m length and was arranged as standard stated in instruction manual [14]. Figure 2 shows field arrangement of 400 m survey line.

The resistivity measurements are normally made by injecting current into the ground through two current electrodes, C1 and C2, and measuring the resulting voltage differences at two potential electrodes, P1 and P2, as in Figure 3. From the current and voltage values, an apparent resistivity, ρ_a value is calculated by multiplying k (geometric factor) and R (resistivity). This geometric value depends on the arrangement of four electrodes which are named array or protocol. Arrays types of Pole-Dipole and Wenner-Schlumberger were chosen for AB and CD survey lines, respectively. The
arrangement of these array was shown in Figure 4. The field data were recorded automatically by the resistivity meter and processed using RES2INV software [15] to produce imaging profile.

![Fig. 3. A conventional array with four electrodes](image1)

![Fig. 4. Type of array used in this study [20]](image2)

In this study, AB survey line were performed and result of imaging profiles were analysed before the position of survey line CD was carried out. This to ensure the intersection of these lines are lies on potential groundwater location. The lines were position in perpendicular in order to re-evaluate the resistivity and chargeability value of the intersection point. In this kind of survey, geological structure of study area is reflected by resistivity imaging profiles while the groundwater is reflected by low chargeability value in induced polarization profiles. The results and discussion of this paper are focused on validating the potential groundwater location of point E in term of both imaging profiles produced from geo-electrical survey.

3. Results and Discussions

The resistivity imaging profiles for AB and CD lines are shown in Figure 5 and 6, respectively. The profiles have an overall depth of 135.5 m for Pole-Dipole array and 84.7 m for Wenner-Schlumberger array. The results of resistivity values were ranging between 1 Ωm to 5,000 Ωm for AB lines whereas the values were extending to 10,000 Ωm for CD lines.

It can be seen that; Figure 5 has more depth compared to Figure 6. The depth of each particular survey will be depended on maximum electrode spacing, depth factor and geometric factor [16]. It is also appeared that, Figure 5 and 6 has three underlying zones; Zone 1, Zone 2, and Zone 3 as labelled in the figures. These zone exist as horizontal structures. However, in Figure 5 there is Zone 4 overlapping these three zones in vertical way. Pole-dipole has better resolution for vertical structures whereas Wenner-Schlumberger array has better resolution for horizontal structures [17].

Zone 1 was detected to compose of clay soil as the resistivity values was ranging from 10 to 100 Ωm. Several researchers have interpreted and proved that, this resistivity value ranging was belonging to clay type of soil [18-20]. Zone 4 was believed to have similar composition as Zone 1. The second underlying zone, Zone 2 has a resistivity value between 100 to 500 Ωm and is expected to compose of moderate weathered rocks. Zone 3 has the highest range of resistivity value of 500 to 10,000 Ωm. It is possible compose of completely into highly weathered rocks. Both zones were perceived to be composed of sedimentary rocks of shale, siltstone and/or sandstone due to high resistivity values [19, 21]. These rocks are a type of rocks in Kubang Pasu – Singa Formation [22].

Figure 7 and 8 show induced polarization imaging profiles for AB and CD survey lines, respectively. The chargeability values in induced polarization profiles in Figure 7 can be divided into two sections; half of the profile on left side has low chargeability measurement while right side of the profiles having a high chargeability value. Through profile in Figure 7, there is a possible freshwater reservoir indicated by greenish-blue colour fill. The values were ranged between 0 – 2 ms. In Figure 8, there is two regions of low chargeability values of less than 10 ms exists. This region is separated by high chargeability structures. All regions (region 1, 2 and 3) located in Figure 7 and 8 are suspected to hold groundwater due to its low chargeability values [21].
Table 1 shows the results of intersection (point E) based on parameters investigated. Despite the resistivity values are much varied for both survey profiles, the chargeability values are within $0 \sim 10$ ms which is fall in groundwater range. Therefore, this results may validate the existing of groundwater reservoir at that location. The depth of reservoir from AB survey lines is around 50 m below ground surface and for CD lines the depth also fall on same depth.
TABLE 1. Results of several parameters at intersect point E.

| Parameters           | Survey Line       |
|----------------------|-------------------|
|                      | AB (Pole-dipole)  | CD (Wenner-Schlumberger) |
| Depth (m)            | ≈ 120             | ≈ 80                      |
| Resistivity value (Ωm) | 250 – 900        | 800 – 10,000              |
| Chargeability value (ms) | 3 – 4           | 6 – 8                     |

4. Conclusions
This study is helpful in validating the potential groundwater location at study area. The potential location of groundwater is located at point E at depth of 45 m below ground surface. The results also show that despite of different resistivity value of geology formation at point E, both lines show low conductivity values of the range 0 to 10 ms. This conductivity range is verified to contain groundwater.

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