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Potential Groundwater Exploration in Use of 2-D Electrical Resistivity Tomography (ERT) Techniques at the Department of Agriculture Kelantan Research and Developmental Platform Padang Raja Kelantan

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ABSTRACT

2-D electrical resistivity has been a proper investigation survey for determination of subsurface geophysical in describing the complex features geology profile. In this study, an electrical resistivity survey was conducted at paddy cultivation area located in Melor, Kelantan, Malaysia. Since the end plot of paddy field experiences water scarcity especially during dry season, there is a need to find other alternative water source. The study was conducted on 1st and 2nd February 2020 to identify zone area of groundwater for Melor, Kelantan. Four resistivity lines using Induced Polarization (IP) and 2-D Electrical Resistivity Imaging Technique were conducted using a set of ABEM Terrameter SAS4000. Short resistivity survey was applied to gained detail of subsurface formation near the ground, while the longer resistivity survey was applied to obtain deeper subsurface delineation. Measured data obtained was analyzed using RES2DINV software and result of contrast resistivity values was used to determine the geological structures, while the chargeability values were analyzed

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accordingly to determine area of expected potential groundwater zone. Results from the resistivity profiles show a range values of 0 Ωm to 50,000 Ωm with total maximum acquired depth of 65.6 m below ground surface. The chargeability profiles show a range values of 0 msec to 500 msec, that shows potential of groundwater zone area lies at 0 to 4 msec. It was found that at a depth of 60 to 75 m, 30 m from center of Profile B was suitable for a production well which was expected to be a potential area for groundwater zone.

Keywords: 2-D electrical resistivity technique, chargeability, geological structures, groundwater, induced polarization, resistivity

INTRODUCTION

To date, worldwide is facing critical issues regarding surface water limitations especially in agriculture industry with approximately 70% of water usage used for agriculture purposes. As water is crucial to achieve a steady healthy crop, any consumption insufficiency at any crop growth stage may result inhibition of crop growth. Although Malaysia receives approximately 2,774 mm in average of annual rainfall that is considered high and more than the global average, however, the rainfall distributions patterns are uneven throughout the country causing some part of areas receiving low rainfall distributions compared to other areas (Hussin et al., 2020). Thus, may lead to changes in rainfall pattern and vegetation process of planted crop (Mohtar et al., 2014).

Rice as staple food for Malaysian has become one of the major crops planted all over the country. Conventional practice that uses continuous flooding system, has once been used to raise paddy crop, however when farmers encounter drought season, this practice can no longer be accessed as standing depth of almost 10 to 15 cm is hard to maintain because of water limitations. Therefore, rather than solely depending on surface water, alternative water supply especially with low cost yet sustainable is needed to be investigated to fulfill water demand for various purposes.

One of the major alternative water sources is groundwater. However, groundwater in Malaysia is yet to be exploited on a bigger scale (Azizan et al., 2018). Studies need to be properly done to investigate complex behavior of subsurface geophysical delineation to extract water from potential groundwater zone area. Hence, in line with technological development, resistivity survey has been frequently introduced in use of determination of subsurface delineation. The resistivity imaging profile specifically shows geological formation of survey line that indicates suitable layers that have the potential of groundwater (Hazreek et al., 2017). Therefore, this study was proposed to determine the zone area of potential groundwater using 2-D electrical resistivity technique and Induced Polarization (IP).

MATERIAL AND METHODS

Description of the Study Area

Melor, Kelantan which geographically lies at about 5^o 57' N and 102^o 17' E was chosen as the study area. Current main crop cultivation at the area is dominant by paddy crop. Since paddy is a high water-intensive crop, water scarcity is a major problem experienced during the dry season, especially the end plot of the paddy field which located far from the water sources. Hussin et al.,(2020) reported Kelantan received less rainfall between April to October with the annual rainfall distribution of 2774 mm annually.

