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Baseflow study of Sungai Chuau and Sungai Bisa, Putrajaya Wetland

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Abstract: The groundwater component in the form of baseflow in Sg. Chuau and Sg. Bisa sub-catchment within Putrajaya wetland during the low flow period was studied. Field investigations show that the alluvium deposits along Sg. Chuau compose more sand and gravel thus increase its hydraulic conductivity and groundwater discharge. Sg. Chuau could be classified as a baseflow river and the groundwater component maintain its flow during any dry period. The existence of this condition would guarantee the stream flow and maintaining the wetland ecosystem in the upper part of Putrajaya Wetland during the long dry period. Sg. Bisa, on the other hand is not a baseflow river and easily dry up.

INTRODUCTION

Background

Groundwater is part of the land-based portion of the hydrologic cycle. The infiltrated water would moves downwards through the unsaturated zone, under the gravitational force and through the saturated zone in a direction determined by the surrounding hydraulic situation. The water would subsequently emerge from the ground as discharges into land surfaces such as streams and rivers as baseflow. The 'sediment monitoring team' of KLCC Urus Harta Sdn. Bhd. (KLCCUH) reported that the wetland area at Upper Bisa sub catchment showed different respond to weather condition compared to Sg. Chuau sub–catchment area (Figure 1). During the relatively long hot period (mid January–February 2002), there was a time when there is completely no flow from UB2 to UB1 cells (Figure 2). Since the groundwater contribution in the form of baseflow normally maintain the low flow in the river during the low-flow period, baseflow condition within the two catchments was studied beginning in early July to mid August (6 weeks period). The hydrological condition behind the UB2 cell is important to ensure the continuous water flow is maintain within the Upper Bisa wetland cells.

Objective

The main objective of the study is to define any groundwater flow contribution in the baseflow form that could support the river flow during any dry weather condition.

Scope of Work

The scopes of work are as listed below:

To study the background, collecting past and present information on the geology and hydrogeology of the two sub-catchments.

To locate locations for groundwater "standpipe" installation for the groundwater level measurement.

To carry out the elevation survey of the water level.

To carry out the *in-situ* estimation of the hydraulic conductivity of the alluvium or aquifer material.

To estimate the baseflow contributions for both rivers in the catchments.

SUMMARY ON GEOLOGY AND HYDROGEOLOGY

Geology

There are three geological formations that could be found in the Putrajaya catchment area. The general geology of the area is shown in Figure 3. The Quaternary river alluvium is the youngest deposit that overlies the older Carboniferous-Permian Kenny Hill Formation and the Silurian Hawthornden Formation is the oldest rock formation found in study area.

Alluvium

The alluviums are found in the flat and low-lying area in the Central and Southern part of the catchment. The Simpang Formation of sand and gravel layer is the subject aquifer of the present study. This river alluvium Quaternary deposits consist of the uncemented layers of fine gravel, sand and silt that overlie the metasedimentary rock. The thickness of this formation varies from 3 to 12 m regionally.

Kenny Hill Formation

Kenny Hill formation is found in the West and Northwest of Putrajaya area and consists of interbedded sandstone and shale that had undergone some degree of regional metamorphism. This formation could be identified from the layers of clastic meta-sedimentary rocks, meta-argilite and meta-arenite. Generally, the layer of meta-arenite is thicker than the meta-argilite. The thickness of meta-arenite is more than 0.5 m while for the meta-argilite, is less than 0.1 m. The general bedding strike

