Chapter 3

Methodology and Data Acquisition

3.1. Introduction

This chapter covers the research methodology and data acquisition. The data include geoelectrical resistivity, direct surface resistivity measurement, borehole geophysics, hydrogeochemical and soil properties. The data will be presented in detail for each study area in the next chapter.

An integration of geoelectrical resistivity, borehole geophysics, hydrogeochemical and soil properties analysis methods has been used for investigating the groundwater characteristics in the study area. The geoelectrical resistivity method is used to detect the water table, fresh-salt water boundary and subsurface geological boundary. However, the method cannot be used to assess the quality of groundwater directly in term of its ion content. Borehole geophysics is used to investigate subsurface geology needed to find geological correlation between geoelectrical resistivity and the subsurface characteristic changes. Borehole data is also used to calibrate the geoelectrical resistivity data to the subsurface geology. The hydrogeochemical method is useful to assess the chemical content of groundwater. The soil property analysis is important to understand characteristics of the soil. The use of all methods is ideal for the investigation of groundwater problem.

General flowchart of this study is given in Figure 3.1 Initially, a desk study was conducted, aimed at identifying the problem facing in the research area according to previous reports (technical reports and publications). A desk study is also to review the use of all methods (geoelectrical resistivity, hydrogeochemical and soil properties analysis) to solve the problem facing in the study area. Consequent to that, geoelectrical resistivity method was employed to obtain subsurface resistivity information. Hydrogeochemical methods were then applied, including in-situ parameters measurement, IC analysis and ICP analysis. Finally, soil properties analysis methods were carried out to give a better analysis and interpretation. The theoretical background of geoelectrical resistivity, hydrogeochemical and soil properties analysis are given in Appendix A, B and C, respectively. Test-site study was conducted in three sites (Test-site 1, 2 and 3) prior the main investigation. The Test-site 1 and 2 was to investigate resistivity characters in the site with fertilization and non-fertilization while the Test-site 3 was besides to study resistivity character in different soil character, was also for detecting the depth of bedrock (granite). The result derived from these study was very important for calibration and standardization prior interpretation in the main investigation. The Test-lab study was to investigate resistivity character in different soil saturated with different salt water content. The detail of Test-sites and Test-lab study can be found in Chapter 4.2 and 6.2, respectively.

3.2. Desk Study

Besides to review the use of all methods (geoelectrical resistivity, hydrogeochemical and soil properties analysis) for solving the existing problem in the study area, gathering information and collecting secondary data was performed in this stage. The secondary data includes groundwater chemical analysis and rainfall data that obtained from Mineral Geosciences Malaysia. The gamma ray log data is obtained from previous published work.

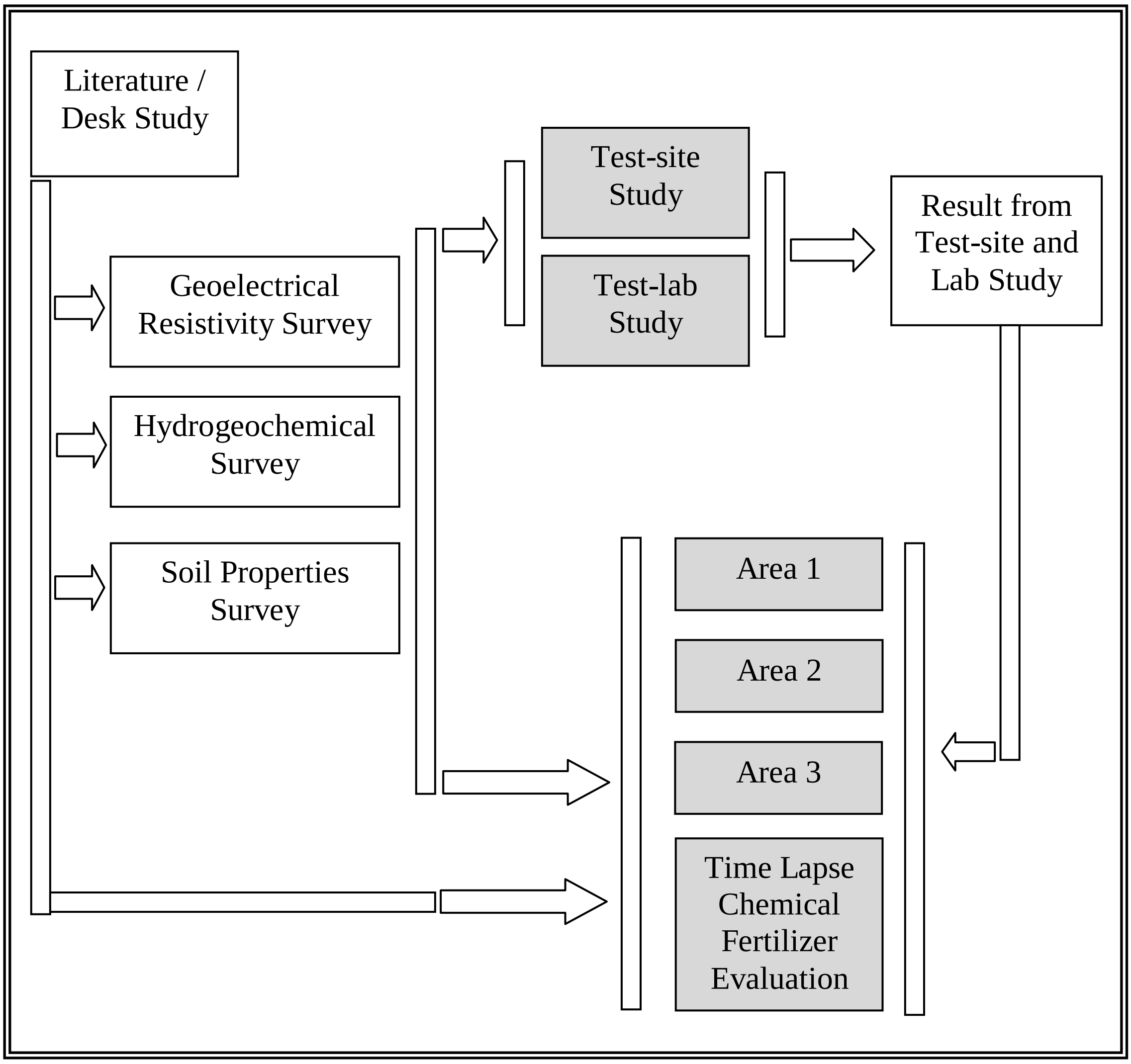


Figure 3.1. General flowchart of the study

3.3. Geoelectrical Resistivity Survey

The geoelectrical resistivity survey was conducted in the Test-site study and in each area, Area 1, Area 2 and Area 3. The following are the field procedure to acquired geoelectrical resistivity data.

The 2D geoelectrical resistivity imaging surveys were performed at the proposed sites using the ABEM Terrameter SAS4000. The Terrameter was connected together with an automatic selector system and multicore cable to which electrodes were connected at takeouts with equal intervals. Figure 3.2 shows the equipment used to obtain the geolectrical resistivity data. It consists of a basic unit (ABEM Terrameter SAS4000), the Electrode Selector ES10-64, and multiconductor cables.

Figure 3.2. ABEM Terrameter SAS4000 and its accessories. 1) Resistivity meter, 2) Box of current selector, 3) Multiconductor cables, 4) Electrodes, 5) Connector, 6) Current source

3.3.1. Equipment Test

The equipment (Terrameter SAS4000) used for geoelectrical resistivity survey needed to have a good performance in the data reading. One way to know is by comparing it to the other standard device. The following procedure was used in order to carry out error analysis on the equipment.

A series of surface resistivity measurement, were taken using the Terrameter SAS4000 and the standard equipment (digital Voltmeter, Ammeter and a current source) at several sites. Fivefold measurement has been taken for each site. All measurements were taken in the morning to avoid direct sunlight to make sure the moisture content within the surface soil for each measurement remained constant. Figure 3.3 is the measurement set up for the Terrameter and standard device. The raw data of both measurements can be seen in Table 3.1.

The first column displays in Table 3.1 is the C1 location. The second column shows electrodes spacing (denoted as “a”) and the third column is the resistivity reading (see ABEM, 2007). The next three columns give the reading data that derived from standard device measurement. The current and voltage unit in the field used is in micro ampere and millivolt, respectively. However in the three columns (table 3.1), the current and voltage unit is difference and calculated resistivity has been changed into ampere, volt and ohm.m, respectively.

Table 3.2 is a summary of the resistivity data for ten different site measurements. In Table 3.2 the measurement for each site using both equipments (Terrameter and standard device) are quite similar. However, the standard deviations of the conventional standard device for each site are higher than the Terrameter. Hence, it can be concluded that the Terrameter SAS4000 is more stable and less prone to errors as compared to the conventional device.

