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Geophysical investigation for groundwater exploration at UKM's Kuala Pilah Matriculation Centre, Negeri Sembilan

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Abstract: A geophysical investigation was conducted at the UKM's matriculation centre in Kuala Pilah, Negeri Sembilan by the Department of Geology, Universiti Kebangsaan Malaysia. The study was initiated as a result of water shortage in the area. The normal supply of piped water by Jabatan Bekalan Air (JBA) is either insufficient or totally cut off for several days especially during dry season. The aim of the study was to look for groundwater as a possible source of back up water supply for the centre. Geoelectrical resistivity sounding and seismic methods were adopted for assessment of the groundwater potential of the site and to determine the subsurface conditions of the area. A total of eleven sounding stations and eight seismic profiles were established. A layer of low resistivity (< 100 ohm-m) was detected at eight sounding localities within the study area. This conductive layer could be associated with a near surface water saturated zone or aquifer. However based on seismic data and by taking velocity of 1,600 to 1,700 m/s for the water saturated zone, only one location (S4/SP3) was found to be favourable. The potential water saturated layer has a resistivity value and a seismic velocity of about 80 ohm-m and 1,690 m/s respectively. Both geoelectrical and seismic results show good agreement in term of depth below surface (~ 2 metres) and layer thickness (~ 30 metres). However, these results need to be confirmed by drilling.

INTRODUCTION

The shortage of piped water supply at UKM's Matriculation Centre in Kuala Pilah, Negeri Sembilan (Fig. 1) has caused considerable problems to about five hundred residents of the centre. The supply of piped water to the educational centre is either insufficient or totally cut off for several days especially during dry season. The irregularity of the water supply has not only caused problems to the students and workers of the centre but it also affected the nearby residential areas. Although the problem was overcome temporarily by having backup water supply from Jabatan Kerja Raya (JKR), the fact remains that the water shortage at the Matriculation Centre is a reality and such a situation could occur again in the future. In order to ensure the restoration of regular water supply in future, the authority of Universiti Kebangsaan Malaysia has decided to use groundwater as a possible alternative source of back up water supply or as a contingency measure against future water problems. The Geology Department of the Universiti Kebangsaan Malaysia has been instructed to make a feasibility study on the groundwater resources and its potential use as future backup water supply at the centre. The Department of Geology has taken the responsibility to conduct a geophysical investigation to evaluate the groundwater resources within the area of the Matriculation Centre. The main objective of the study is mainly to determine the possible presence of water saturated layer or groundwater aquifer within the educational centre area.

MATERIAL AND METHOD

The potential location of the groundwater resources in the study area was investigated by employing both geoelectric resistivity and seismic refraction techniques. The geoelectric resistivity survey was carried out to determine the existence of subsurface low resistivity zones (< 100 Ω-metre) which could be associated with water saturated layers or aquifers in the study area. This method uses natural resistivity of the earth material. Different type of rocks or earth material have different range of resistivity values. By introducing current into the ground through two electrodes and measuring the voltage at the two inner electrodes one can calculate the approximate apparent resistivity of the earth material within the area of influence. The theory and technique of geoelectrical sounding and its interpretation can be found in most geophysics text books such as Dobrin and Savit (1988) and Telford *et al.* (1990). The main aim of the geoelectrical resistivity survey was to assist in delineating possible water saturated zones in the study area. A limited resistivity survey was carried out in the area at eleven (11) stations (Fig.

