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Water Security: Embarking on a River Bank Filtration Approach for Resource Abstraction

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INTRODUCTION

Peninsular Malaysia is drained by a dense network of rivers and streams with about 150 major river basins. Major rivers that drain into the South China Sea are the Kelantan, Terengganu, Dungun, Endau, and Sedili rivers. Major river basins in East Malaysia tend to be larger than those in Peninsular Malaysia.

Out of an annual rainfall volume of 990 km³, 360 km³ (36 per cent) are lost to evapotranspiration. The total surface runoff is 566 km³ and about 64 km³ (7 per cent of the total annual rainfall) contribute to groundwater recharge. However, about 80 per cent of the groundwater flow returns to the rivers and is therefore not considered an additional resource. The total internal water resources of Malaysia are estimated at 580 km³/year.

This shows that protection of river and groundwater are very important in order to obtain a sustainable water usage. River bank/bed filtration (RBF) offers a good practice to treat and protect the surface water as well as groundwater. It is because RBF uses the bed of a reservoir, lake or river and an adjacent sand and gravel aquifer as a natural filter. The technology can be applied directly to existing surface water reservoirs, streams, lakes and rivers, and now it is often a guiding factor in the hydrogeological investigation of new source supplies.

River bank filtration is the influx of river water to the aquifer induced by a hydraulic gradient. Collector wells located on the banks at a certain distance from the river creates a pressure head difference between the river and aquifer, which induces the water from the river to flow downward through the porous media into the pumping wells. By applying this system of drinking water extraction, two different water resources are used. On the one hand, surface water from the river percolates towards the well; and groundwater of the surrounding aquifer is utilised (Michael Schön, 2006)

Most RBF systems are constructed

in alluvial aquifers located along riverbanks. These aquifers can consist of a variety of deposits ranging from sand: sand and gravel, to large cobbles and boulders. Ideal conditions typically include coarse-grained, permeable water-bearing deposits that are hydraulically connected with riverbed materials. These deposits are found in deep and wide valleys or in narrow and shallow valleys. RBF systems in deep and wide valleys may have a wider range of options since wells (vertical and horizontal collector wells) can be placed at greater depths (which can provide higher capacities) and can be placed further away from the river to increase the degree of filtration.

For large or small scale RBF, the production well will be constructed to col-

lect the water from riverbank filtration and the number of production wells will be based on population demand. In Germany the production wells of RBF range from 20 to 600,000 m³/day. In Berlin, RBF consists of 116 wells, 30-60m deep and distance to the lake of 100m. The pumping rate for each well ranges from 50 to 150m³/hour, leading to a capacity of up to 260,000 m³/day used for the drinking water supply for 700,000 inhabitants (Hoffmann and Gunkel, 2011). The production well does not only receive a portion from bank filtration but also from groundwater, recharged in the landward catchment area. Therefore, the abstracted raw water from production well is a mixture of waters, where each of the water has different chemical composition. While