Generally, the area is covered by alluvium deposits of Quaternary age. The sediment quaternary can be divided into three major units: Gula Formation, Beruas Formation and Simpang Formation (Hutchison & Tan, 2009). The quaternary deposits that occupy the north of Kelantan river valley mainly consists of unconsolidated to semi consolidated gravel, sand, clay, and silts. The silty and clay deposit which lies at 13 m to 15 m is basically at recent age (Zakaria, 1972), while the thickness of alluvium may reach up to more than 200 m towards the seas (Suratman, 1997). Same pattern is shown by the unconsolidated deposit to form thick wedge towards the coastal that overlays granite and sediment (Stauffer, 1973).

Geographically, study area major potential zone for groundwater is at northern Kelantan as supported in Geological Map of Kelantan at Figure 1. Primarily, the area is underlain by the Quaternary alluvium. The alluvium region covers an area of 1500 km^2 that is 10% of the state area and mainly underlain by granitic and sedimentary/ metasedimentary bedrock, and the latter layer can be phyllite, slate, sandstone, or shale. The sedimentary/metasedimentary rocks which consist of phyllite, slate, shale and sandstone occur generally towards the western parts along the Kelantan River, while the granitic rocks exhibit existence at the eastern part (Pour & Hashim, 2017). Figure 1 presents the location of the study area at paddy cultivation, Melor Kelantan.

Data Acquisition

A 2-D electrical resistivity survey was conducted at the study area by measuring the potential of electrical between two electrodes that were injected with direct current by another pair of electrodes (Drahor et al., 2006; Osazuwa & Chii, 2010). The resistivity data and induced polarization were measured and automatically recorded by resistivity meter. RES2DINV software was used to processed measured data obtained by converting and distinguish the apparent resistivity data and true resistivity data using inversion method approach (Hazreek et al., 2017). The 2-D model separates the subsurface into several number of blocks and then produces the apparent resistivity which agrees with an actual measurement (Osazuwa & Chii, 2010). The generated contrast resistivity values are used to determine the subsurface geological structures, while the chargeability values are analyzed accordingly to determine area of expected potential groundwater zone (Rahmawati et al.,

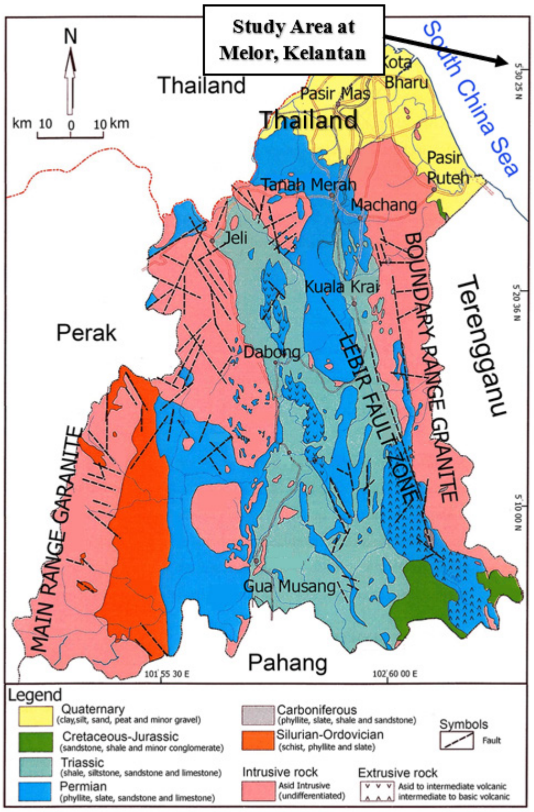
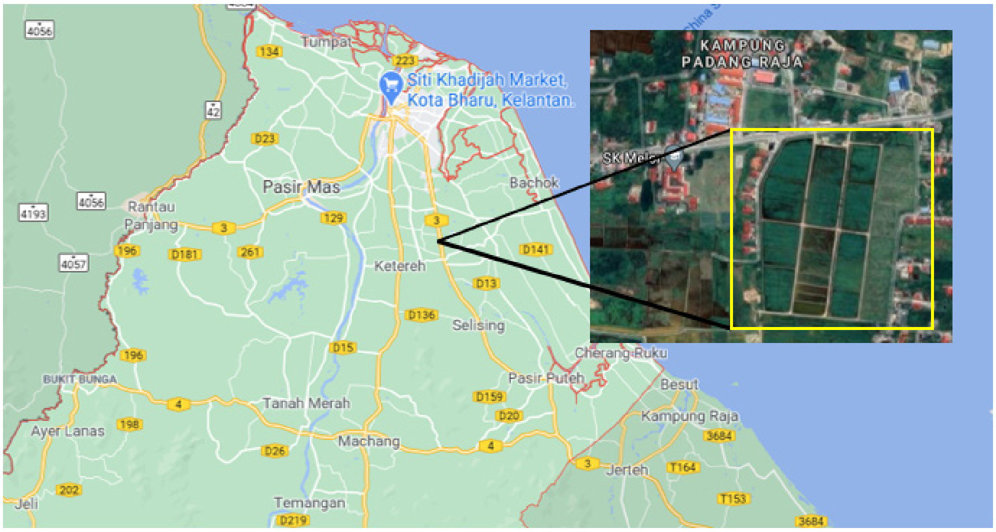