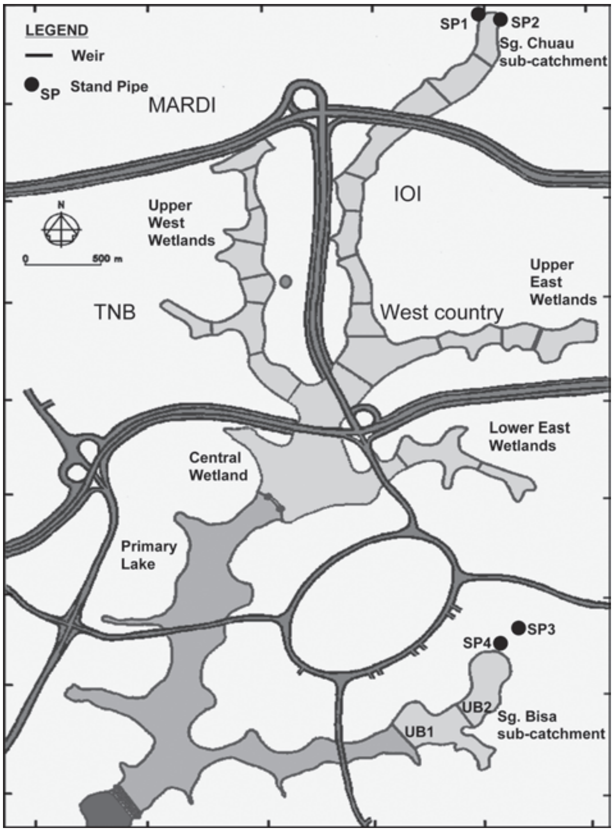

Figure 1. Map of Putrajaya wetlands and lake showing the Sg. Chuau and Sg. Bisa sub-catchment. Wetland cells of UB1 and UB2 are also shown.

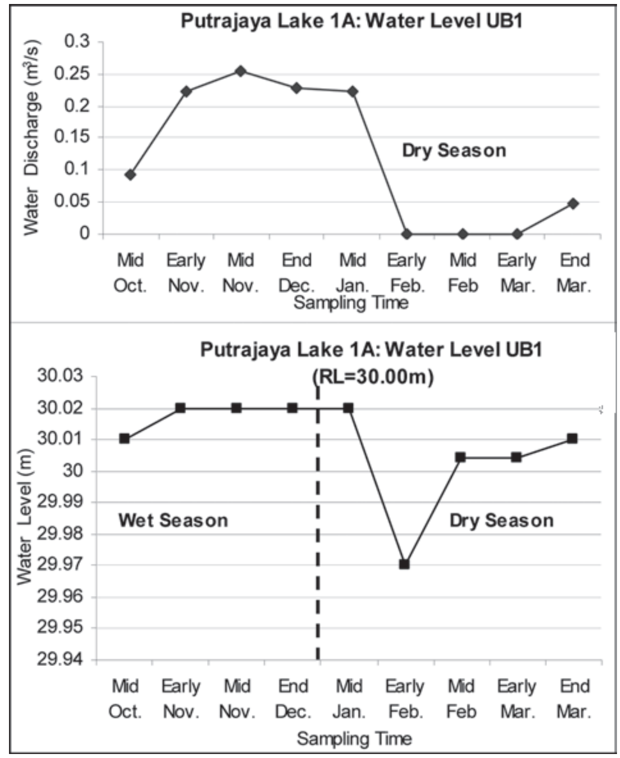

Figure 2. Graph of water level and water discharge for UB1 wetland cell from mid October 2001 to end March 2002.

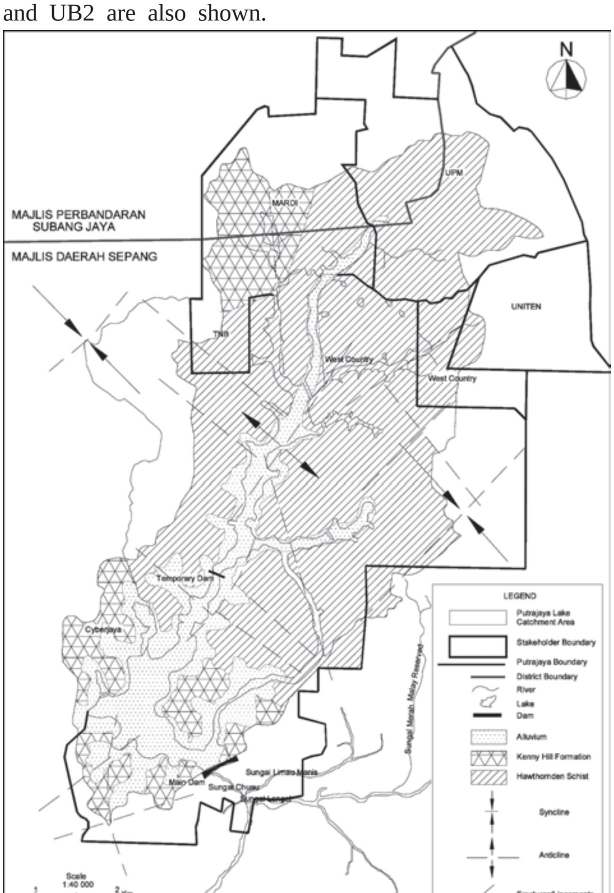

Figure 3. Geological map of Putrajaya area.

of the meta-sedimentary rock is Northeast-Southwest and parallel with the lineament in this area.