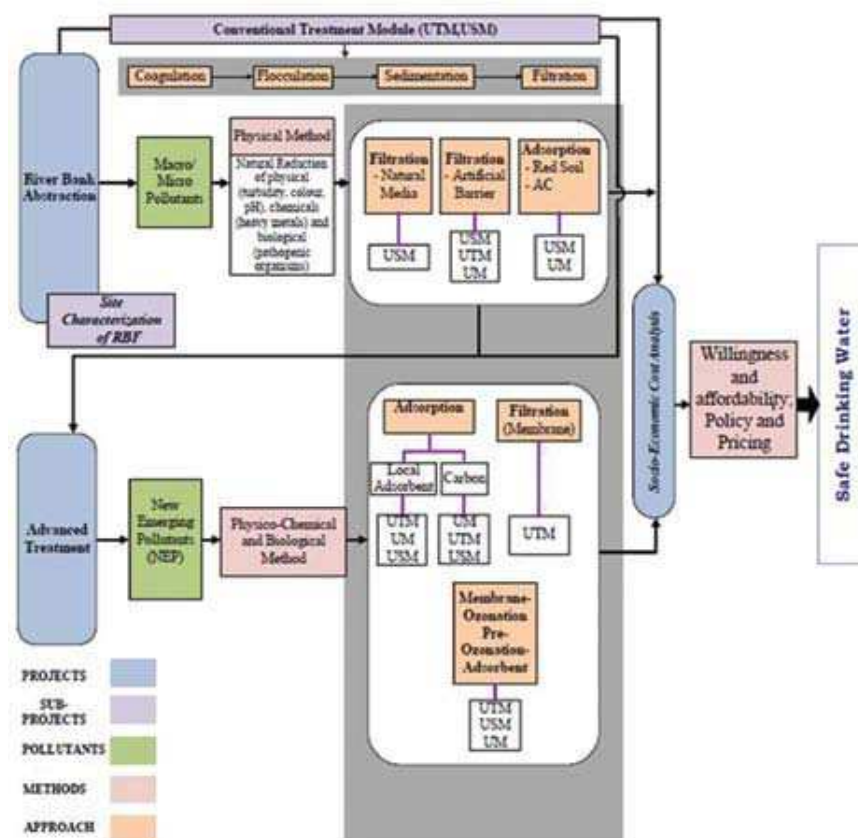


Figure 1 : Research approach

groundwater-quality depends on the land use in the catchment area (urban, agriculture, etc.), bank filtration-quality depends on river water quality and the efficiency of purification processes during riverbank filtration (Ray et al. 2002). Hence, the assessment of the bank filtration/groundwater ratio and the extent of the catchment area play an important role in determining the resultant quality of the water in production wells.

Typical aquifers used for RBF consist of alluvial sand and gravel deposits with a hydraulic conductivity greater than approximately 10 m/day (Goldschneider et al., 2007). The advantages of RBF include reductions in turbidity, total coliforms, microbial contaminants, natural organic matter and organic contaminants (Tufenkji et al., 2002; Wang et al., 2002). Several studies have revealed that RBF is highly effective in reducing the risk of *Giardia* and *Cryptosporidium* contamination of drinking water when flow path length and filtration time are sufficient (Berger, 2002; Hiscock and Grischek, 2002; Gollnitz et al., 2003) besides removing some pesticides and pharmaceuticals (Kuehn and Mueller, 2000). Undesirable effects of bank filtration on water quality can include increases in hardness, ammonium and dissolved iron and manganese concentrations and the formation of hydrogen sulphide and other malodorous sulphur compounds as a result of changing redox conditions (Hiscock and Grischek, 2002).

Currently RBF study is not well documented in Malaysia. The development is hindered by big project such as inter basins water transfer. As more rivers are getting polluted, such scheme could not materialise in the near future. In view of the future needs emphasizing on resource abstraction, a group of researchers from Universiti Sains Malaysia (USM) has embarked on the exploration of this untapped resource. A proposal was made to the then Ministry of Higher Education for an integrated approach gathering researchers from different institutions to research on specific topics ranging from resource abstraction to treatment. USM researchers are focusing on resource abstraction whereas those from Universiti Teknologi Malaysia (UTM) are focusing on

treatment methodology. Collaborations were also made with researchers from Universiti Malaya, UiTM and NAHRIM. Three river basins were chosen based on the environmental issues, water demand, site availability, comparison of study parameters as well as economic distance of sites from USM. These sites are Langat, Perak and Kerian rivers basins. This paper will focus on the Langat river basin.

RESEARCH APPROACH

Under a Long Term Research Grant Scheme (LRGS), USM and UTM research teams are focussing on a niche area of water security for a period of 5 years. The research covers aspects of resource abstraction using river bed/bank filtration, advance water treatment and social study. The integrated approach of the research project is shown in Figure 1. The total grant to be allocated for this project is RM4.56 million.

The study site for Langat river basin is located at Kg Jenderam Hilir, Dengkil which is approximately 4 km to the south of raw water intake of SYABAS water treatment plant. The latter is currently taking raw water from Sg. Langat to be treated and supplied for public water supply to the surrounding areas. As the RBF site is situated downstream of the water treatment plant, future comparison on the cost of treatment and the viability of RBF as an alternative source is plausible in the context of its application.