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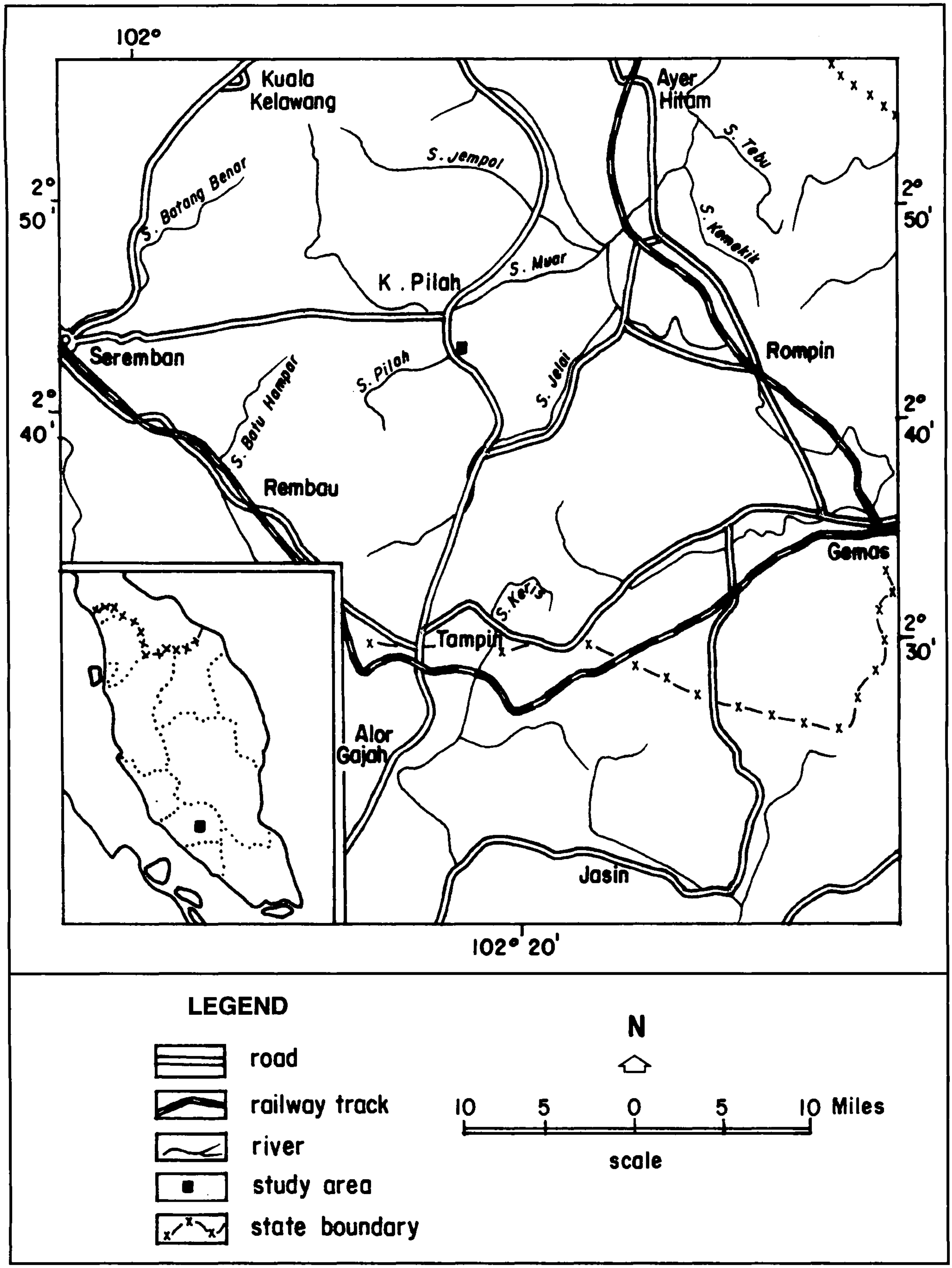

Figure 1. Location of the study area.

