Chapter 7

Conclusions and Recommendations

7. 1. Introduction

Integrated geoelectrical resistivity, hydrogeochemical and soil properties analysis methods were used to investigate groundwater and associated problem along Kelantan River Delta, North Kelantan. Data required consist of primary and secondary data. The primary data includes geoelectrical resistivity survey, direct surface resistivity measurement, lab resistivity measurement, well physical parameters (well location, well depth and depth to water), in-situ water parameter (temperature, pH, salinity and conductivity), water chemical analysis (major cations and major anion), soil properties data (in-situ hydraulic conductivity, grain size distribution and moisture content), soil chemical analysis, land-uses and fertilization scheme. The secondary data includes anion and cation from several monitoring well, gamma ray log and rainfall data, which were obtained from Jabatan Mineral dan Geosains Malaysia. The study area was divided into three divisions; Area 1, Area 2 and Area 3. The Area 1 was located at southernest, followed by Area 2 and the Area 3 which located at northernest and surrounded by South China Sea. The division was made based on geological condition and problem involves in each areas.

7.2. Conclusion

Geoelectrical resistivity and hydrochemical methods have been successful for studying groundwater and its associated problem within the North Kelantan Delta plain areas. The objectives in this research were accomplished by doing a series of comprehensive study.

In the pilot test study, the nitrate concentration is higher at an area within a former palm oil plantation, compared to the area with no palm oil plantation. The application of chemical and natural fertilizer is the reason for the relatively higher nitrate concentrations found in palm oil plantations area. In the soil with relatively higher nitrate concentration, subsurface geoelectrical resistivity values are relatively lower although the moisture content is lower and soil properties are similar. The subsurface resistivity value is relatively higher in the zone with lower nitrate content. In the catchment area within palm oil plantation, subsurface resistivity show lower value compared to other location which have similar soil condition. The site where the chemical and farm yard fertilizer are used for agricultural activity, again, subsurface resistivity show relatively lower value. Within all these locations, nitrate concentration tends to be higher. One of the fundamental results here is that the nitrate content in pore soil is good correlated to the resistivity measurements.

A novel investigation in monitoring of chemical fertilizer has been examined in the site where the nitrate concentration tends to be higher (palm oil plantation and tobacco area). The study involves three types of measurement methods to determine the changes in the chemical content with time. Five measurements were taken at about a month interval. The resistivity measurement shows a sharp decrease in resistivity value at the first month. The resistivity value increases to the initial level gradually from the second monitoring. This indicates that the geoelectrical resistivity method can be used to detect chemical fertilization in near surface. The decrease of the resistivity value with time is complimented by the rise in nitrate content with time. The two values however reach about the initial level at the last measurement. The moisture content decrease with depth however the values remain almost the same in all the time lapse measurement. Furthermore, hydrogeochemical data show that chloride and sulphate anion content decrease with almost power trend. However, the fate of nitrate anion shows the nonmonotonic trend function. Nitrate concentration will be at maximum concentration 36 days after fertilization and will be at initial values 100 days after the fertilization process in the semi-pervious soil. In the soil at the border of pervious and semi-pervious category, nitrate concentration reach the maximum value at 67 days after fertilization and will be at the initial value 195 days after fertilization. The measurements indicate that the integration of geoelectrical resistivity, hydrogeochemical and soil property analysis methods give better resolution for chemical fertilizer monitoring.

The pre-Quaternary bedrock is clearly imaged in almost of Area 1, in mostly of Area 2 and in 1 line of Area 3 geoelectrical models. This allows developing the shape of aquifer geometry. The depth of basement varies in particular region. In southern of Area 1, the pre-Quaternary bedrock appear 10 m relative to mean sea level and dips to the northwestern. Fortunately, at the middle of Area 1, the pre-Quaternary bedrock resists the potential polluted groundwater to enter northern area which has lower elevation. In the northern and beginning of Area 2, the depth of pre-Quaternary bedrock is around -25 m relative to mean sea level. The bedrock dips to the northwestern and rise to Marak Hill direction (northeastern). In all of the geoelectrical models, some lines show that there is the possibility direct connection of surface water to the shallow aquifer. In the area around Pengkalan Datu River, shallow aquifer has direct connection to the subsequence deeper aquifer.

A novel study on the use of the geoelectrical method to delineate the zone of heavy metal, especially Fe and Al, in soil groundwater systems has shown successfully. In utilising this method, the heavy metal analysis in soil and groundwater is essential. Fe concentration was found in almost all groundwater samples, varying with depth and location. Fe concentration was found relatively lower and safe for human consumption in a shallow aquifer at the southern region. However in the middle and northern regions, Fe concentration tends to be higher and the water not safe for human consumption. Fe concentration is relatively higher in the zones which have lower geoelectrical resistivity value. Fe concentration in soil has a positive correlation with Fe concentration in groundwater around where the soil sample was taken. High Fe concentration in soil causes high Fe concentration in groundwater. However, there is no correlation between Al concentration in soil and Al concentration in groundwater. The zones of higher Fe concentration extend from the northern side of Boundary Range to the northwestern. High Fe concentration occurs from around 0–20 m relative to the mean sea level at the southeast and dips to a northwest direction. In the northwestern area, high Fe concentration occurs at around -5 m to -25 m relative to mean sea level. In the Area 3 where the brackish water presents, occurrence of heavy metal in the soil aquifer is difficult to detect only using geoelectrical resistivity. This is due to the light brackish water show similar resistivity value with aquifer of high heavy metal content.

An improving geoelectrical interpretation in term of salt/brackish content in the aquifer has been successful done in this study. The resistivity value decreases drastically when low percentage of sea water (<10%) present in the pore soil. A degree of percentage of sea water could be predicted in the geoelectrical model through the resistivity value.

The depth slice visualisation of resistivity distribution in Area 3 has been successful to image the zone which has high percentage of sea water mixture in the aquifer. The resistivity value increase to the land ward and decrease to the seaward as the changing of percentage of sea water decrease to the landward. Furthermore, this interpretation is supported by water chemical analysis. Finally the zone of salt/brackish water content definitely can be mapped which salt/brackish water take a place until 6-7 km from the beach line.

7.3. Recommendations

The following are recommendations for the future work.

i. The bacteria that involve in the process of nitrification in the area where high nitrate concentration was found needs to be considered in order to see the specific growth of the nitrate.

ii. Installation of sampling equipments for pore soil water and shallow boreholes in the area of high nitrate concentration can be used to monitor and live control chemical concentration in groundwater.

iii. The potential groundwater maps generated from this study can help the local authorities to carry out mitigation in term of the groundwater resources such as water treatment for current well, locating of new suitable wells, and information for public about specific water purposes.

iv. The methods applied in this study have been successful for detecting nitrate in shallow aquifer, monitoring chemical fertilizer, delineating present of heavy metal in the aquifer and predicting concentration of salt water content in the aquifer. A similar approach could be applied to the other location in the Peninsula Malaysia to get new water resources.

v. More boreholes with gamma ray data are needed at the central part of Kelantan River basin to get more reliable subsurface information.