Figure 3.3. Measurement set up for Terrameter SAS4000 and standard device.

Table 3.1. The raw data of Terrameter SAS4000 and conventional device reading.

C:\SAS4000\Data\rz0001.s4k				Conventional Measurement		
1						
1						
5						
0						
0				I (Ampere)	V(Volt)	R (ohm.m)
	0.00	0.05	110.754049	0.000691	0.242	110.0682241
	0.00	0.05	110.305942	0.000693	0.241	109.2970522
	0.00	0.05	110.385728	0.000694	0.239	108.2338411
	0.00	0.05	110.47095	0.000695	0.239	108.0781089
	0.00	0.05	110.518072	0.000695	0.242	109.4347379
0						
0			110.4869482	Mean		109.0223928
0			0.169982531	Stdev		0.84449914
0						
0						
0						
0						

Table 3.2. Summary data for ten different sites measurement.

Site ID	Terrameter		Conventioanl	
	Mean	Stdev	Mean	Stdev
Site 1	110.487	0.170	109.022	0.844
Site 2	146.077	0.850	144.195	1.453
Site 3	76.132	0.042	78.517	0.535
Site 4	76.221	0.026	71.630	1.317
Site 5	76.703	0.004	71.666	1.260
Site 6	95.608	0.092	105.746	3.697
Site 7	109.100	0.028	112.658	0.420
Site 8	106.163	0.186	124.544	0.328
Site 9	82.139	0.021	86.920	0.244
Site 10	112.158	0.013	110.191	0.499

3.3.2. Field Procedures

In geoelectrical resistivity surveys, determination of the survey site is important prior data acquisition. This is due to the resistivity survey need a certain field condition including, away from vehicle disturbance, long space and far from the noise source. A proper location is searched in the Google Earth and marked into navigation equipment Garmin eTrex Vista HCx GPS (Figure 3.4).

The Wenner array configuration was used to the data acquisition. The spread length of surveys line depended on the target and space available in the field. The maximum spread was 400 m in length. This spread was aimed to locate deeper targets such as basements and deep aquifers. The minimum spread used was 20 m in length. The electrode spacing was decreased to obtain higher resolution.

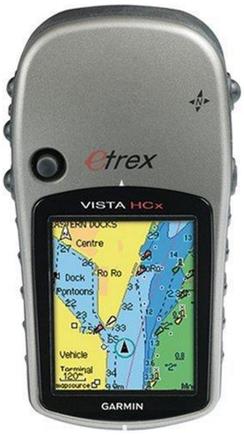


Figure 3.4. The equipment used for navigation (GPS Garmin eTrex Vista HCx).

The data cover for the resistivity surveying with cable systems in general is dependent on several factors such as: the total number of electrode take-outs, the number of sections the cable array is divided into, the measurement array type used (Wenner, Schumberger, pole-pole, dipole-dipole etc.), and whether there are any restrictions on how the electrodes can be combined. The Terrameter SAS4000 displays measured resistance or apparent resistivity values on the screen during data acquisition, the smallest inter electrode distance and the midpoints coordinate (ABEM 2007).

The ABEM Terrameter SAS4000 with Lund Imaging System tool had specific field arrangement when used with four cable set up with 61 takeout. Figure 3.5 (A) illustrates the equipment set up with the four wheel cables. In this setting, 61 electrodes were required with ‘a’ meter electrode spacing. The data acquisition for this set up is using WENNER_L and WENNER_S protocols. The maximum spreading length for such configuration is 400 m length for the 61 electrodes with 5 m spacing. Figure 3.5 (B) shows measurement using electrode combinations that gave basic separations of ‘a’ spacing for shallowest target, and then 2a, 3a, 4a, etc for more information about deeper target. Figure 3.5(C) depicts the data cover for four wheel cables using ABEM Terrameter SAS4000.

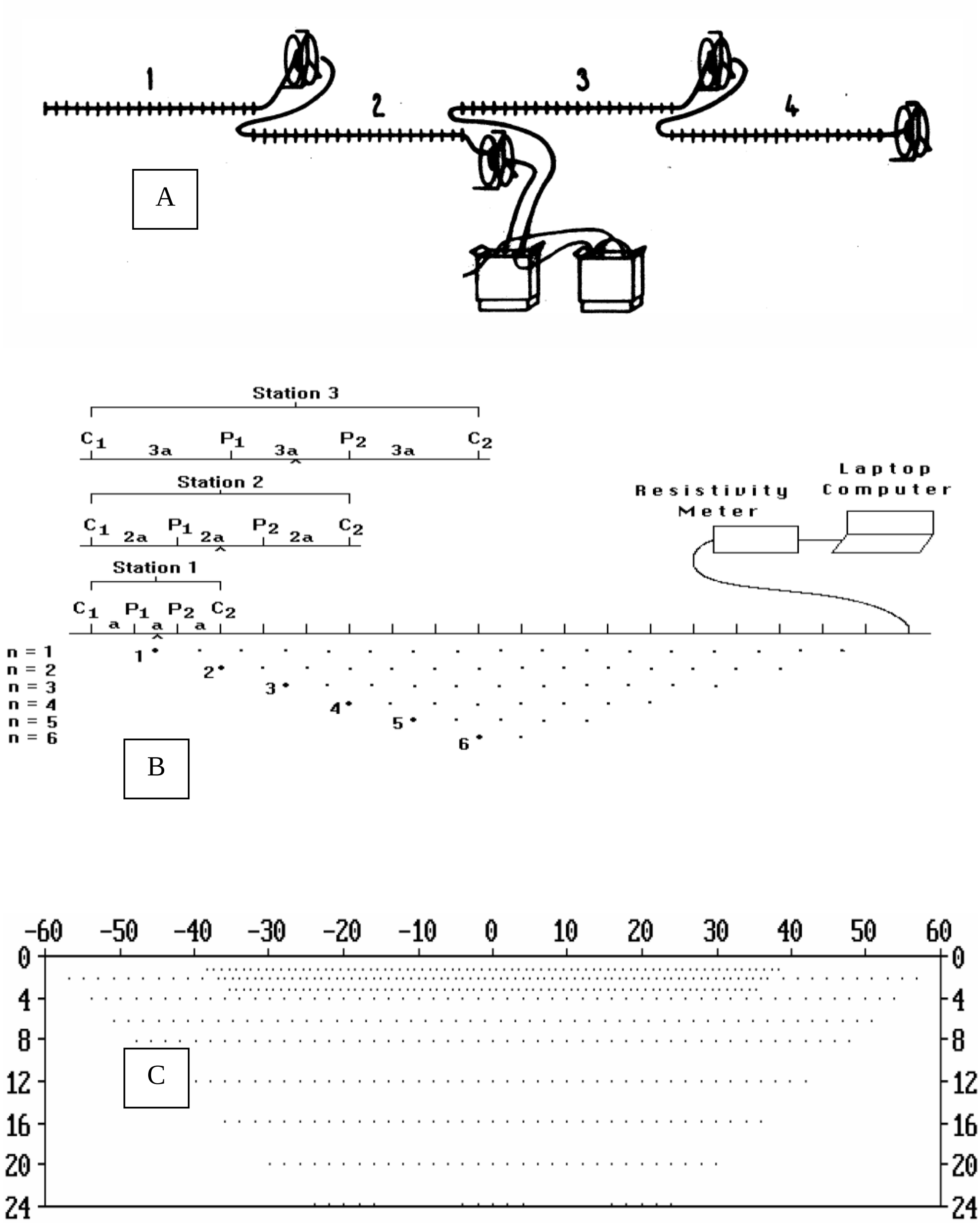


Figure 3.5. Equipment set up for four wheel cables (A). Sequence of measurements to build up a pseudo section using Terrameter SAS400 (B). Data cover of standard Wenner using WENNER_L and WENNER_S protocols for roll-along with three stations (C) (ABEM, 2007).

Marking and tracking the line survey was what followed for the completion of the equipment set up. The position of the cable wheel was orientated in the “plus” direction mark in the inverse model. Generally, the surveys line direction depends on the target in the subsurface. Other factors like the space availability are also considered. If the space is enough, two lines which are perpendicular to each other were conducted.

Direct surface geoelectrical resistivity measurements were carried out to define the surface resistivity. This was done using a “Standard Measurement” tool in the Terrameter equipment. It uses four short cables (C1, C2, P1 and P2) that are connected from the terminals in the equipment to the ground surface. The Wenner configuration was employed to obtain data with 5 cm of electrode spacing. The measured resistivity from this procedure is the true resistivity of the material (Telford, 1990). Figure 3.6 shows the field set up for the direct surface resistivity measurement.