Figure 1. Geological map of Kelantan (Pour & Hashim, 2017)



Source: Google Map, 2021

Figure 2. Study area located at paddy cultivation field in Melor, Kelantan.

2018). Wenner-Schlumberger protocol was selected which basically an integration of Wenner and Schlumberger arrays for electrical resistivity technique (ERT). Resistivity surveys were carried out at four different location in the study area. Length of each lines varied from 200 – 400 m with electrode spacing of 2.5 m to 5 m. The exact position of each resistivity lines is shown in Figure 2. Shortest distance of resistivity survey was applied to obtain details of subsurface formation near the ground. Meanwhile longer distance of resistivity survey was conducted to gain deeper subsurface delineation.

In this study, a total of four resistivity lines using Induced Polarization (IP) and 2-D Electrical Resistivity Imaging Technique (ERT) were proposed with varied length range from 200 m to 400 m at random location to give better description of the study area. To control the induction of current and the electrodes potential readings, a set of ABEM Terrameter SAS4000 and a switcher unit was used and connected by multicore-cable along the survey line.

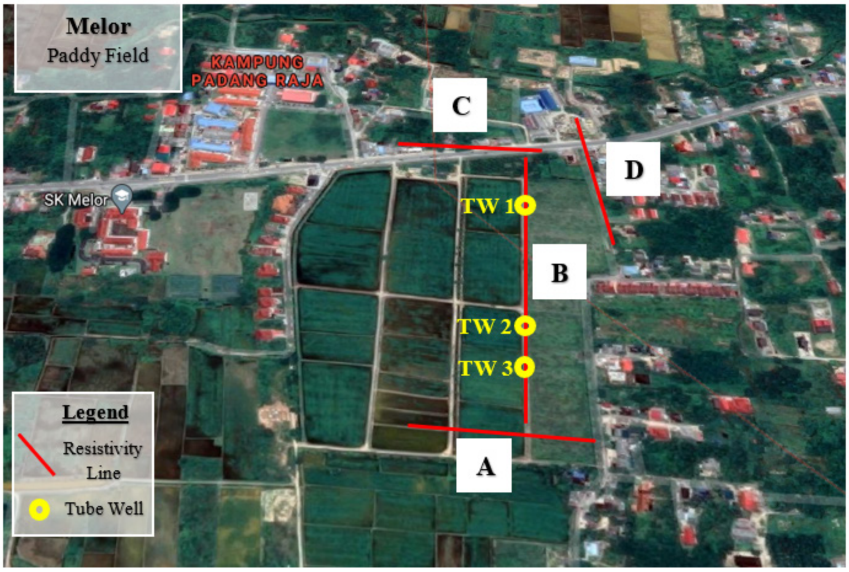


Figure 3. The location of the survey lines (Line A - D)

RESULTS AND DISCUSSIONS

In Figure 2, several tube wells can be seen (TW1, TW2 and TW3) owned by *Jabatan Pertanian Kelantan*, however, these tube wells were built using traditional methods thus no detail report was available.