GEOLOGY OF THE AREA

The Langat Basin has an area of about 2,100 km², and which comprises about 1,155 km² of hilly and mountainous terrain and 945 km² of coastal plain. Figure 2 shows the general geological map of the Langat Basin. The bedrock

in the mountainous area includes Permian igneous rocks and Pre-Devonian schist and phyllite of the Hawthornden Formation. Hawthornden Formation rocks are highly deformed and have undergone two phases of deformation (Gobbet and Hutchison 1973). The predominant rocks in the foothills include Permo-Carboniferous meta-sandstone, quartzite, slates, phyllites and quartz schist of Kenny Hill Formation.

On the coastal plain, Quaternary deposits of the Simpang, Kempadang, Gula, and Beruas Formation are found. There is also unconformable overlay eroded bedrock consisting of gravel, sand, silt, and clay that have been unconsolidated from the Palaeocene through the Holocene period, which have progressively grown younger and thicker toward the coast (Gobbet and Hutchison 1973). In general, these sediments grade downward from gravel to clay, and are deposited in fluvial and shallow marine environments. Coarse to very-coarse sandy gravel of the Simpang Formation (Palaeocene to Pliocene) at the base of the Quaternary strata is considered to be the primary aquifer of the Langat Basin. Typically, the aquifer near the foothills has a thickness of several metres, and varies from about 50 m to more than 100 m further toward the coast (JICA and MGD 2002). The geology of the Sepang and Kuala Langat District is characterized by the Kenny Hill Formation, Schist Hawthornden, granite, and alluvium (Abdullah Sani 1985). The Kenny Hill Formation, Hawthornden, and granite have a series of faults. The geology of the study area consists of phyllite, schists, slate and sandstone layers, which alternate with the Kenny Hill Formation with some conglomerates overlain by alluvium consisting of sand, gravel, clay, and silt.

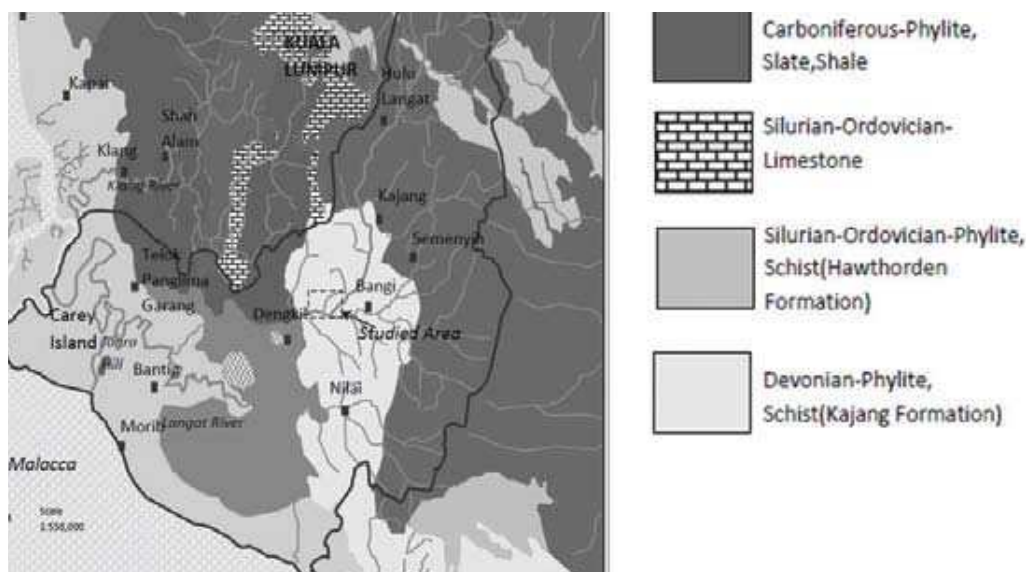


Figure 2 : Geology of Langat Basin

POTENTIAL OF RIVERBANK FILTRATION

A pumping well has been constructed by NAHRIM and the borehole log is shown in Figure 3. From the borehole it can be deciphered that this area is rich in alluvial soil which is a good potential for raw water. A resistivity survey was conducted by USM team to understand the underneath soil stratification and the layout of resistivity lines are shown in Figure 4. Details of Lines 6 and 7 which passed through the pumping well are shown in Figures 6 and 7. From the resistivity survey (included other lines as shown in Figure 4), it has revealed further data on the soil stratification within this alluvial basin which reinforces our findings that it has suitable soil for water abstraction. Thus observation wells have been constructed as shown in Figure 7.