Water samples were taken from areas surrounding the geoelectrical resistivity surveys line to carry out hydrogeochemical analysis.

In areas with greater potential for groundwater contamination due to agricultural activities, the time lapse geoelectrical resistivity survey was used to detect and monitor nitrate movement in the subsurface.

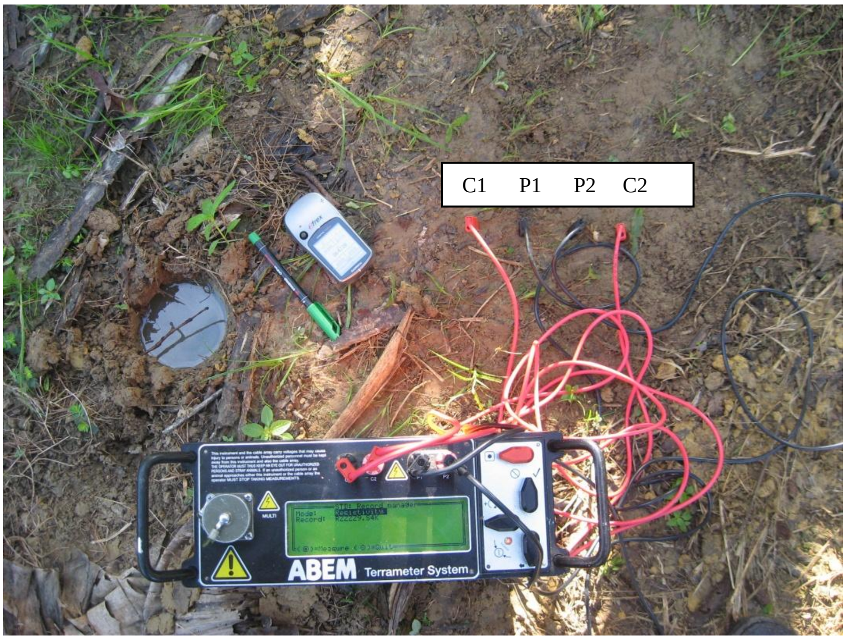


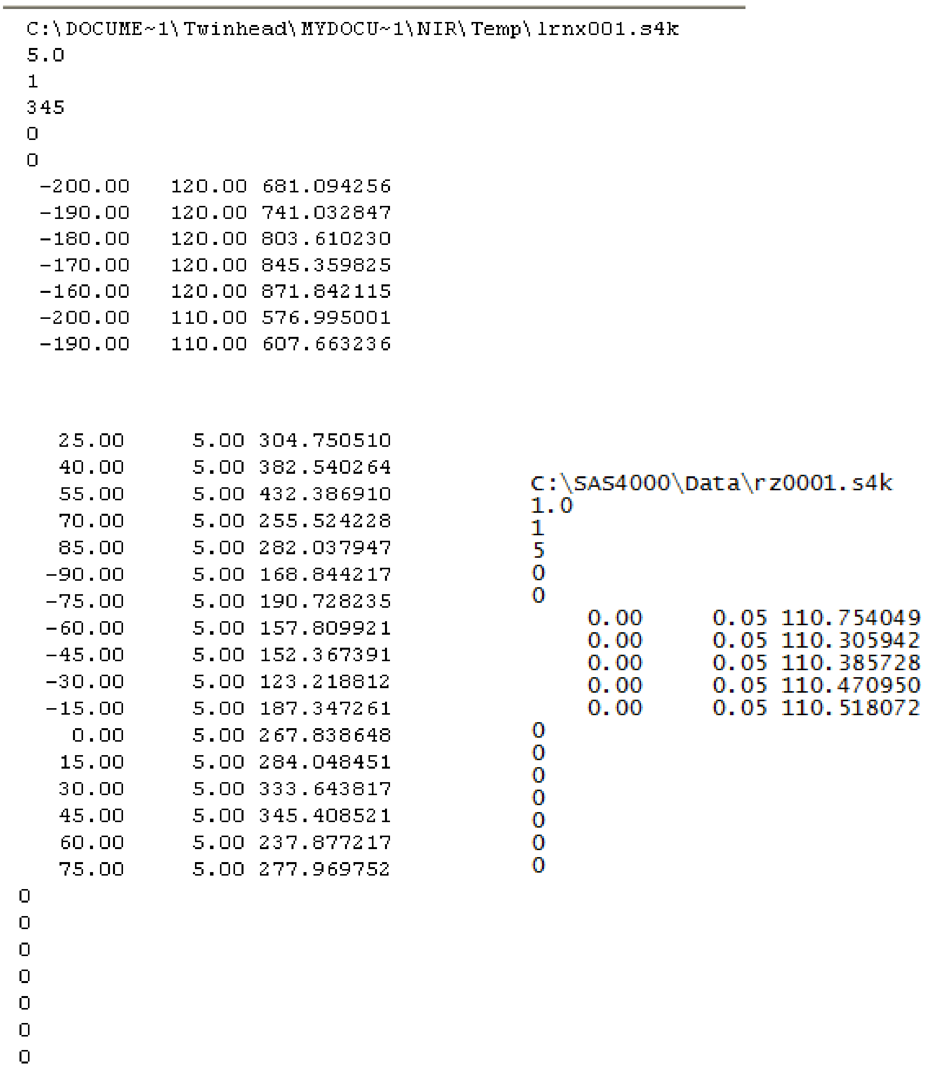
Figure 3.6. Equipment set up for direct surface resistivity measurement with Standard Measurement tool.

3.3.3. Data Presentation

ABEM S4KWin 3.32 software was used to transfer the raw data from Terrameter and convert it into a standardized format readable by Res2DINV (ABEM, 2007). The format data consists of (1) header, (2) data body and (3) end. The complete data readable by Res2DINV is given in Figure 3.7. The data header indicates the path location of the raw data file before conversion. The second raw is the number of electrode spacing (5.0) in meter. The third row is the Wenner code (1) and the fourth row designates the total number of data samples obtained (345).

In the Wenner configuration for the data body (Figure 3.7), the first column is the starting point of the C1 position, the second column is the electrode spacing, and the last column gives the apparent resistivity. The third column is an apparent resistivity.

The final data is geoelectrical resistivity model derived from apparent resistivity values after inversion process using Res2DINV. The scale of resistivity values of the geoelectrical resistivity model needs to be standardized in order to make the visualization and interpretation process easier. A contour plots is used to present the true subsurface resistivity for certain areas. This data presentation was chosen to present data in terms of X and Y location. The product of this presentation is the mapping of certain groundwater cases.



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C:\DOCUME~1\Twinhead\MYDOCU~1\NIR\Temp\lrnx001.s4k
5.0
1
345
0
0
 -200.00   120.00 681.094256
 -190.00   120.00 741.032847
 -180.00   120.00 803.610230
 -170.00   120.00 845.359825
 -160.00   120.00 871.842115
 -200.00   110.00 576.995001
 -190.00   110.00 607.663236


   25.00     5.00 304.750510
   40.00     5.00 382.540264
   55.00     5.00 432.386910
   70.00     5.00 255.524228
   85.00     5.00 282.037947
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  -75.00     5.00 190.728235
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  -45.00     5.00 152.367391
  -30.00     5.00 123.218812
  -15.00     5.00 187.347261
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   15.00     5.00 284.048451
   30.00     5.00 333.643817
   45.00     5.00 345.408521
   60.00     5.00 237.877217
   75.00     5.00 277.969752
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0
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C:\SAS4000\Data\rz0001.s4k
1.0
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    0.00      0.05 110.754049
    0.00      0.05 110.305942
    0.00      0.05 110.385728
    0.00      0.05 110.470950
    0.00      0.05 110.518072
0
0
0
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0
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0
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Figure 3.7. Example of Wenner converted data (left side) and direct surface resistivity measurement (right down).

3.3.4. Inverse Parameter Examination

In this research, least-squares inversion method of Res2DINV software was used in geoelectrical resistivity data processing. The “damping factor” parameter provided in the Res2DINV software, were examined here. The objective will be achieve here is to answer the question when the damping factor is needed. Two data with high noises and low noises are used. The apparent resistivity value with smoother data variation refers to lower noise, and the opposite refers to higher noise (Loke, 1999; 2004). Figure 3.8 shows the two set of different qualities data points with. Knowing data quality is important prior to data processing stage. The first way is to look at the apparent resistivity pseudosection. If there are spots with relatively low or high values, they are likely to be bad datum points. The other way is also to plot the data in profile form that helps to highlight the bad datum points (Loke, 1999) (Figure 3.8). Figure 3.9 and Figure 3.10 exhibit the same data from Fig. 3.9 after applying several damping factor values. For the noisy data in Figure 3.9, the larger initial damping factor causes an increase of the RMS error and the smoothness is not too varied. While increasing of minimum damping factor definitely increase the smoothness result.