Figure 4 to 7 represent the respective electrical resistivity and chargeability tomography at four different profiles (Profile A to D). The resistivity values obtained ranged from 0 Ωm to 50,000 Ωm while the chargeability values ranged from 0 msec to 500 msec. The maximum depth that had been acquired was 65.6 meters below ground surface for line B.

Profile A shows several zones with low resistivity with high chargeability that indicated presence of clay. While at high resistivity with low chargeability, there can be assumed to have a potential water zone, however since it is just around area of water table, it cannot be assumed as groundwater zone. Profile B indicates the presence of expected groundwater zone area at fractured zone appearing in high resistivity with low chargeability zone. 'JP' in this Profile B shows several tubes wells owned by *Jabatan Pertanian Negeri Kelantan* which had been built before. However, no detailed report was available from boring procedure as it was built by traditional method. 'New' indicates the new proposed tube well recommended by analysis from Profile B. At low resistivity with low chargeability in Profile C, clay is dominating the zone at that specific area. While at low resistivity and high chargeability, weathered rock where high impurities area is considered to cover up the zone area. At low resistivity with high chargeability in Profile D, it may indicate the present of clay. However, at high resistivity with high chargeability, it can be presumed that the area is a highly impurities area.

Results show the study area mainly consists of unconsolidated materials with resistivity value ranging from 10 to 80 Ωm. The resistivity reading and the colour indicate soil availability for the layer consists of variation of clay, silt, sand, and gravel. This layer was classified as alluvium that characterized the deposit of clay, silt, sand, and gravel. The resistivity value for alluvium is commonly ranging from 10 to 800 ohm.m. The lowest resistivity reading is ranging from 1 to 10 ohm.m and is represented by the dark blue colour. The colours specify the type of soil at this depth was soft clay or clay. High resistivity value ranging from 2000 Ωm to 50,000 Ωm portrays expected availability of granitic rock (Pour & Hashim, 2017). The granitic rock that underlay the layers of alluvial was at 40 m deep.

The measured chargeability is the discharged measure of polarization in the subsurface. Basically, it is related to the water content in the subsurface media and the minerals conductivity (Riwayat et al., 2018). Hence, the chargeability profile could be used to determine the characteristic of water either it has impurities or not. The profile, however, still needs to be supported by further water quality analysis to determine the groundwater quality.

It can be seen from the profile, that the chargeability distribution is ranging from very low chargeability reading; 0 msec to very high chargeability reading; 500 msec. Chargeability tomogram can indicate potential groundwater zone. It has been proven, that the groundwater occurrence is indicated with chargeability value ranging from 0 to 4 msec (Juanah et al., 2013). Thus, it was considered chargeability value of 0 to 4 msec specify the potential groundwater zone.

From the chargeability profile, high chargeability reading ranging from 4 msec to 100 msec represented by colour scheme between yellow to red shows highly contaminated area. Among the sources of groundwater contamination, may be agricultural pollutants such as fertilizers and pesticides from the use in paddy field (Jeyaruba & Thushyanthy, 2009; Vandermaesen et al., 2016)

Commonly, fractures in subsurface indicate the present of groundwater. The lower the resistivity values may exhibit the greater the fractures are (Kim et al., 2011). From Profile B, it can be assumed that the fractured zone is a zone area with high potential groundwater source. The production tube well is recommended at 30 m from the centre line (Profile B) with depth of 60 – 75 m below ground surface.

