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The Relationship between Morphometry and Hydrologic Properties of the Semenyih River Basin and Their Significance

(Perkaitan Diantara Ciri Morfometri dan Sifat Hidrologi Lembangan Sungai Semenyih dan Kepentingannya)

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Abstract: A study was carried out to evaluate the characteristics of surface landforms of the Semenyih River Basin. The study was based on quantitative measurements of land surface geometry such as topography, basin area, basin shape, slope angles, drainage patterns, stream lengths and stream frequency of the 36 sub catchments in the basin. Field observations showed that the study area generally consists of weathered rock, with a high permeability soil cover and dominated by sand particles. The bedrock in the Semenyih Basin is characterized by a large number of discontinuities due to the development of structures such as folds, joints and faults due to past tectonic events. The morphometry of drainage density and bifurcation ratio shows that the Semenyih Basin can be characterized as a homogenous rock, with high permeability and sparse vegetation and is dominated by high rates of infiltration and sub-surface flow. From the available hydrological data, it was interpreted that only 35% to 45% of the total rainfall was transformed into surface runoff and the rest (55% to 65%) as seepage into the ground after evaporation and interception. Five main tributaries, namely Sg. Lalang, Sg. Batangsi, Sg. Tekala, Sg. Rinching and Sg. Saringgit were identified as significantly contributing to the Semenyih River.

Abstrak: *Satu kajian telah dijalankan untuk menilai ciri-ciri bentuk muka bumi di Lembangan Sungai Semenyih berdasarkan kepada pengukuran kuantitatif geometri permukaan bumi seperti topografi, keluasan lembangan, bentuk lembangan, kemiringan cerun, sistem saliran, serta panjang dan kekerapan sungai di 36 sub lembangan kawasan kajian. Hasil cerapan lapangan menunjukkan kawasan kajian terdiri dari batuan yang terluluhawa, dengan permukaan tanah yang mempunyai ketelapan tinggi yang didominasi oleh pasir. Jasad batuan di Lembangan Semenyih adalah dicirikan dengan nilai ketidakselanjaran yang tinggi yang disebabkan oleh pembentukan struktur geologi, seperti perlipatan, kekar dan sesar akibat peristiwa tektonik masa lampau. Aspek morphometri seperti ketumpatan saliran dan nisbah bifurkasi menunjukkan Lembangan Semenyih dicirikan sebagai terdiri dari batuan yang homogen, mempunyai ketelapan tinggi dan taburan tumbuhan yang jarang serta didominasi oleh kadar penyusupan air dan pergerakan air bawah tanah. yang tinggi. Daripada data hidrologi, ditafsirkan bahawa hanya 35-45% dari jumlah hujan terubah menjadi aliran permukaan dan bakinya (55-65%) sebagai tirisan air bawah tanah selepas pengwapan dan proses cegatan. Lima cabang sungai utama, seperti Sg. Lalang, Sg. Batangsi, Sg. Tekala, Sg. Rinching dan Sg. Saringgit dikenal pasti sebagai pembekal utama kepada aliran Sungai Semenyih.*

INTRODUCTION

Morphometry is concerned with the quantitative measurement of land surface geometry such as topography, basin area, basin shape, slope angles, drainage patterns, stream lengths and stream frequency. Morphometric analysis is important as it can be used to interpret drainage basin conditions with respect to hydrology of the basin, erosion processes and water quality distribution. Based on previous work (Shu, 1989 and Yin, 1989) the bedrock masses in the Semenyih Basin appear to have a large number of discontinuities and high infiltration rates due to the development of geological structures such as bedding, joint and fault systems as a result of past tectonic events (Fig.1). The drainage pattern in the Semenyih River Basin was formed as a result of the combination between trellis (folds) and rectangular (joint and fault) systems before culminating in the existing dentritic pattern (Fig.2).

Strahler (1957) and Verstappen (1983) stated that a drainage density value of less than 5.00 reflects a coarse texture lithology which is common in resistant rocks such as sandstone or quartzite; a value between 5.00 to 13.7 reflects medium texture, and from 13.7 and above as fine