For relatively good quality data as in Figure 3.10, the initial damping factor is not too influential on the RMS values. While increasing of the minimum damping factor definitely can increase the RMS error and more smoothness result. It can be concluded that variable damping factors (initial damping factor or minimum damping factor) is required to handle data with relatively lower quality.

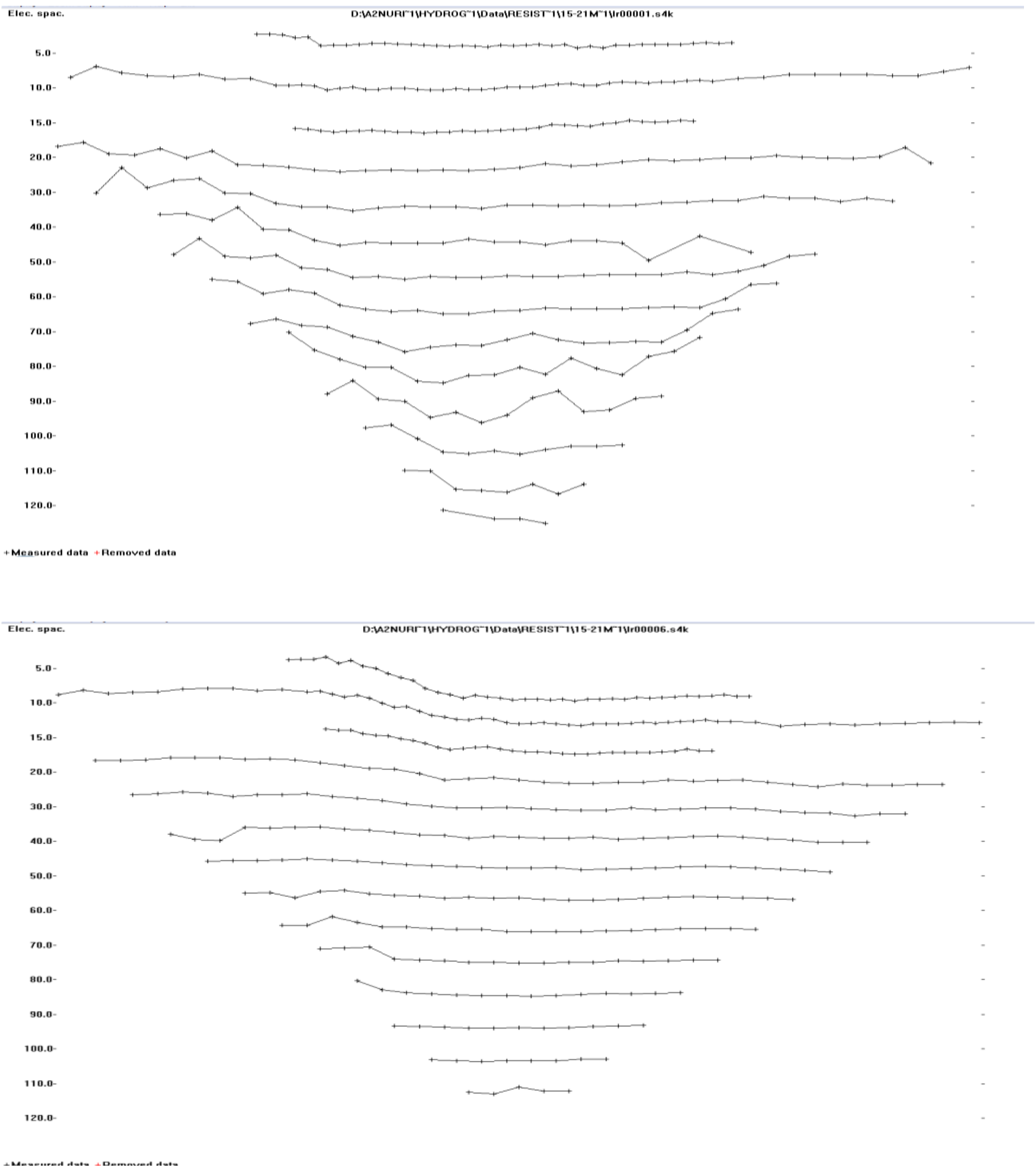


Figure 3.8. Graphical presentation of two separate data readings, displaying differences in quality. Two data with different its quality. Relatively bad quality data (top) and better quality data (bottom)

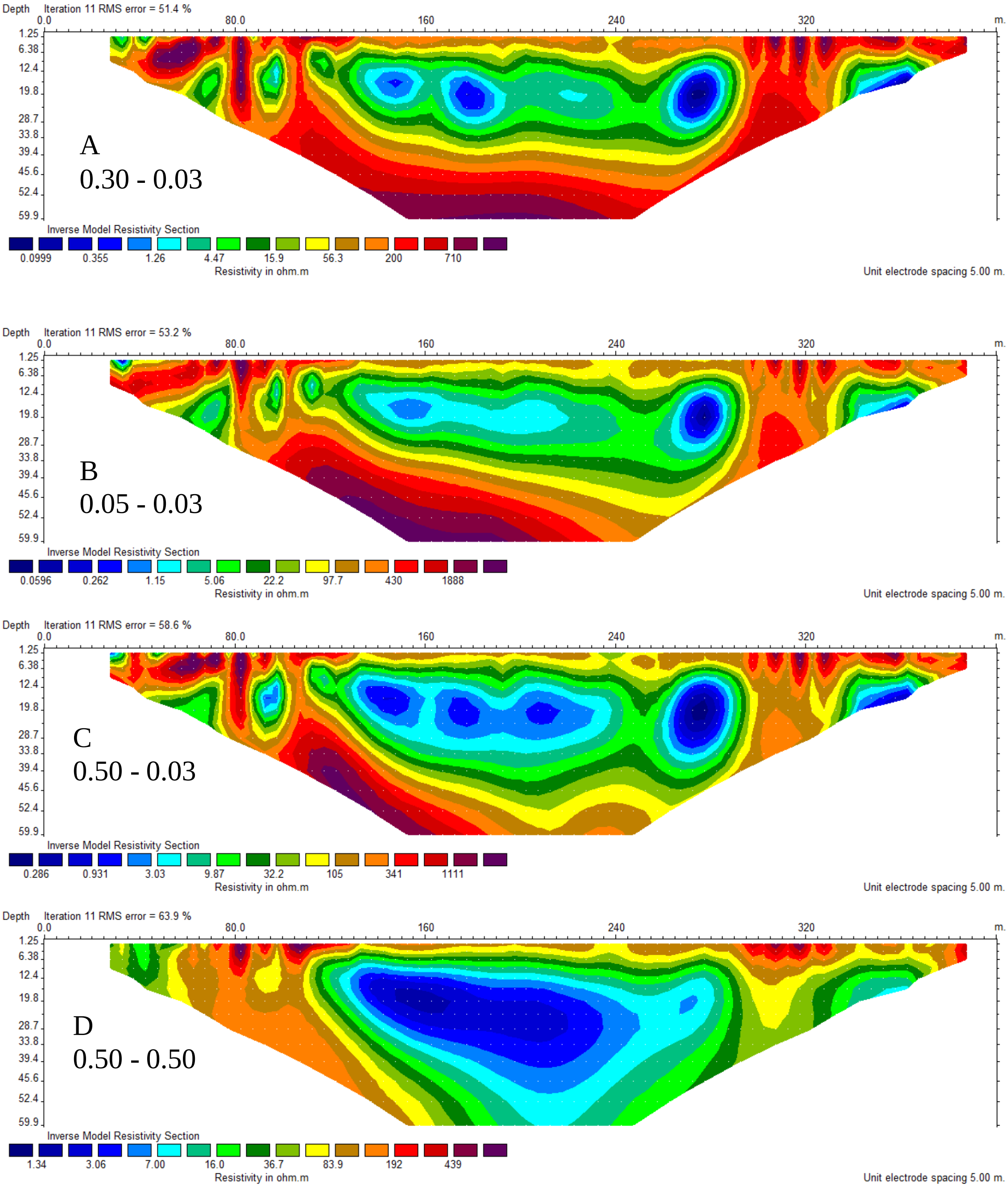


Figure 3.9. Damping factor application to relatively bad quality data. (A) Default damping factor, (B) initial 0.05, minimum 0.03. (C) initial 0.5, minimum 0.03 and (D) initial 0.5, minimum 0.5.