Hawthornden Formation

The Silurian-Ordovician Hawthornden Formation occupies about 70% of the area and is the oldest rock unit outcropping in the catchment area. The formation could be found in the East and Northeast Putrajaya. This formation is made up of metamorphosed rocks unit i.e. moderate to fine-grained quartz-mica-schist, quartz schist and graphitic schist. The weathering process took place to the formation formed the soil of more than 20 m in thickness.

Hydrogeology

The three geological formations in the Putrajaya catchment area, have a significant potential to be an aquifer that store and allow water to flow underground.

Alluvium Aquifer

The shallow groundwater source had been detected in the alluvium layers with depth ranging from 0.09 m to 7 m. Sand and gravel formed the lower layers while finer components of clay and silt constitute the upper parts of the alluvium aquifer zone. Pumping test conducted by the JMG reports that the Transmissivity (T) and storage coefficient (S) of the alluvium aquifer range from 84 to 163 m^2 /day and 4.8 x 10^{-4} to 4.9x10^{-3} respectively (Institut Penyelidikan Hidraulik Kebangsaan *et al.*, 1999). Wells sunk in these layers give yields up to 6.8 m^3/hour (1500 gallons/hour).

Hard Rock Aquifer

The water bearing zones, the Kenny Hill and Hawthornden formations are commonly described as hard rock aquifer that related to secondary features such as joints and fracture. Joints and fractures increase the storage capacity and facilitate greater mobility of the groundwater. Two wells were constructed by JMG at Perang Besar estate to reach depths of 137 m and 53 m. These respectively gave an optimum yield of 16 m^3/hour/well. The initial discharge rate was higher, 22 m^3/hour/well (4040 gallons/hour/well), indicating that the fracture system is local in extent and the aquifer is restrictive and irregular in size (Institut Penyelidikan Hidraulik Kebangsaan *et al*., 1999).

Groundwater Flow

In general, the groundwater flow direction in Putrajaya area is from North to South with some flow to the nearby river based on the geometry of the groundwater basin.

FIELD INVESTIGATION: RESULTS AND ANALYSIS

Standpipe Installation

To study the baseflow and groundwater flow in the two sub-catchment, four groundwater standpipes (standpipe piezometer) were installled between 11 and 14 July 2002. Two standpipes (SP1 and SP2) were installed at Sg. Chuau and the other two at Sg. Bisa (SP3 and SP4). The locations of the standpipes were shown in Figure 1. The standpipes with diameter not less than 35 mm were constructed by using the water rotary drilling method. Generally, it was done by advancing a boring with a drilling rig, installing a well casing with screen and backfilling the annulus between the casing and the wall of the borehole. The maximum depth of the boreholes was decided to be 10 m since the investigation only confined to surface aquifer that has hydraulic interaction with river or stream. The elevations of the standpipes, water levels and river stage were also measured. The *in-situ* hydraulic permeability tests of the aquifer were carried out in the field on 2nd August 2002. Photographs of various stages of field investigation are shown in Figure 4(a-d).

Geology

The drilling logs with borehole geology and final standpipe designs in Sg. Chuau are shown in Figure 5. Regarding the geology of the area, it was found out that: The surface geology of Sg. Chuau and Sg. Bisa is generally similar. The area is covered with alluvium of sand, silt and clay which is underlain by weathered original soil. The parent material of the soil is probably the Hawthornden Schist. The thickness of the alluvium in Sg Chuau is thicker (more than 8.2 m thick) compared to Sg. Bisa (between 6 - 6.5 m thick). Both boreholes in Sg. Bisa intercepted original soil or bedrock geology. The sand in Sg. Chuau comprise more gravel than sand in Sg. Bisa. This factor should be considered when dealing with aquifer hydraulic properties.