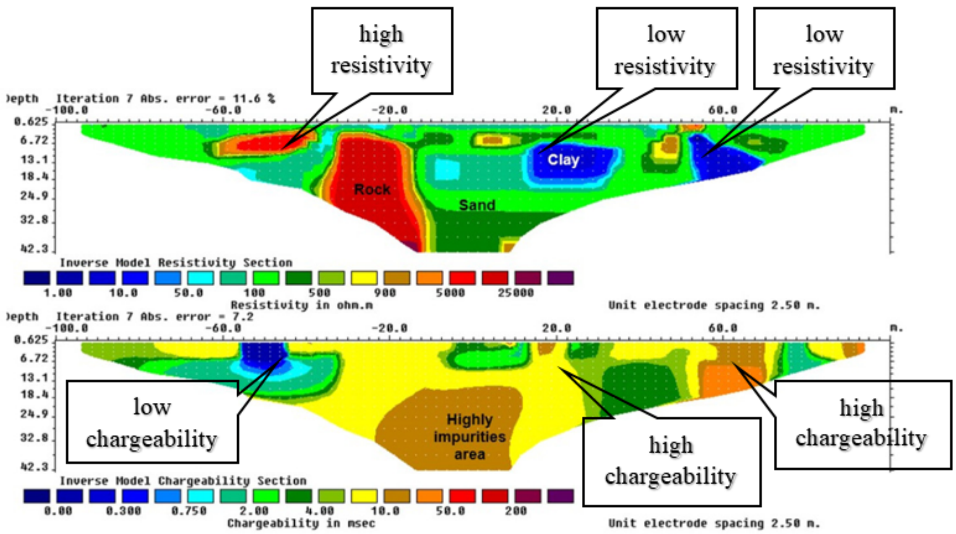
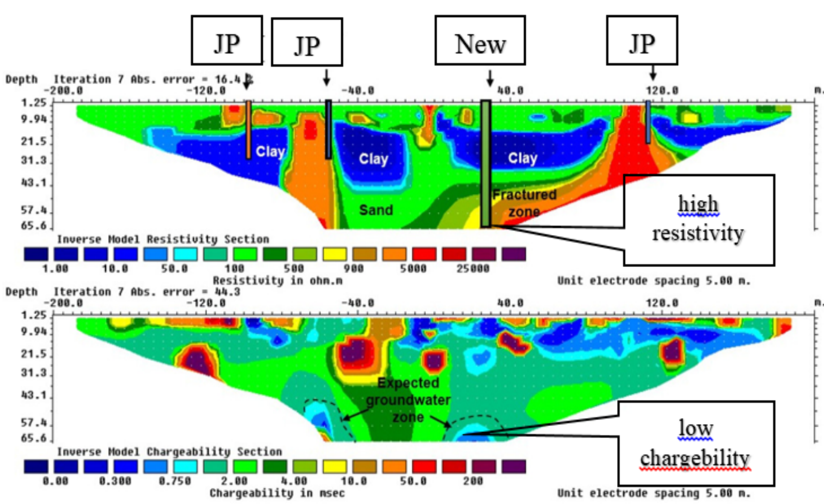


Figure 4. Electrical resistivity and chargeability tomography at Profile A (resistivity survey line of 200m)



**JP = *Jabatan Pertanian* Existing Tube Well; New = New Propose Tube Well

Figure 5. Electrical resistivity and chargeability tomography at Profile B (resistivity survey line of 400m)