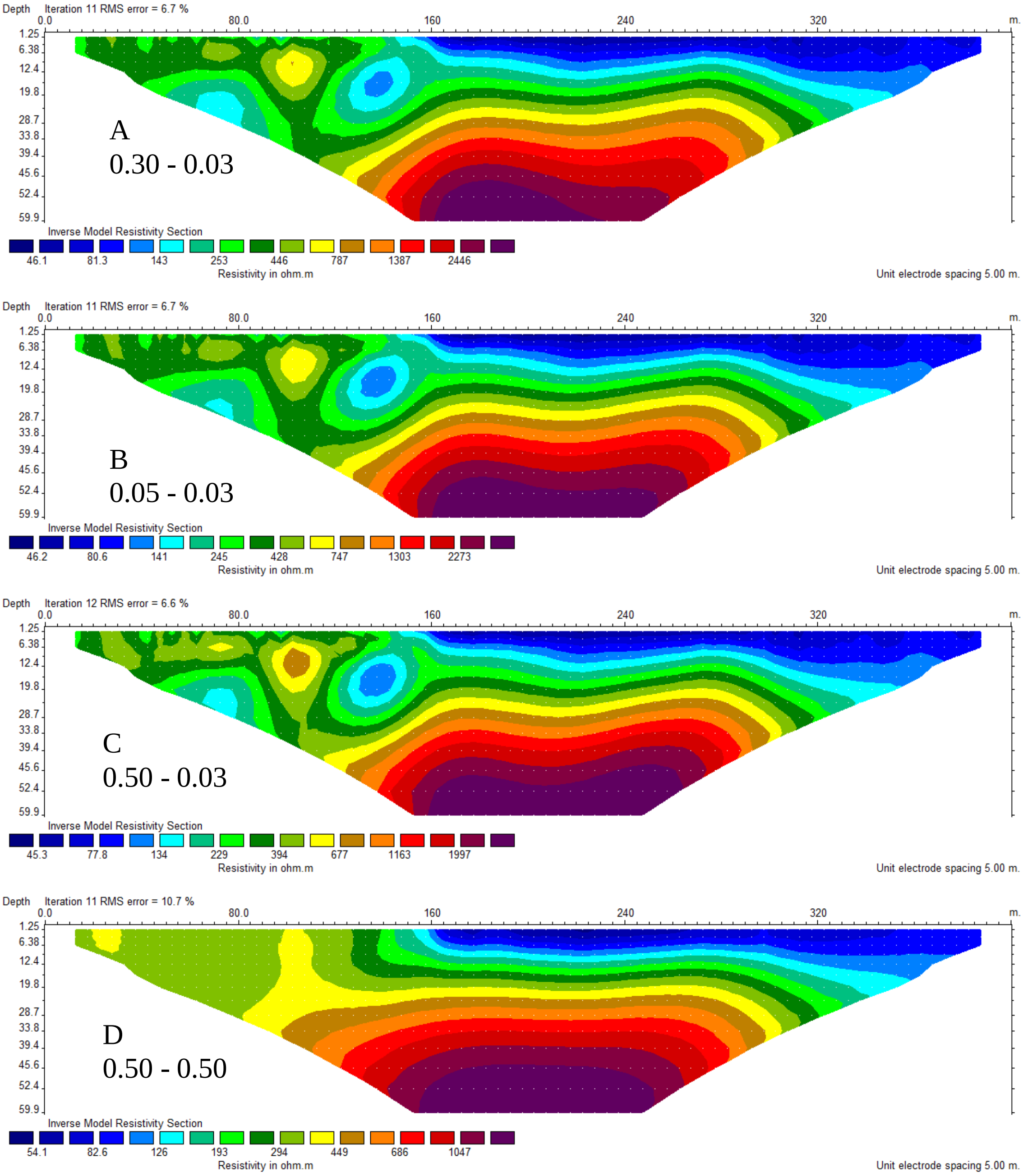


Figure 3.10. Damping factor application to relatively good quality data. (A) Default damping factor. (B) initial 0.05, minimum 0.03. (C) initial 0.5, minimum 0.03 and (D) initial 0.5 minimum 0.5.

3.3.5. Data Collection

Instrument set up for data acquisition depends on the target and available space in the field. Four wheel cables with maximum electrode spacing (5 m) are required for deep target. If the targets need higher resolution (e.g. nitrate monitoring), electrode spacing is to be smaller. Figure 3.11 shows examples of geolectrical model for deep targets, moderate resolution targets and higher resolution target.

Other resistivity data collections are the direct surface resistivity measurements. The data is collected almost for the entire site survey. The data is very useful in the geoelectrical model interpretation. Figure 3.12 is an example of the data. The data obtained for the geoelectrical resistivity and direct surface resistivity measurements will be presented simultaneously in the next chapter for each site survey.

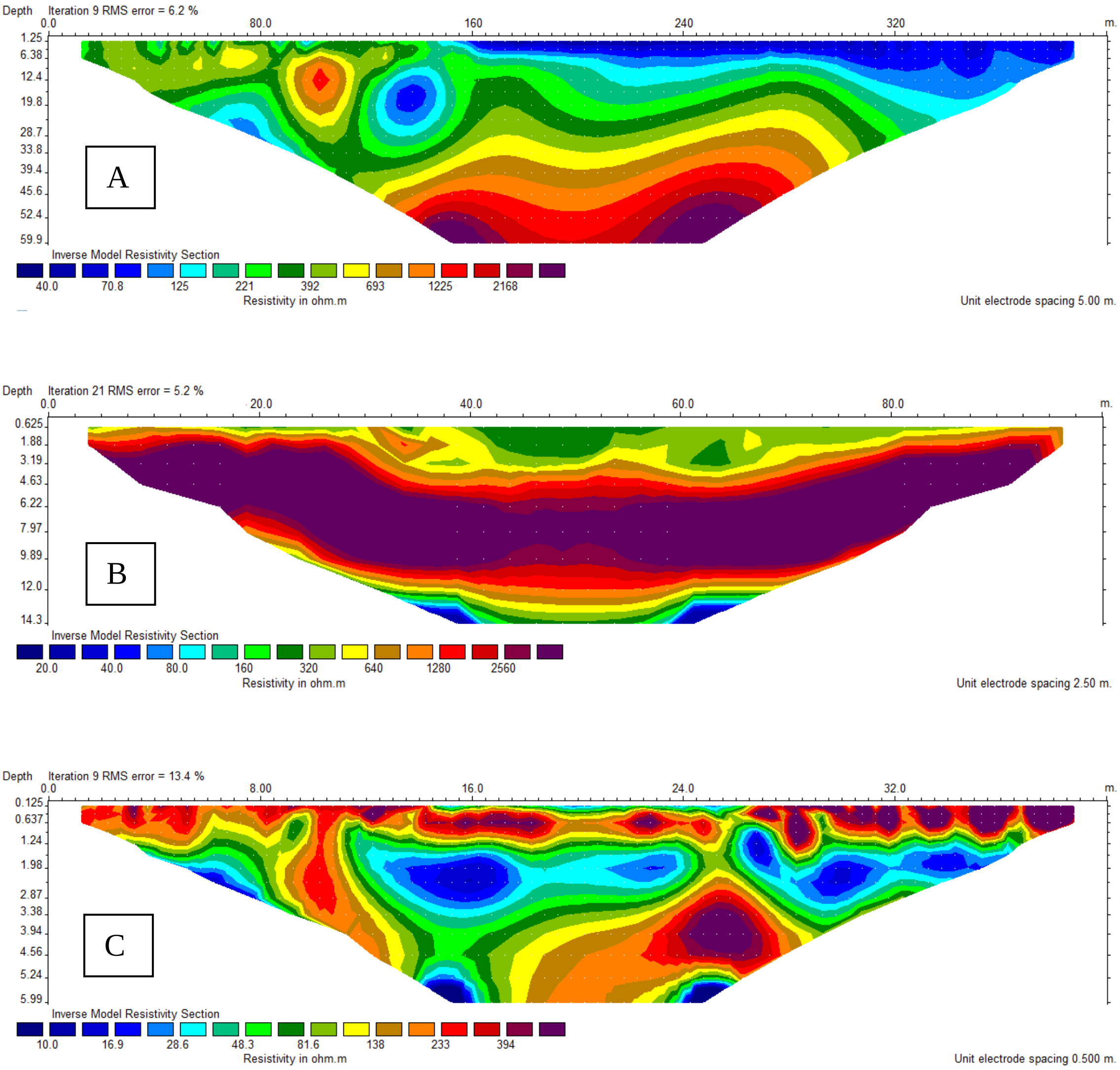
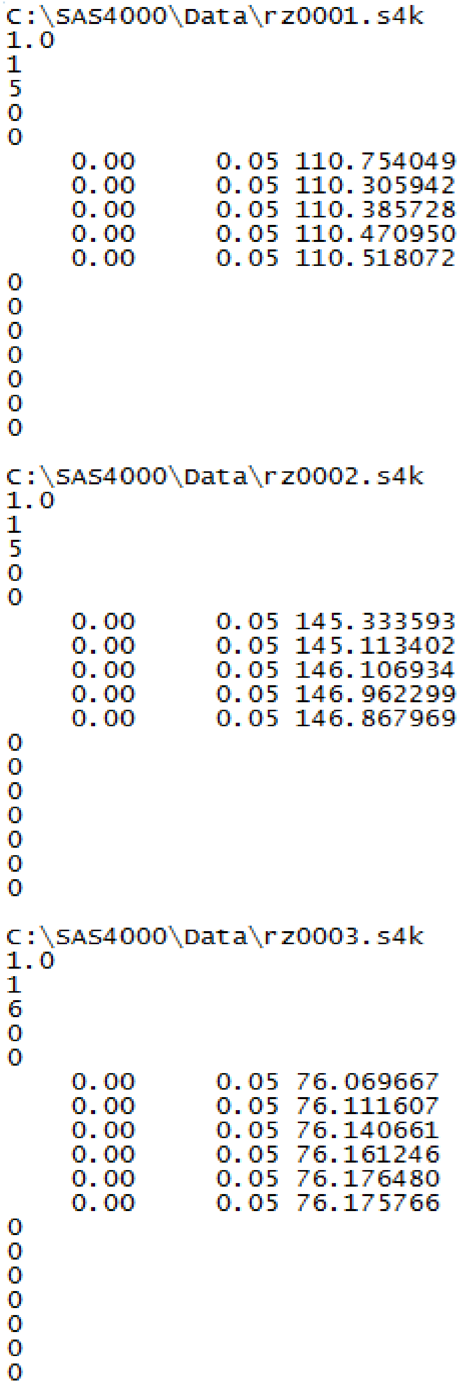