Hydrogeology

Aquifer System

The main aspect of the system is summarised in Table 1. The surface aquifer is alluvium deposits of sand, silt and gravel which form an unconfined aquifer. The schematic hydro geological section illustrating the aquifer system of Sg. Chuau and Sg. Bisa is shown in Figure 6a and Figure 6b respectively.

Figure 4. Field investigation scenes. a) Standpipe installation. b) Gravel packing material and PVC standpipe. c) Installing of the PVC standpipe. d) Completed standpipe.

Table 1: The shallow aquifer system in Putrajaya.

Parameter	Sg. Chuau		Sg. Bisa	
	SP1	SP2	SP3	SP4
Well elevation (m)	30.035	30.426	35.064	33.687
Depth to water level (m)	0.7	0.69	3.05	2.95
Water level elevation (m)	29.335	29.736	32.014	30.737
Type of alluvium/Lithology	Light grey, silty sand, trace of gravel	Light grey, silty sand, trace of gravel	Light grey, silty sand, trace of gravel	Light grey, silty sand and gravel
Alluvium Thickness (m)	4.5	>8.2	6	6.5

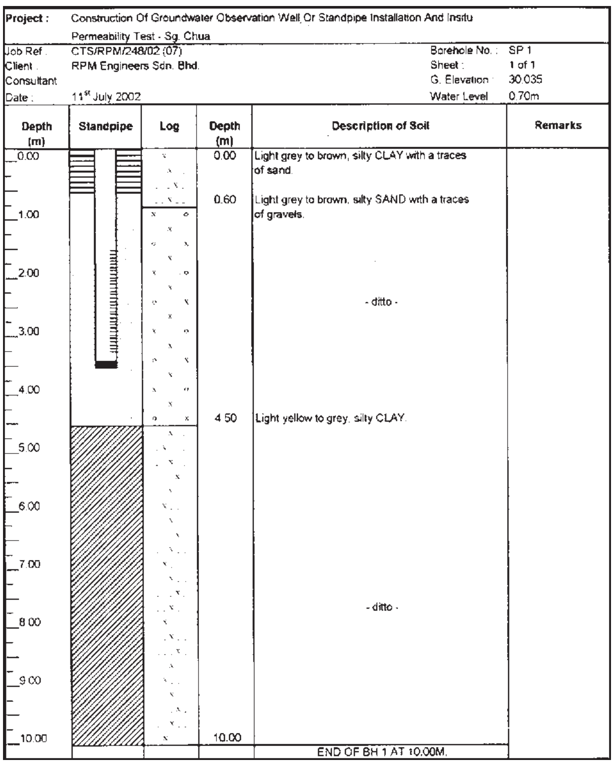

Figure 5a. Borehole log and well design for SP1.

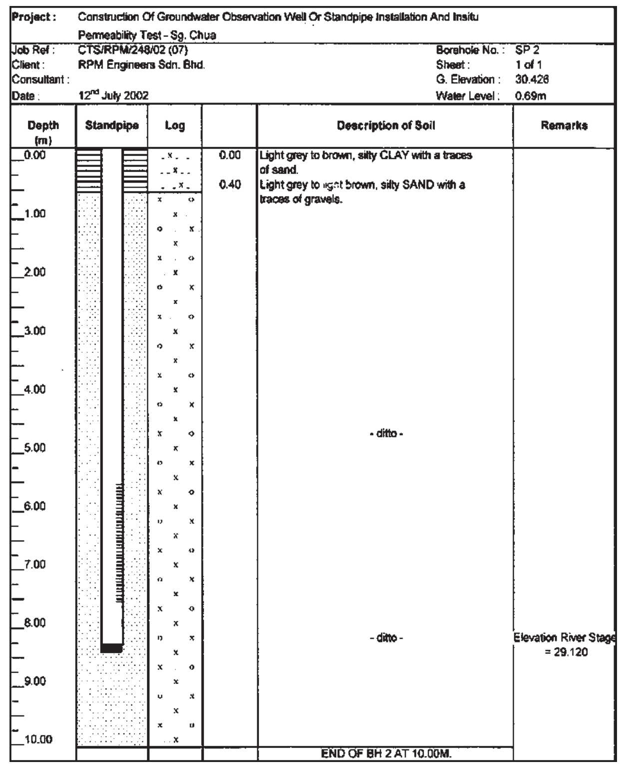

Figure 5b. Borehole log and well design for SP2

Hydraulic Testing

Constant head tests were carried out using standpipe SP2 in Sg. Chuah and SP3 in Sg. Bisa. The brief explanation of the test is explained below.