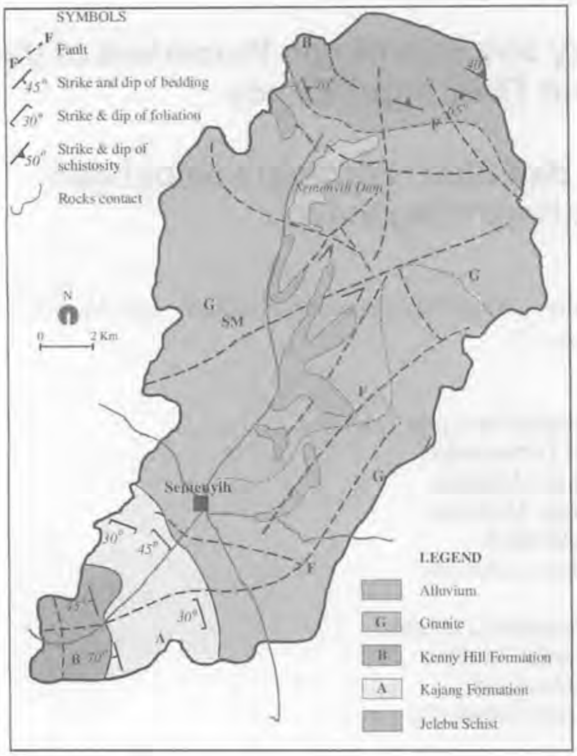

Figure 1: Distribution of joint and fault systems in the Semenyih Basin (Revised from Shu, 1989 and Yin, 1980)

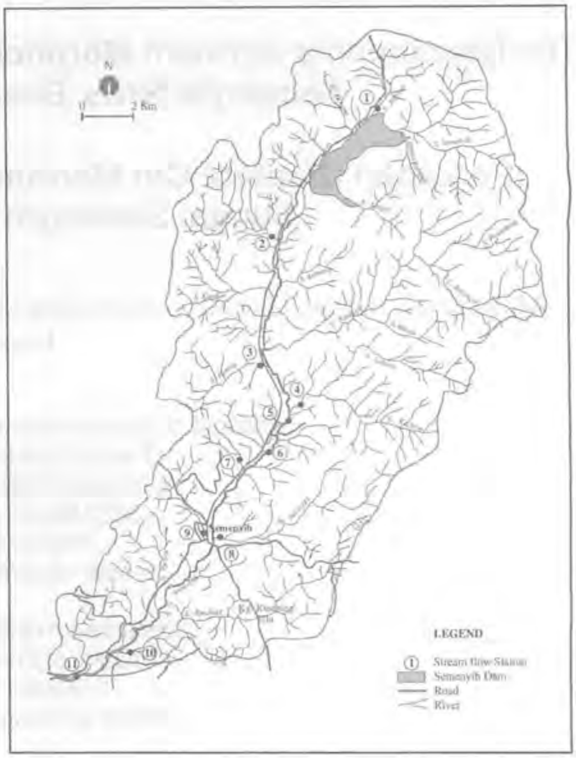

Figure 2: Drainage pattern of the Semenyih River

texture which is common in soft rocks like clay or shale. Bifurcation ratio (R_o) is defined as the ratio of the number of streams of a given order to the next higher order (using Strahler ordering). Where the geology is reasonably homogeneous throughout a basin, the R_o values usually range from 3.0 to 5.0 (Dale et al. 1978). The length ratio (R_L), similar in context to the bifurcation ratio, is the ratio of the average length of streams of a given order to those of the next higher order. The length ratio can be used to determine the average length of streams in an unmeasured given order (L_o) and their total length. A stream segment from Horton's method that was refined by Strahler (1952a) becomes the ordered units. Carlston (1963) introduced the application of the Jacob Model in order to relate the connection between morphometry (landform) and stream flow (hydrology) in form of a regression relationship. The amount of surface runoff may be quite small since surface flow over a permeable soil surface can occur when the rainfall rate exceeds the infiltration capacity (Linsley at al. 1975).

MATERIALS AND METHODS

The structures interpretation was made based on field observations, geological maps and air-photos of the study area. Four series of geological map sheets 94, 95, 102 and 103 on 1:63,360 scale were used. The geological features of the study area were interpreted based on the photo geology from flight series: C_{14}, L_{47} no. 10, 15, 20; C_{13}, L_{48} no. 220, 225, 230; and C_{13}, L_{49} no. 170, 175 and 180 on 1:25,000 scale. The sub basins of the Semenyih Basin were redrawn on tracing paper with a scale of 1:50,000 to determine their morphometric characteristics. Daily rainfall data from 1975 to 1981 and 1993 from the Rinching Station was obtained from the Department of Irrigation and Drainage (DID). Total runoff was generated from total rainfall through water balance analysis using Thornthwaite and Mather Model.

RESULTS

The morphological study was carried out to determine morphometric characteristics of the Semenyih River Basin. The following descriptions are the results of the nine morphometric parameters which were evaluated for the Semenyih River Basin.

1. Basin area (A): The size of the sub basins are categorized into 2 classes, viz. 1.0 to 5.0 km^2 for a small sub basin, between 5.0 to 36 km^2 for a medium sub basin. The largest sub-basin is the Sg. Batangsi sub basin, with an area of 35.57 km^2. Generally, the larger the area of the sub-basin, the higher the amount of water discharged.