Figure 3.11. Geolectrical model for (A) deepest target with 5 meter of electrodes spacing. (B) 2.5 meter of electrodes spacing. (C) Higher resolution with 0.5 meter of electrodes spacing.



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1.0
1
5
0
0
        0.00        0.05 110.754049
        0.00        0.05 110.305942
        0.00        0.05 110.385728
        0.00        0.05 110.470950
        0.00        0.05 110.518072
0
0
0
0
0
0
0

C:\SAS4000\Data\rz0002.s4k
1.0
1
5
0
0
        0.00        0.05 145.333593
        0.00        0.05 145.113402
        0.00        0.05 146.106934
        0.00        0.05 146.962299
        0.00        0.05 146.867969
0
0
0
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0
0
0

C:\SAS4000\Data\rz0003.s4k
1.0
1
6
0
0
        0.00        0.05 76.069667
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        0.00        0.05 76.140661
        0.00        0.05 76.161246
        0.00        0.05 76.176480
        0.00        0.05 76.175766
0
0
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0
0
0
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Figure 3.12. Direct surface resistivity measurement data for 5 cm of electrodes spacing.

3.4. Borehole Geophysics

Borehole geophysics is the science of recording and analyzing measurements of physical properties made in wells or test holes. The main objective of obtaining borehole data is to get direct information of the subsurface with depth. Probes that measure different properties are lowered into the borehole to collect continuous or point data that is graphically displayed as a geophysical log (Robinson, 1988).

Borehole geophysics is used in groundwater and environmental investigations to obtain information on rock lithology and fractures, permeability and porosity, and water quality. The common borehole geophysics used in the hydrogeology study are gamma ray, self potential (SP), resistivity and neutron porosity. In this research, the existing natural gamma ray data was used to study subsurface litology.

3.4.1. Field Procedure

There are nine existing well log measurement in the coastal plain area. However, there is no well data exists in the area from Perol pumping well station to the shouthern part. Thus, installation of a new well is required to obtain subsurface information. The zone of interest and the position of new well target were derived from geoelectrical resistivity interpretation. It was then determined whether a boring equipment would be permitted to drill the new well in the area of interest. Due to the logging company cannot provide the logging service (technical problem), a subsurface lithology was obtained from disturbed soil. The photograph of boring work is shown in Figure 3.13.

Figure 3.13. Boring equipment to drill a well.

3.4.2. Data Collection

In this research, a hard copy of gamma ray data of nine wells was obtained from Abdul (1989). Hence digital conversing of the hard copy of gamma ray data was conducted using tool in the Surfer 8 software. Figure 3.14 is an example of gamma ray data derived from the existing wells (Kubang Kerian and Perol pumping well station). The detailed gamma ray data will be presented and discussed in the next chapter.

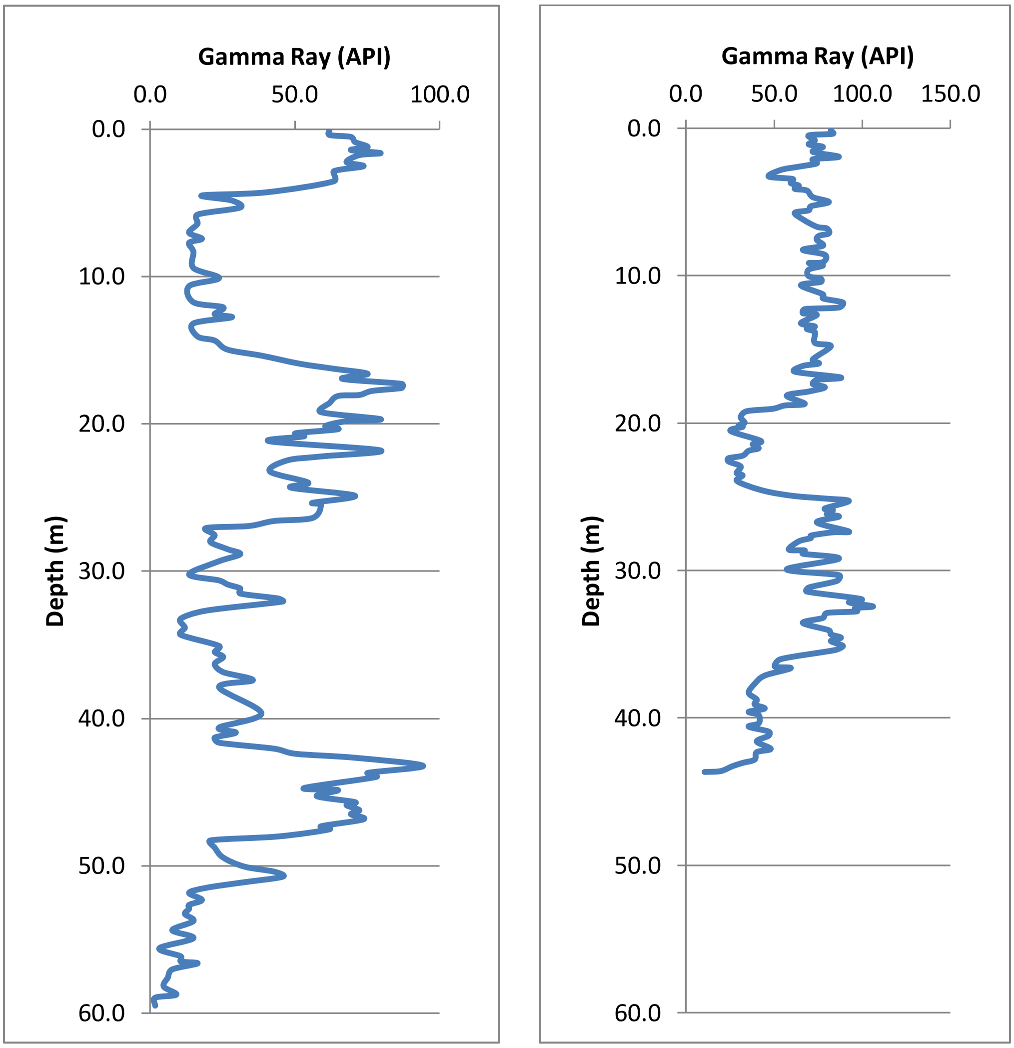


Figure 3.14. Gamma ray data of Kubang Kerian (left) and Perol (right) pumping well stations.

3.5. Hydrogeochemical Method

Geoelectrical resistivity methods provide information in terms of resistivity variations in the subsurface. However, it does not give further details on the exact condition of groundwater in terms of total dissolved solid (TDS), pH, and other cation and anion content. Other methods are needed to support the geoelectrical resistivity method. In this research, a combination of geoelectrical resistivity, hydrogeochemichal, borehole geophysics and soil property analysis methods have been used.

Two conditions of measurement needed to obtain hydrogeochemical data are (i) in-situ parameters measured at the site and (ii) cations and anions concentration in the water sample.