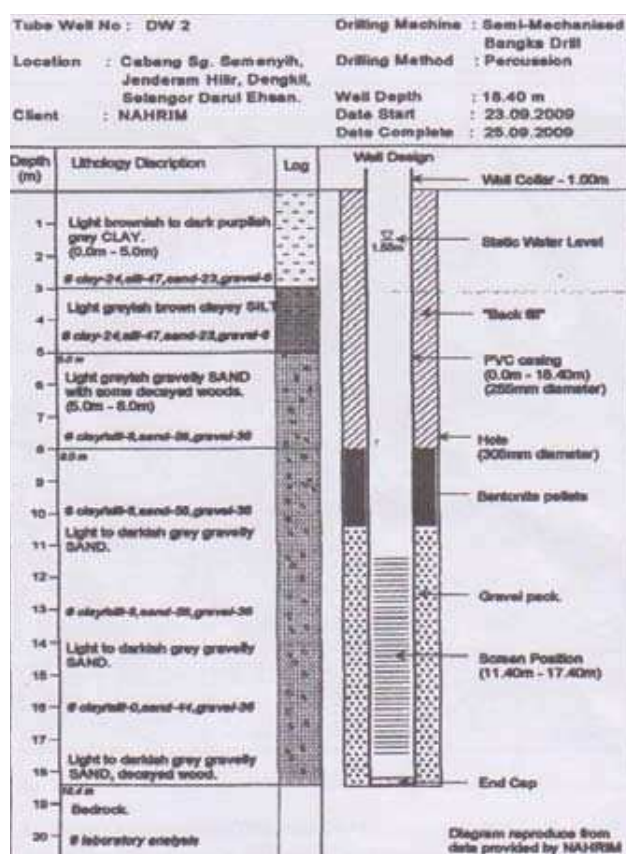


Figure 3 : Borehole log of pumping well at Jenderam Hilir, Dengkil, Selangor.