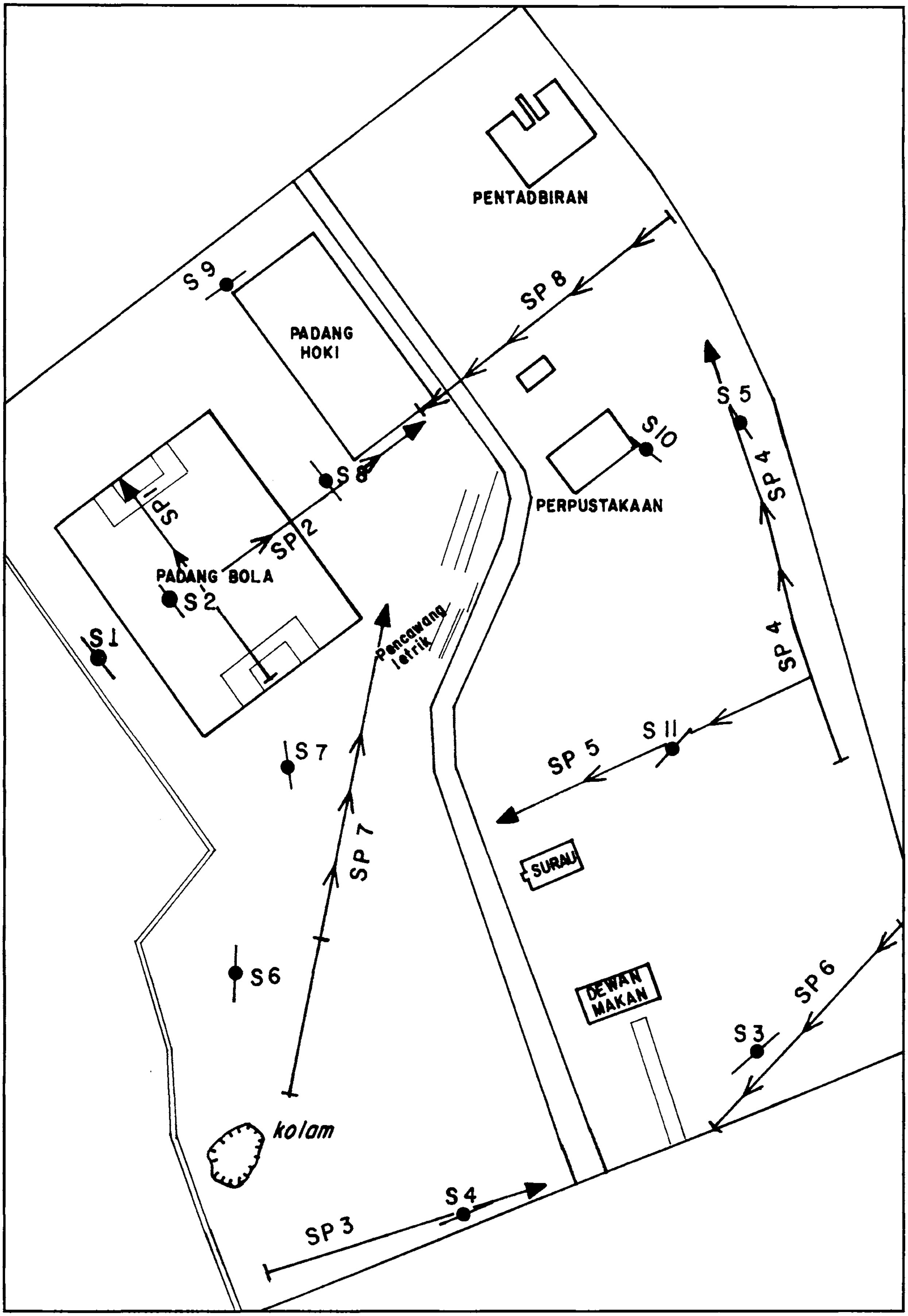

Figure 2. Location of the geoelectrical sounding stations and seismic refraction profiles.

Table 1. Vertical resistivity sounding results interpreted using resistivity inversion program (RESIX).