3.5.1. Field Procedures for In-situ Parameter Measurement

The equipment for in-situ parameter measurement was calibrated according to the manufacturer's instructions prior to use. At a minimum, a two-point calibration should be conducted to ensure the accuracy of the meter. The following calibrations are minimum requirements.

1. Rinse the probe with de-ionized water and blot dry or otherwise remove excess rinse water and immerse it into the original buffer and read as a sample.

2. Put the probe into pH 7.00 buffer. Rinse the probe with distilled water from a wash bottle into an empty beaker before immersing it into new solution.
3. It should do it every time probe is moved from one solution to other to minimise contamination. Check if the working part of the electrode is completely immersed in the buffer. Wait for the reading to stabilize.

4. The next step involves the calibration of pH meter. For pH in acidic solutions, a pH 4.00 buffer was used. For measuring high pH, a pH=10.00 buffer was used.
5. The specific solution (calibrator 1000 μS/cm) was also used to calibrate other equipment in terms of TDS, conductivity, and salinity meter.

In the field, approximately 400 ml water samples was required to measure their in-situ parameters. The medium of water sample was rinsed by the water sample in order to remove impurities from previous water samples using the medium. The probe, in turn was rinsed by pure water to ensure no foreign materials are still attached prior to the reading was started. TDS, Conductivity, Salinity, pH and temperature are the major in-situ parameters measured. Equipment that was used to obtain the in-situ parameters are shown in Figure 3.15.

Well physical data were retrieved directly from the existing well or piezometer including well location (X, Y coordinate), ground level, well depth and depth to water table. Well location was obtained from GPS equipments (Global Positioning System). Unfortunately, due to the limitations of GPS equipments used, the ground level (elevation relative to mean sea level) cannot be measured at the site. The GPS used in this research was not sensitive enough in measuring elevation level. It was only used for determining the location in terms of X and Y or latitude and longitude with 0.5 m resolution. The Google Earth provided the elevation of each particular location. Well depth was obtained from the well owner or measured directly. In turn, water level was known using the equipment shown in Figure 3.16.

Figure 3.15. Equipment used in order to attain in-situ parameters: pH meter (left), and Conductivity-TDS-Salinity-Temperature meter (right).

Figure 3.16. Deep meter for water level equipment.

3.5.2. Field Procedures for Cation and Anion Measurement

In the field, to make sure that the water sample is collected from the aquifer, the well is pumped for 10 minutes before collecting the water sample. Two plastic bottles with 100 milliliters water samples is required after filtering processes (through 0.45 μm membranes). These bottles had been rinsed with deionised water before sampling. The water samples were kept at a temperature of 4^0C until to be sent to the hydrogeology laboratory for chemical determination analysis using Ion Chromatography (IC) and Inductively Coupled Plasma (ICP) (Figure 3.17). For ICP purpose, additional acid within the water sample was required to achieve 4 of its pH level (Black, 1965). It is required to keep them from other reaction before processing stage in the laboratory.

An equipment manufactured by Soil moisture Equipment Corp USA “1900 Soil Water Samplers” was used to collect soil pore water (water in vadoze zone) at certain depth in the vadose zone. The equipment consists of a 4.8 cm screen, PVC tube and 2 bar (200-k Pa) porous cup, Santoprene and handpump (Figure 3.17).

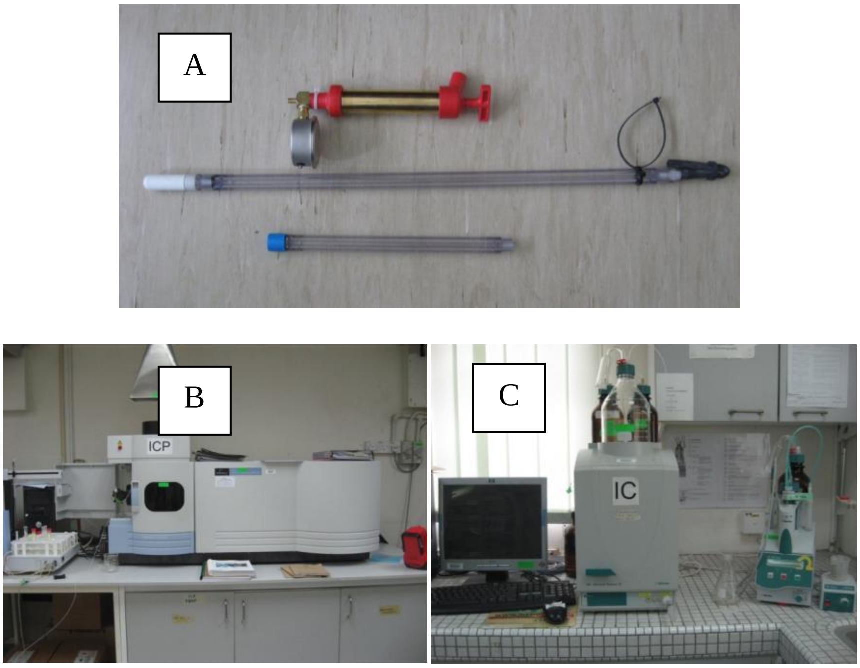


Figure 3.17. Equipment for cation and anion analyses in Hydrogeochemical lab. (A) 1900 Soil Water Samplers, (B) ICP, (C left) IC and (C right) tritor.

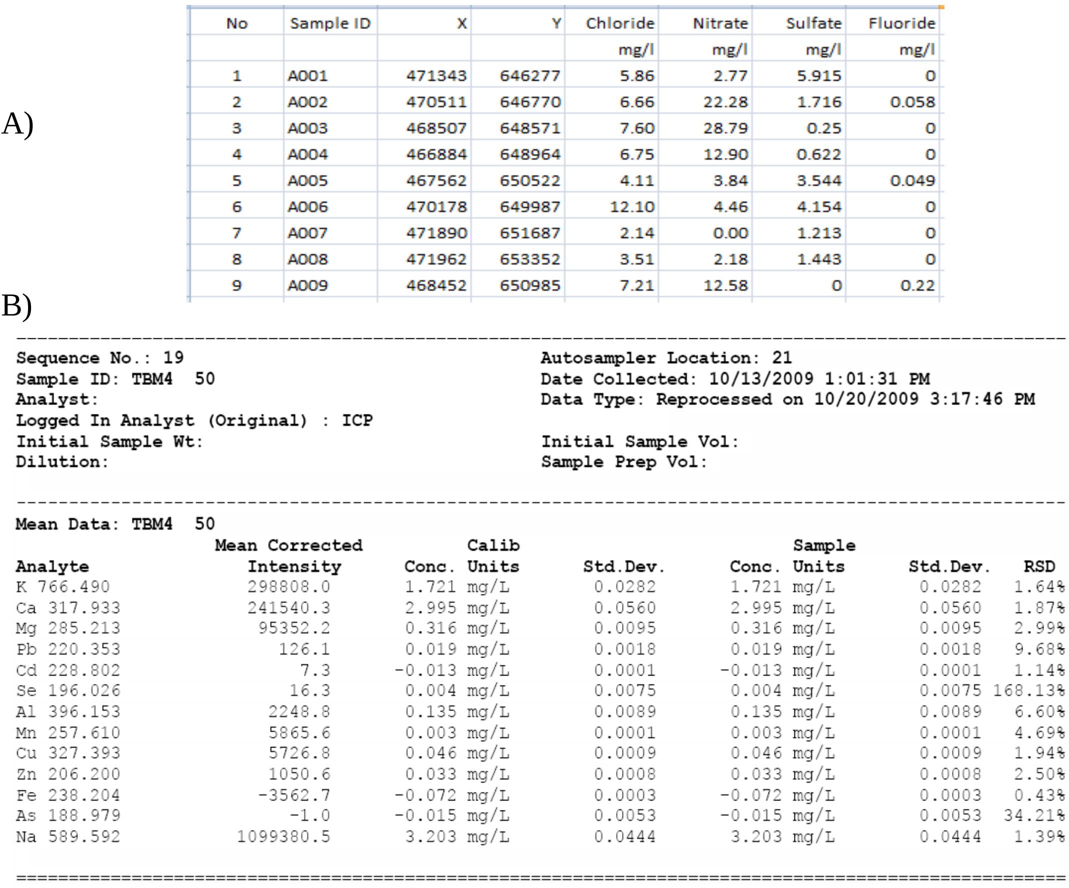
3.5.2. Data Collection

The in-situ physical well parameters and water parameters is given in Table 3.3. In the table, both in-situ water parameters (TDS, Conductivity Salinity Temperature and pH) and physical well parameters (X, Y, Well depth, Well elevation, Water level and water level relative to mean sea level) are presented together. Detailed in-situ parameter data for each problem faced in each area is given in the next chapter.