Constant Head Hydraulic Permeability Test

A constant head test is normally conducted as an inflow test in which arrangements are made for water to flow into the ground under a sensibly constant head. It is essential to use clean water. It will not be possible to achieve a constant head if the ground water level is not constant or the head lost by friction in the pipes is significant. Where a high flow rate is anticipated and where the installation comprises a piezometer tip surrounded by a filter material, two standpipes should be installed, one to supply the water and the other to measure the head in the filter material surrounding the piezometer tip. The rate of water flow is adjusted until a constant head is achieved and, in the simplest form of test, flow is allowed to continue until a steady rate of flow is achieved. In some ground, this may take a long period of time and in such cases the method suggested by Gibson may be used, in which the actual rate of flow is measured and recorded at intervals from the commencement of the test.

Result of Hydraulic Permeability Test

The results and analysis of the constant head tests for Sg. Chuau and Sg. Bisa are given in Table 2 and Table 3 respectively. The constant head test in cased hole are likely to produce an under estimate of the hydraulic conductivity as water could leave the hole only through screen slot. The results of the analyses of the constant head test should therefore be considered with this in mind.

The hydraulic conductivity values calculated were between 2.038 x 10^{-11} (Sg. Bisa) and 1.08 x 10^{-10} m/sec (Sg. Chuau). The hydraulic conductivity values calculated for Sg. Chuau were approximately five order of magnitude higher than those calculated for Sg. Bisa. These values should be treated with caution as the test conditions were not ideal due to the nature of the test as well as the field condition but these confirm the low permeabilty nature of the Sg. Bisa alluvium deposits.

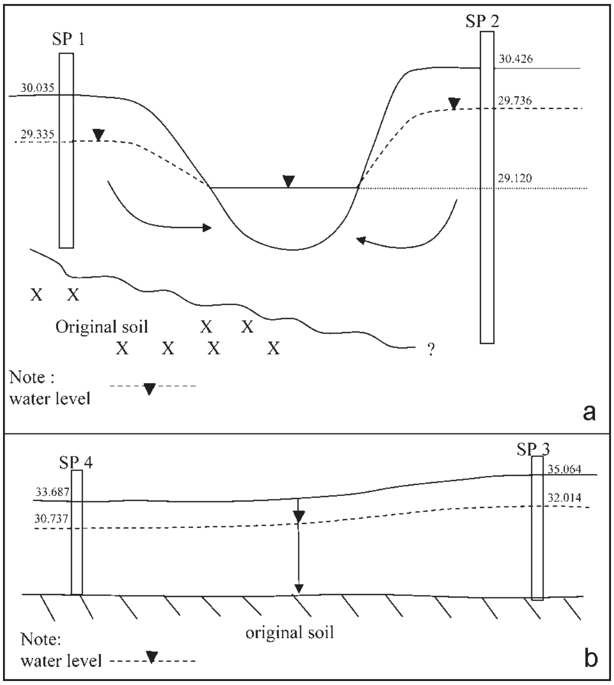

Figure 6. Schematic hydrogeological section of a) Sg. Chuau and b) Sg. Bisa (river was dry).

Table 2: Result of constant head hydraulic conductivity test for SP2 (Sg. Chuau).

Time (min)	Time Interval (min)	Meter Reading (cc)	Water Volume (cc)	Flow Quantity Q (cc/min)
0.00	0	1.4735	0	0
5.00	5	1.5070	0.0335	0.0067
10.00	5	1.5406	0.0336	0.0067
15.00	5	1.5652	0.0246	0.0049
20.00	5	1.5924	0.0272	0.0054
25.00	5	1.6188	0.0264	0.0053
30.00	5	1.6452	0.0264	0.0053
35.00	5	1.6703	0.0251	0.0050
40.00	5	1.6964	0.0261	0.0052
45.00	5	1.7224	0.0260	0.0052
50.00	5	1.7479	0.0255	0.0051
55.00	5	1.7730	0.0251	0.0050
60.00	5	1.7979	0.0249	0.0050
			cm/min	0.0054
			cm/s	0.000090