Sounding	Layer 1	Layer 2	Layer 3	Layer 4
S1	500 (1.8)*	250 (21.2)	85 (Infinite)	
S2	200 (1.0)	400 (40.0)	350 (10)	> 10,000 (Infinite)
S3	400 (7.0)	10 (1.0)	450 (3.0)	> 10,000 (Infinite)
S4	400 (2.0)	80 (34.0)	150 (4.0)	> 10,000 (Infinite)
S5	500 (5.5)	200 (0.7)	110 (Infinite)	
S6	350 (0.5)	650 (14.5)	250 (Infinite)	
S7	400 (2.0)	900 (3.5)	55 (2.0)	1,000 (12.0)
S8	450 (0.4)	230 (6.0)	70 (Infinite)	
S9	250 (4.0)	80 (70.0)	3,000 (Infinite)	
S10	260 (8.0)	30 (29.0)	80 (1.0)	4,000 (Infinite)
S11	550 (2.0)	300 (7.0)	60 (Infinite)	

* *Resistivity value in ohm-metre*
(Thickness in metre)

2). An ABEM ac terrameter model EL66-010 was employed for the survey and Schlumberger electrode configuration was utilised for the geoelectrical sounding with maximum electrode spacings (AB/2) of about 100 metres. The resistivity data were processed and interpreted by using a resistivity computer programme (Resix v.2.0, 1990). Resix is a forward and inverse modeling programme for interpreting resistivity sounding data in terms of a layered earth model.

The refraction seismic survey was conducted to obtain additional subsurface information of the study area. This method enables the determination of the thicknesses and depths of subsurface layers as well as velocity of the seismic p-wave travelling within the layered materials.

The seismic p-wave passing through a water saturated layer would normally have velocity ranging from 1,600 to 1,700 m/s. For the seismic survey, a 24 channels ABEM MARK III signal enhancement seismograph with hammer source was used. The refraction seismic method enables subsurface data to be obtained using a straight-forward linear shooting pattern. Geophone spacing was 5 metres which give a geophone coverage of 115 metres for 24 geophones. A seven shot point (hammer points) configuration (–25, 2.5, 27.5, 57.5, 87.5, 112.5 and 140 m) was employed. For arrivals at the distant geophones, which are weak because of the large distance travelled and due to noise, the signal was enhanced by summing a number of hammer blows together. By enhancing the signal in this manner and with spread lengths of 115 metres, a maximum estimated penetration of up to approximately 40 metres vertical depth was possible. The seismic records obtained from each spread were stored on 3.5 inches floppy disks which were later used to determine the first arrival time at each geophone. A time-distance graph was constructed for each spread and used to calculate the velocity and depth to each individual layer interface. Seismic refraction software was used for the seismic data interpretation which enabled the depth determination at each geophone position to be carried out. A total of eight (8) seismic profiles were established and their locations are shown in Figure 2.

RESISTIVITY AND SEISMIC RESULTS

Results from 11 vertical geoelectrical resistivity soundings are given in Table 1. The interpreted resistivity results were obtained using three or four layer computer interpretation models. There is no borehole data available in the study area for checking the interpreted subsurface resistivity models. However results from the seismic survey (Table 2) conducted at or close to the resistivity stations were used in the final assessment of the groundwater potential of the study area.

In general, three (S1, S5, S6, S8, S9 and S11) to four (S2, S3, S4, S7 and S10) subsurface geoelectrical layers can be delineated in the study area. The first layer, represented by bulk resistivities of 250–550 ohm-metre, corresponds to the top residual soils with calculated thickness from 0.4 to 8.0 metres. The second and third layers indicated by bulk resistivities of 30 to 3,000 ohm-metres are probably related to weathered schist with thickness ranging from 0.7 to 70 metres. The fourth geoelectrical layer has considerable high resistivity value which probably related to slightly weathered

Table 2. Results of seismic refraction survey, Matriculation Centre, Kuala Pilah, Negeri Sembilan.