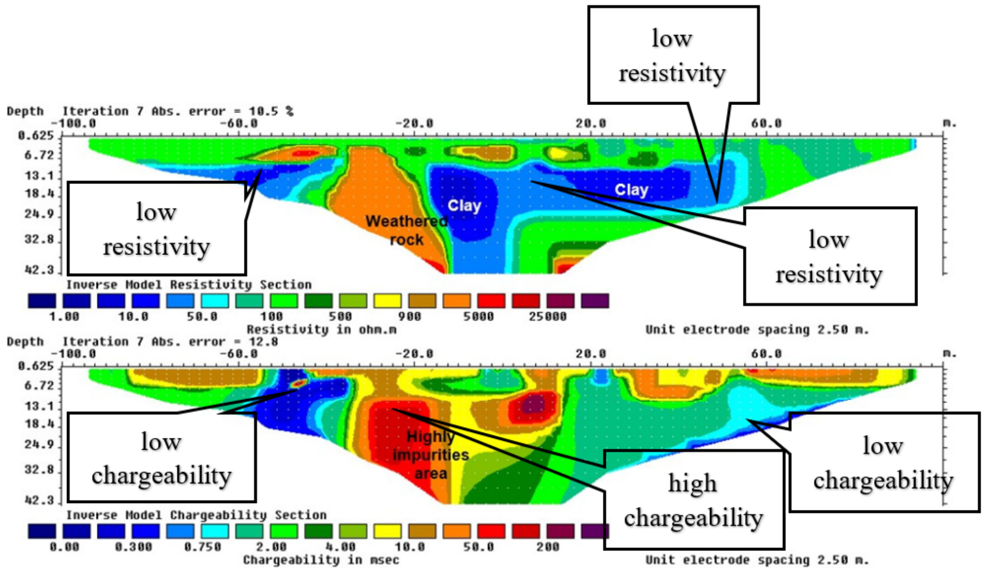


Figure 6. Electrical resistivity and chargeability tomography at Profile C (resistivity survey line of 200m)

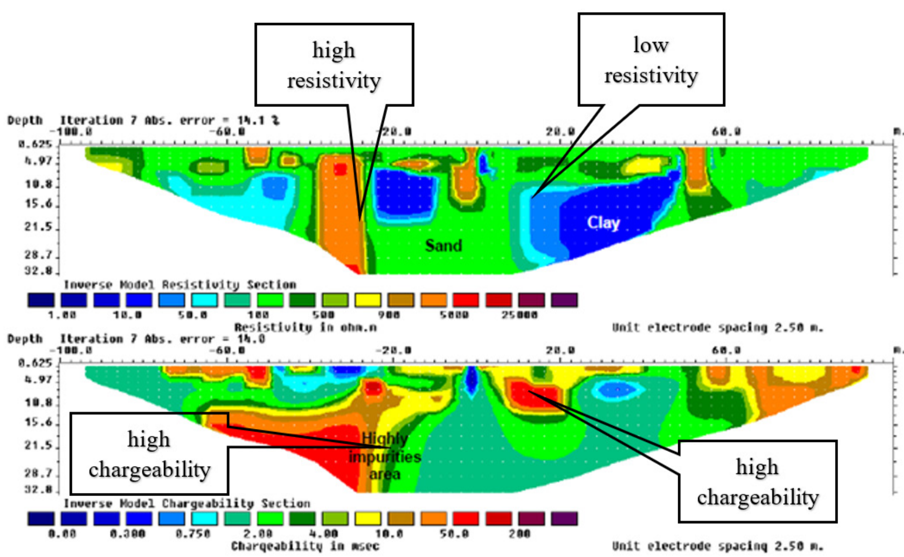


Figure 7. Electrical resistivity and chargeability tomography at Profile D (resistivity survey line of 200m).

CONCLUSIONS

The aquifer within study area has been identified as a fractured aquifer with the resistivity value ranging from 10 to 80 Ωm and chargeability value ranging from 0 to 4 msec. The groundwater type in Melor, Kelantan is considered as unconfined aquifer. Thus, the suggested location for production well is located at 30 m from the centre line (Profile B) and at depth of 60 – 75 m beneath ground surface. The suggested area is considered as the possible location of potential groundwater zone. However, further study needs to be done to confirm the subsurface delineation, lithology borehole log and further test in terms of quality of potential groundwater zone.

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REFERENCES

Azizan, F. A., Aznan, A. A., Ruslan, R., Nazari, M., & Jaafar, M. N. (2018). Groundwater assessment using geophysical survey at Insat, Perlis, Malaysia. *IOP Conference Series: Materials Science and Engineering* (Vol. 429, No. 1). Institute of Physics Publishing. https://doi.org/10.1088/1757-899x/429/1/012026

Drahor, M. G., Göktürkler, G., Berge, M. A., & Kurtulmuş, T. Ö. (2006). Application of electrical resistivity tomography technique for investigation of landslides: A case from Turkey. *Environmental Geology, 50*(2), 147-155. https://doi.org/10.1007/s00254-006-0194-4

Google Maps. (2021). *Google Maps directions in Melor, Kelantan*. Retrieved February 10, 2021, from https://www.google.com.my/maps/place/Kelantan