(After HVORSLEV) Where
Q = Quantity of Flow
F = 2.75D = Intake Factor for soil flush bottom of casing in uniform soil
Hc = Constant Head
Casing Interval diameter, D = 4 cm
Casing Height above ground = 45 cm
Depth of cased borehole = 820cm
Average Quantity, q = 0.0001 cc/sec
Constant Head, Hc = 22 + 820 = 842 cm
Coefficient of Permeability, K = q/FHc
= $1.08 \text{ X}10^{-8}$ cm/sec
= $1.08\text{X}10^{-10}$ m/sec

Table 3: Result of constant head hydraulic conductivity test for SP3 (Sg. Bisa).

Time (min)	Time Interval (min)	Meter Reading (cc)	Water Volume (cc)	Flow Quantity Q (cc/min)
0.00	0	1.8098	0	0.0000
5.00	5	1.8144	0.0046	0.0009
10.00	5	1.8169	0.0025	0.0005
15.00	5	1.8251	0.0082	0.0016
20.00	5	1.8286	0.0035	0.0007
25.00	5	1.8319	0.0033	0.0007
30.00	5	1.8354	0.0035	0.0007
35.00	5	1.8387	0.0033	0.0007
40.00	5	1.8423	0.0036	0.0007
45.00	5	1.8459	0.0036	0.0007
50.00	5	1.8494	0.0035	0.0007
55.00	5	1.8529	0.0035	0.0007
60.00	5	1.8564	0.0035	0.0007
			cm/min	0.0008
			cm/sec	0.000013

(After HVORSLEV) Where
Q = Quantity of Flow
F = 2.75D = Intake Factor for soil flush bottom of casing in uniform soil
Hc = Constant Head
Casing Interval diameter, D = 4 cm
Casing Height above ground = 83 cm
Depth of cased borehole = 500 cm
Average Quantity, q = 0.000013 cc/sec
Constant Head, Hc = 80 + 500 = 580 cm
Coefficient of Permeability, K = q/FHc
= $2.038 \text{ x } 10^{-9}$ cm/sec
= $2.038 \text{ x } 10^{-11}$ m/sec

Groundwater Baseflow Calculation

For steady state conditions Darcy's Law applies as follows:

Q = kiA (Fetter, 1994)

Where

Q = Baseflow/groundwater flow
k = hydraulic conductivity of alluvium (m/s)
i = groundwater gradient
A= area of aquifer through which flow take place

For a unit flow area of 1 m^2, the following baseflow or groundwater flow would be expected to occur given the measured parameter:

For Sg. Chuau (Baseflow)
k = $1.08 \text{ x } 10^{-10}$ m/sec
i = 0.176
Q = $1.08 \text{ x } 10^{-10}$ m/sec x0.176 x1 m^2 x86400 sec/day
= $1.64 \text{ x } 10^{-7}$ m^3/day

For Sg. Bisa (Groundwater flow)
k = $2.038 \text{ x } 10^{-11}$ m/sec
i = 0.028
Q = $2.038 \text{ x } 10^{-11}$ m/sec x0.028x1 m^2 x86400 sec/day
= $4.93 \text{ x } 10^{-8}$ m^3/day

The results show that the groundwater baseflow in Sg. Chuau is approximately three order of magnitude greater than value calculated for Sg. Bisa groundwater flow.

CONCLUSIONS

Sg. Chuau clearly show that the flow is strongly supported by groundwater baseflow meanwhile Sg. Bisa is presently dried out and there is no baseflow contribution. The current development within the Sg. Bisa area probably has disturbed the natural river system.

The alluvium deposition within Sg. Chuau catchment composed of more sand and gravel with thicker thickness compared to those at Sg. Bisa.

The hydraulic conductivity of the sediment in Sg. Chuau is five time greater (value of 1.08×10^{-10} m/sec) than the sediment in Sg. Bisa.

The groundwater water table gradient towards the river in Sg. Chuau is greater (value of 0.176) compared to Sg. Bisa which is more gentle towards the lake system.

The groundwater baseflow in Sg. Chuau is approximately three order of magnitude greater than value calculated for Sg. Bisa groundwater flow.

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