Figure 4 : Layout for resistivity survey lines

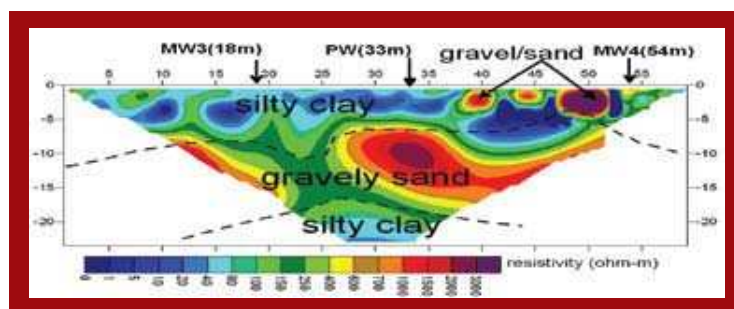


Figure 5 : Line 6

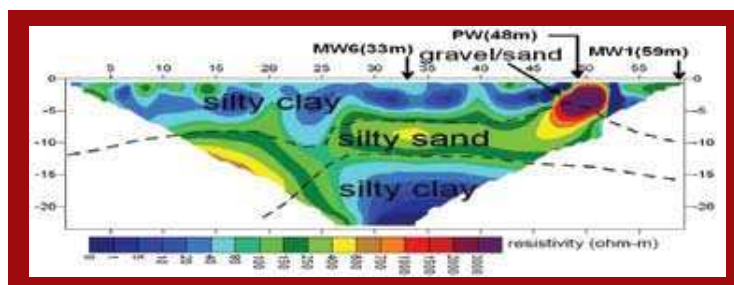


Figure 6 : Line 7

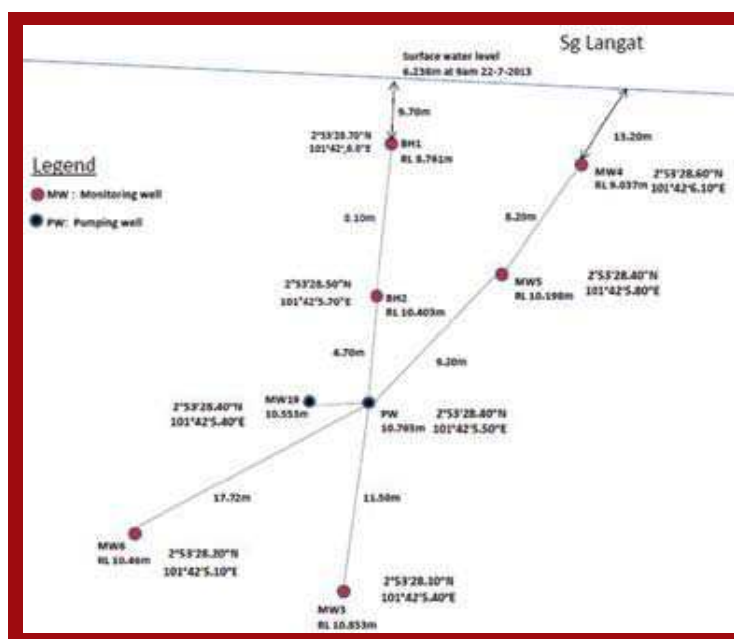


Figure 7 : Layout of pumping well and monitoring wells prior to pumping test.

In order to ascertain the potential of this location for water source abstraction, pumping test needs to be carried out. Prior to pumping test, a step test was carried out in order to make a judgement on the abstraction rate. Results from step tests are shown in Tables 1, 2 and Figure 8. From these results the drawdown at a flow rate of 142.21 m³ per hour (3.4 million litres per day) after 120 minutes is only 1.73m from the original static water level in the pumping well.

During the step tests, a resistivity survey was also conducted. The result is shown in Figure 9 which revealed concentration of blue colour element surrounding the pumping well. However further refinement could be done if several resistivity lines were made.

Table 1: Raw data for step drawdown test (0 to 7.5 minutes)

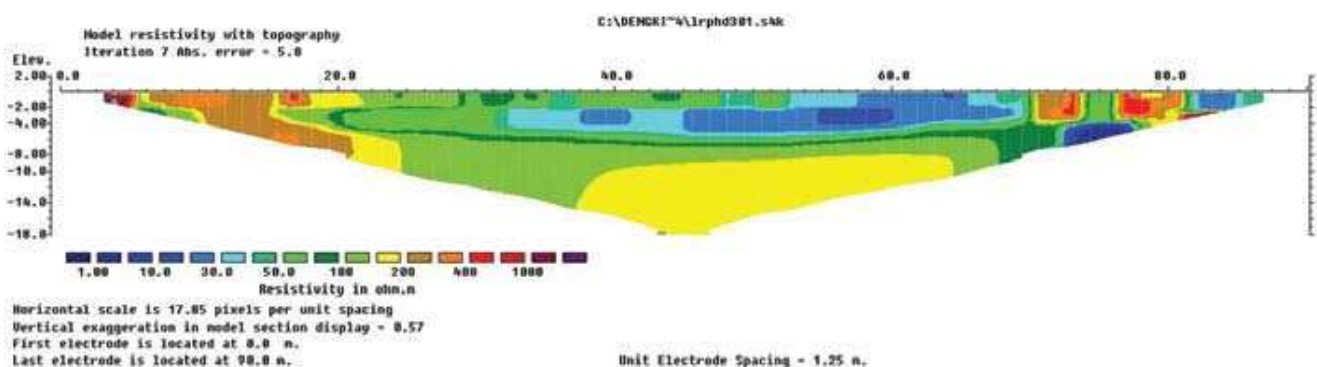
STEP DRAWDOWN TEST

Well No.	:	DW 2	Date & Time Started	:	20.07.2013 - 9.00 am
Location	:	Jenderam Hilir, Dengkil, Selangor.	Date & Time Stopped	:	20.07.2013 - 5.00 pm
Well Type	:	Alluvium	Statistic Water Level	:	5.10 m bgl
Depth of Well	:	18.40 m bgl	Measuring point :	1.00 m agl	Well Collar : 0.85 m agl
Depth of Screen	:	11.40 - 17.40 m bgl	Prepared by :	Yeap CS	