The original anion data received from the IC equipment was plotted graphically. Whilst, the cation data received from the ICP equipment was plotted in a pdf file. An example of the selected data for anion and cation are presented in Figure 3.18. A detailed version of the summarised data is presented in each of next chapters.

Table 3.3. Physical well and in-situ parameter data.

No	Sample ID	Location X (m)	Location Y (m)	Well Depth (m)	Ground Level (m)	Depth to Water (m)	Water L (a.m.s.l) (m)	TDS mg/L	Conductivity µS/cm	Salinity 0/00	T ^{0}C	pH
1	WA101	467159	646187	5	24	1.43	22.57	370	751	0	28.3	6.88
2	WA102	467455	645676	5	26	1.92	24.08	247	501	0	28.3	5.98
3	WA103	469175	646657	3	28	2.38	25.62	49	98	0	30.5	5.09
4	WA104	469982	645778	7	38	2.46	35.54	60	121	0	28.1	4.49
5	WA105	470622	646025	5	29	1.22	27.78	35	70	0	28.5	6.19
6	WA106	470630	645415	<7	33	2.96	30.04	48	97	0	30.1	6.42
7	WA107	471343	646277	<7	28	2.56	25.44	76	159	0	27.8	4.77
8	WA108	470511	646770	<7	24	2.1	21.9	323	654	0.1	30.5	5.98
9	WA109	468507	648571	5	22	1.96	20.04	407	830	0	29.4	4.93
10	WA110	466884	648964	<7	21	0.86	20.14	76	159	0	29.2	4.63
11	WA111	467562	650522	<7	22	0.98	21.02	78	163	0	29.1	5.72
12	WA112	470178	649987	<7	18	0.67	17.33	151	313	0	27.4	5.75
13	WA113	471890	651687	<15	40	10.62	29.38	57	120	0	28.5	6.14
14	WA114	471962	653352	<7	24	1.35	22.65	83	173	0	31.7	4.86
15	WA115	468452	650985	<7	20	0.91	19.09	50	104	0	34.4	5.72
16	WA116	473804	654980	<7	19	1.02	17.98	183	381	0	42.2	4.77
17	WA117	473733	656574	<7	14	0.23	13.77	84	170	0	31.1	6.4
18	WA118	470689	656930	5	17	0.65	16.35	89	180	0	25.7	6.42
19	WA119	470404	658785	6	28	2.11	25.89	64	130	0	28.7	6.22
20	WA120	470475	654957	<7	17	0.61	16.39	106	217	0	27.2	4.11



(A)

No	Sample ID	X	Y	Chloride	Nitrate	Sulfate	Fluoride
				mg/l	mg/l	mg/l	mg/l
1	A001	471343	646277	5.86	2.77	5.915	0
2	A002	470511	646770	6.66	22.28	1.716	0.058
3	A003	468507	648571	7.60	28.79	0.25	0
4	A004	466884	648964	6.75	12.90	0.622	0
5	A005	467562	650522	4.11	3.84	3.544	0.049
6	A006	470178	649987	12.10	4.46	4.154	0
7	A007	471890	651687	2.14	0.00	1.213	0
8	A008	471962	653352	3.51	2.18	1.443	0
9	A009	468452	650985	7.21	12.58	0	0.22

(B)

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Sequence No.: 19                                  Autosampler Location: 21
Sample ID: TBM4  50                               Date Collected: 10/13/2009 1:01:31 PM
Analyst:                                          Data Type: Reprocessed on 10/20/2009 3:17:46 PM
Logged In Analyst (Original) : ICP
Initial Sample Wt:                                Initial Sample Vol:
Dilution:                                         Sample Prep Vol:

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Mean Data: TBM4  50
                   Mean Corrected          Calib                          Sample
Analyte              Intensity      Conc. Units     Std.Dev.       Conc. Units     Std.Dev.     RSD
K 766.490             298808.0       1.721 mg/L        0.0282       1.721 mg/L        0.0282   1.64%
Ca 317.933            241540.3       2.995 mg/L        0.0560       2.995 mg/L        0.0560   1.87%
Mg 285.213             95352.2       0.316 mg/L        0.0095       0.316 mg/L        0.0095   2.99%
Pb 220.353               126.1       0.019 mg/L        0.0018       0.019 mg/L        0.0018   9.68%
Cd 228.802                 7.3      -0.013 mg/L        0.0001      -0.013 mg/L        0.0001   1.14%
Se 196.026                16.3       0.004 mg/L        0.0075       0.004 mg/L        0.0075 168.13%
Al 396.153              2248.8       0.135 mg/L        0.0089       0.135 mg/L        0.0089   6.60%
Mn 257.610              5865.6       0.003 mg/L        0.0001       0.003 mg/L        0.0001   4.69%
Cu 327.393              5726.8       0.046 mg/L        0.0009       0.046 mg/L        0.0009   1.94%
Zn 206.200              1050.6       0.033 mg/L        0.0008       0.033 mg/L        0.0008   2.50%
Fe 238.204             -3562.7      -0.072 mg/L        0.0003      -0.072 mg/L        0.0003   0.43%
As 188.979                -1.0      -0.015 mg/L        0.0053      -0.015 mg/L        0.0053  34.21%
Na 589.592           1099380.5       3.203 mg/L        0.0444       3.203 mg/L        0.0444   1.39%

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Figure 3.18. Water chemical data for (A) anion concentration, (B) cation concentration.

3.6. Soil Properties Analysis

In this research soil property analysis was carried out to support geoelectrical resistivity interpretation and hydrogeochemical analysis. The soil property analysis includes soil grain size distribution analysis, moisture content analysis and hydraulic conductivity analysis.

Soil is sampled from the surface to 100 cm depth. At certain location, the sampling depth can reach up to 4.5 m deep. This depth is the maximum penetration of the equipment (hand auger) which is used for soil digging. The sample was dried using electrical oven with 105^0 C for 24 hours. The dried soil is sieved using mechanical sieving manufactured by Wykeham Farrance (Figure 3.19.A) to divide soil into separates classes. The dried soil is classified according to the grain size classification scheme by Hamlin (1991), such as, gravel, sand, silt and clay.

A hole is created using hand auger with 11 cm of diameter and 60 cm depth (Figure 3.19.B). After the digging finished, the surface in borehole bottom is clear and flat. Water is filled into borehole as soon as possible to void more water infiltrating to everywhere before the time counter is started. The stopwatch is started after the water really crating the same plane with the elevation datum. The rate of decreasing water level was initially intermittent but eventually stabilized to a constant rate after some time. Reducing of water in the hole is recorded and the time as well.

The soil sampling was carried out within each survey. Soil samples as a mixture of several depths with a threefold replication were taken from depth 0 to 1 m. After this, soil samples were weighed, at 105°C dried for 24 hour and the weight reduction as gravimetrical soil moisture content (%) are estimated. Almost all the sampling for grain size distribution is also determined their soil moisture content.

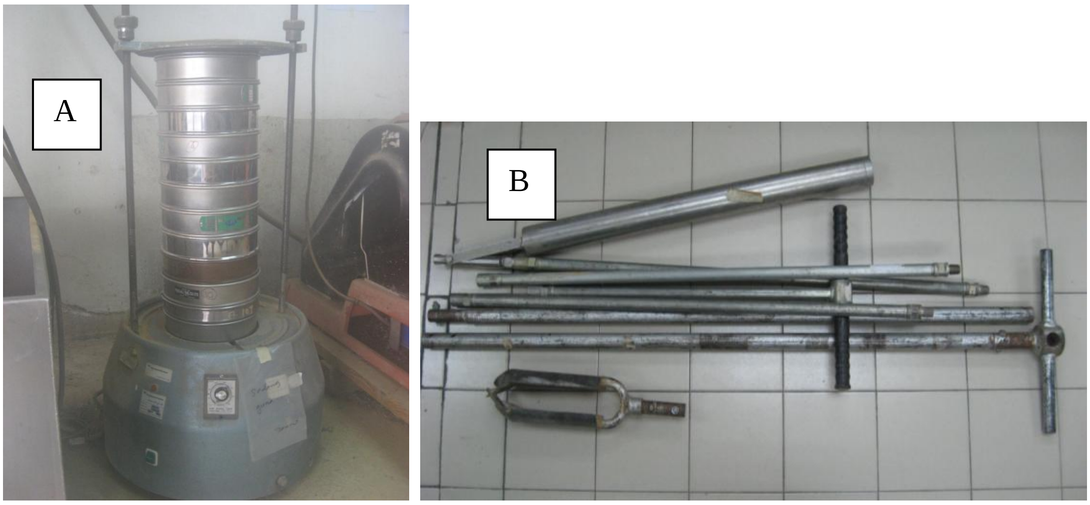

Figure 3.19. Hand auger with a diameter of 11 centimetres (A). Mechanical sieving equipment (B).