Seismic Profiles	Layer 1	Layer 2	Layer 3
SP1 (S2)#	300 (7.0)*	1,790 (18.0)	3,710
SP2 (S8)#	440 (8.5)	1,570 (19.8)	3,730
SP3 (S4)#	590 (2.0)	1,690 (26.0)	4,670
SP4 (S5)#	390 (4.2)	695 (11.3)	3,780
SP5 (S11)#	360 (3.0)	815 (12.1)	4,360
SP6 (S3)#	450 (8.8)	2,830	–
SP7 (S6, S7)#	460 (4.0)	1,245 (11.0)	5,380
SP8	530 (12)	1,690	–

* *Velocity of seismic P-wave in metre/sec*
(Thickness in metre)
\# *corresponding resistivity station*

to fresh schist bedrock.

For all the refraction seismic profiles (except for SP6 and SP8), three subsurface layers with the following characteristics have been recognized:

i) the first layer or top most layer has a low p-wave velocity ranging from 300 to a maximum value of 590 m/s. Most values fall within the 300–450 m/s range. Such values are typical for soil material. The thickness of this layer ranges between 2 to 12 metres.

ii) the intermediate or second layer shows considerable velocity variation, ranging from 695 m/3 to 2,830 m/s. The average velocity of this layer is approximately 1,540 m/s. Such velocities can be correlated with weathered rock materials. The variability of seismic velocity reflects the heterogeneous nature of the material. An increase in seismic velocities could be caused by greater degree of compaction or a decrease in the degree of weathering of the parent rock. The individual layer thickness also shows considerable variation, ranging from 11 to 26 metres.

iii) the third layer is the lowest or deepest layer at the site under investigation. The seismic velocities range from 3,710 to 5,380 m/s with an average value of 4,272 m/s. These velocities can be correlated to the bedrock at the investigation site, which is a quartz mica schist (Mohammad Yamin bin Ali, 1983). The depth of bedrock lies between 15.0 m to 28.3 m, showing the considerable variation in the thickness of the weathering profile.

GROUNDWATER SITE EVALUATION

In the absence of any borehole data, interpretation was made based on local and field geological information. Based on the results of the sounding thicknesses obtained, both the resistivity of layer two and three (Table 1) can be represented by the seismic second layer (Table 2). The wide variation of the resistivity values (for layer two and three) and seismic p-wave velocities (for seismic layer two) suggest the heterogeneous nature of the layered materials. Without borehole data, for the purpose of groundwater site evaluation, the layer with resistivity value of less than 100 ohm-m (Mooney, 1980) and seismic velocity of 1,600–1,700 m/s was presumably layer that has been affected by the presence of groundwater.

The geoelectrical sounding results (Table 1) suggest that there exist a conductive layer in the area where sounding stations S1, S3, S4, S7, S8, S9, S10 and S11 are located. In all the soundings, it is the second and/or third layer which is the probable aquifer. The resistivity values of the layer ranges from 10 to 85 ohm-m with maximum thickness of up to 70 metres. However their corresponding seismic velocities (Table 2) are not within the range specified for groundwater except for sounding station S4. The conductive layer detected at depth of about 2 metres below surface at station S4, satisfies both resistivity and seismic velocity criteria. It shows resistivity value of 80.0 ohm-m and average seismic velocity of about 1,690 m/s with average thickness of 30 metres. There is high probability of striking water at this sounding location if drilling is done.

CONCLUSION

The geophysical study conducted using both resistivity and seismic methods appear to have been successful in locating a conductive layer which could presumably be related to a potential near surface groundwater aquifer at the Matriculation Centre. The result of the geophysical study however needs to be confirmed by drilling. If the drilling test is positive, the next question to answer is whether the potential aquifer has the necessary quantity and quality to be used as a source of backup water supply for the centre. The groundwater of shallow aquifer is normally subjected to contamination by discharge of domestic wastewater that percolate into the groundwater via septic tanks or leakage of sewage piping and treatment facilities. Further investigation need to be conducted in the study area in order to characterise the hydrogeological condition and to assess the optimum water requirement of the centre.

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