Hazreek, Z. A. M., Raqib, A. G. A., Aziman, M., Azhar, A. T. S., Khaidir, A. T. M., Fairus, Y. M., Rosli, S., Fakhrurrazi, I. M., & Izzaty, R. A. (2017). Preliminary Groundwater Assessment using Electrical Method at Quaternary Deposits Area. *IOP Conference Series: Materials Science and Engineering* (Vol. 226, No. 1). IOP Publishing. https://doi.org/10.1088/1757-899x/226/1/012042

Hussin, N. H., Yusoff, I., & Raksmey, M. (2020). Comparison of applications to evaluate groundwater recharge at lower Kelantan River Basin, Malaysia. *Geosciences, 10*(8), Article 289. https://doi.org/10.3390/geosciences10080289

Hutchison, C. S., & Tan, D. N. K. (Eds.). (2009). *Geology of peninsular Malaysia*. Published jointly by the University of Malaya and the Geological Society of Malaysia.

Jeyaruba, T., & Thushyanthy, M. (2009). The effect of agriculture on quality of groundwater: A case study. *Middle-East Journal of Scientific Research, 4*(2), 110-114.

Juanah, M. S., Ibrahim, S., Sulaiman, W. N. A., & Latif, P. A. (2013). Groundwater resources assessment using integrated geophysical techniques in the southwestern region of Peninsular Malaysia. *Arabian Journal of Geosciences, 6*(11), 4129-4144. https://doi.org/10.1007/s12517-012-0700-9

Kim, M. I., Kim, J. S., Kim, N. W., & Jeong, G. C. (2011). Surface geophysical investigations of landslide at the Wiri area in Southeastern Korea. *Environmental Earth Sciences, 63*(5), 999-1009. https://doi.org/10.1007/s12665-010-0776-z

Mohtar, Z. A., Yahaya, A. S., Ahmad, F., Suri, S., & Halim, M. H. (2014). Trends for daily rainfall in northern and southern region of peninsular Malaysia. *Journal of Civil Engineering Research, 4*(3A), 222-227.

Osazuwa, I. B., & Chii, E. C. (2010). Two-dimensional electrical resistivity survey around the periphery of an artificial lake in the Precambrian basement complex of northern Nigeria. *International Journal of Physical Sciences, 5*(3), 238-245.

Pour, A. B., & Hashim, M. (2017). Application of Landsat-8 and ALOS-2 data for structural and landslide hazard mapping in Kelantan, Malaysia. *Natural Hazards and Earth System Sciences, 17*(7), 1285-1303. https://doi.org/10.5194/nhess-17-1285-2017

Rahmawati, D. R., Supriyadi, A. N., & Naufal, M. A. (2018). Groundwater potential prediction by using geoelectricity method a case study in Simpang Lima and around it. In *Journal of Physics: Conference Series* (Vol. 983). IOP Publishing. https://doi.org/10.1088/1742-6596/983/1/012003

Riwayat, A. I., Nazri, M. A. A., & Abidin, M. H. Z. (2018). Application of electrical resistivity method (ERM) in groundwater exploration. In *Journal of Physics: Conference Series* (Vol. 995, No. 1, p. 012094). IOP Publishing. https://doi.org/10.1088/1742-6596/995/1/012094

Stauffer, P. H. (1973). Kenny hill formation. In D. J. Gobbett, & C. S. Hutchison (Eds.), *Geo1ogy of the Malay Peninsula* (pp. 87-91). Wiley.

Suratman, S. (1997). Groundwater protection in Kelantan. *Warta Geologi, 23*(6), 351.

Vandermaesen, J., Horemans, B., Bers, K., Vandermeeren, P., Herrmann, S., Sekhar, A., Seuntjens, P., & Springael, D. (2016). Application of biodegradation in mitigating and remediating pesticide contamination of freshwater resources: state of the art and challenges for optimization. *Applied Microbiology and Biotechnology, 100*(17), 7361-7376. https://doi.org/10.1007/s00253-016-7709-z

Zakaria, A. S. (1972). Morphometry of part of Kelantan River catchmen. *Sains Malaysiana, 1*(1), 59-76.