Time Since Pumping (minutes)	STEP 1		STEP 2		STEP 3		STEP 4		STEP 5	
	Q = 28.44 m ³ /hour		Q = 56.88 m ³ /hour		Q = 85.33 m ³ /hour		Q = 113.77 m ³ /hour		Q = 142.21 m ³ /hour	
	Water Level (m)	Drawdown (m)	Water Level (m)	Drawdown (m)	Water Level (m)	Drawdown (m)	Water Level (m)	Drawdown (m)	Water Level (m)	Drawdown (m)
0.0	5.10	0.00	5.33	0.23	5.75	0.65	6.10	1.00	6.59	1.49
0.5	5.18	0.08	5.43	0.33	5.80	0.70	6.11	1.01	6.62	1.52
1.0	5.22	0.12	5.48	0.38	5.81	0.71	6.11	1.01	6.63	1.53
1.5	5.25	0.15	5.52	0.42	5.85	0.75	6.12	1.02	6.65	1.55
2.0	5.28	0.18	5.53	0.43	5.87	0.77	6.17	1.07	6.67	1.57
2.5	5.29	0.19	5.56	0.46	5.87	0.77	6.18	1.08	6.69	1.59
3.0	5.30	0.20	5.57	0.47	5.88	0.78	6.19	1.09	6.70	1.60
3.5	5.30	0.20	5.58	0.48	5.88	0.78	6.20	1.10	6.70	1.60
4.0	5.30	0.20	5.58	0.48	5.88	0.78	6.20	1.10	6.71	1.61
4.5	5.31	0.21	5.59	0.49	5.88	0.78	6.21	1.11	6.72	1.62
5.0	5.31	0.21	5.59	0.49	5.88	0.78	6.21	1.11	6.72	1.62
7.5	5.32	0.22	5.60	0.50	5.89	0.79	6.21	1.11	6.72	1.62

Table 2: Raw data for step drawdown test (10 to 100 minutes)

Time Since Pumping (minutes)	STEP 1		STEP 2		STEP 3		STEP 4		STEP 5	
	Q = 28.44 m ³ /hour		Q = 56.88 m ³ /hour		Q = 85.33 m ³ /hour		Q = 113.77 m ³ /hour		Q = 142.21 m ³ /hour	
	Water Level (m)	Drawdown (m)	Water Level (m)	Drawdown (m)	Water Level (m)	Drawdown (m)	Water Level (m)	Drawdown (m)	Water Level (m)	Drawdown (m)
10.0	5.32	0.22	5.60	0.50	5.90	0.80	6.22	1.12	6.76	1.66
15.0	5.32	0.22	5.59	0.49	5.90	0.80	6.22	1.12	6.76	1.66
20.0	5.32	0.22	5.59	0.49	5.90	0.80	6.22	1.12	6.76	1.66
25.0	5.33	0.23	5.59	0.49	5.90	0.80	6.23	1.13	6.77	1.67
30.0	5.33	0.23	5.59	0.49	5.90	0.80	6.23	1.13	6.78	1.68
35.0	5.33	0.23	5.60	0.50	5.91	0.81	6.23	1.13	6.79	1.69
40.0	5.33	0.23	5.60	0.50	5.91	0.81	6.23	1.13	6.80	1.70
45.0	5.33	0.23	5.60	0.50	5.92	0.82	6.24	1.14	6.80	1.70
50.0	5.33	0.23	5.60	0.50	5.92	0.82	6.25	1.15	6.80	1.70
55.0	5.33	0.23	5.60	0.50	5.91	0.81	6.25	1.15	6.80	1.70
60.0	5.33	0.23	5.60	0.50	5.92	0.82	6.27	1.17	6.80	1.70
70.0	5.33	0.23	5.60	0.50	5.92	0.82	6.27	1.17	6.81	1.71
80.0	5.33	0.23	5.60	0.50	5.92	0.82	6.27	1.17	6.81	1.71
90.0	5.33	0.23	5.60	0.50	5.92	0.82	6.27	1.17	6.81	1.71
100.0									6.81	1.71
110.0									6.81	1.71
120.0									6.83	1.73



A Malaysian River with potential for exploration in river bed/bank filtration.

CONCLUSION

Initial results from this study, which was funded by Ministry of Education under LRGS, on water security entitled "Protection of Drinking Water for Society: Source abstraction and treatment" has shown the light at the end of the tunnel. Langat basin in Selangor has great potential for riverbank/bed filtration for resource abstraction. The players in drinking water industry should embark on this agenda as initial results on turbidity and pathogenic organisms' removal using laboratory model currently conducted in USM has also shown promising results.