2. Total length (Lc): Sg. Batangsi has the longest flow path within the Semenyih Basin (86.45 km) followed by Sg. Rinching (66.50 km) and Sg. Lalang (65.km). The total length of the other tributaries range between 5.51 to 50.07 km for a medium size sub-basin and from 0.76 to 11.97 km for a small size sub-basin. Sg. Hulu Semenyih, which has an area of 35.38 km^2 is the second largest sub-basin but is only the fourth largest in terms of total length.

3. The length ratio (Rl): The length ratio distribution in the Semenyih Basin range from 1.0 to 2.8

Table 1: Morphometric characteristics of Semenyih River Basin

No	Sub Basin	A (km^2)	Lc (km)	Rl	Rb	Dd (Lc/A)	F (ΣNu/A)	L_B (km)	H (m)	Rr (H/L_B)
1	Sg. Rinching	23.13	66.50	2.1	7	2.9	2.20	16.20	70	0.004
2	Sg. A	4.22	5.70	1	4	1.4	1.18	3.45	15	0.004
3	Sg. Saringgit	17.62	38.95	1.6	5	2.2	1.70	11.40	420	0.04
4	Sg. B	3.43	8.55	2.4	2.8	2.5	2.92	3.80	90	0.02
5	Sg. Lalang	25.50	65.55	3.3	3.9	2.7	2.27	12.16	848	0.07
6	Sg.Batangsi	35.57	86.45	1.7	4.3	2.4	1.94	19.95	680	0.03
7	Sg. Nong	1.75	5.70	2	3	3.3	2.29	2	30	0.02
8	Sg. Kemang	6.79	12.92	2.3	2.8	1.9	1.62	4.75	155	0.03
9	Sg. Lanjut	7.74	12.30	2.7	3.5	1.6	1.68	3.80	228	0.06
10	Sg. H.Semenyih	35.38	50.07	2.8	3.5	1.4	1.72	9.31	830	0.09
11	Sg. Rephen	8.12	19.95	2.1	3.9	2.5	2.22	4.75	152	0.03
12	Sg. Kesuma	4.22	9.12	1.7	5	2.2	1.42	3.80	318	0.08
13	Sg. C	2.04	6.08	2.2	5	3	2.94	3.42	242	0.07
14	Sg. D	2.99	8.93	1.7	2.9	3	4.01	3.23	270	0.08
15	Sg. Tekala	9.73	36.48	1.8	3.2	3.7	3.91	7.60	167	0.02
16	Sg. Kundor	7.74	28.12	1.7	2.9	3.6	4.26	5.70	275	0.05
17	Sg. E	1.75	7.60	2.3	2	4.3	3.43	3.61	90	0.02
18.	Sg. $Pening_2$	8.88	19.57	1.9	3.9	2.2	2.03	5.51	190	0.03
19	Sg. F	2.04	10.26	2.8	2	5	3.43	4.75	163	0.03
20	Sg. G	1.56	7.22	1.1	4	4.6	4.49	3.99	170	0.04
21	Sg. H	1.75	5.51	2.6	2	3.1	1.71	3.42	210	0.06
22	Sg. Purun	6.12	16.53	1.6	3.7	2.7	2.94	5.70	100	0.02
23	Sg. I	6.31	20.52	1.9	3.9	3.3	2.85	5.89	40	0.007
24	Sg. J	2.04	5.70	1.5	6	2.8	3.43	2.85	36	0.01
25	Sg.K	4.22	7.60	1.7	2.8	1.8	2.37	3.80	24	0.06
26	Semenyih Reservoir	3.60	-	-	-	-	-	-	-	-
27	Sg. Sub x	1.85	2.95	4.2	2	1.6	1.08	1.40	182	0.13
28	Sg. Sub a	3.68	7.41	2.3	2.5	2.4	2.27	1.90	200	0.10
29	Sg. Sub b	4.41	7.60	3	3	1.7	2.72	1.52	225	0.15
30	Sg. Sub c	2.23	3.04	0.5	2	1.4	1.35	2.28	20	0.008
31	Sg. Sub d	1.37	0.76	0.8	1	0.6	0.73	0.95	32	0.03
32	Sg. Sub e	2.89	2.09	4.5	2	0.7	1.03	1.33	40	0.03
33	Sg. Sub f	4.80	11.97	3.2	3.5	2.5	3.54	2.47	175	0.07
34	Sg. Sub g	2.99	3.42	5	2	1.1	1	1.52	36	0.02
35	Sg. Sub h	1.90	3.04	0.3	2	1.4	1.35	2.18	20	0.09
36	Sg. Sub i	2.10	3.70	1.50	6.0	2.8	2.43	2.85	36	0.03

Note: A = Area; Lc = the total length of the channel system within a basin; Rl = the length ratio (Lu/Lu+1); Rb = the bifurcation ratio (Nu/Nu+1); Dd = the drainage density; L_B = the overall maximum basin length measured from the mouth; F = the stream frequency, Nu = the number of streams of a given order u; H= relief; Lu= the length of stream segment of a given order and Rr = the relief ratio.

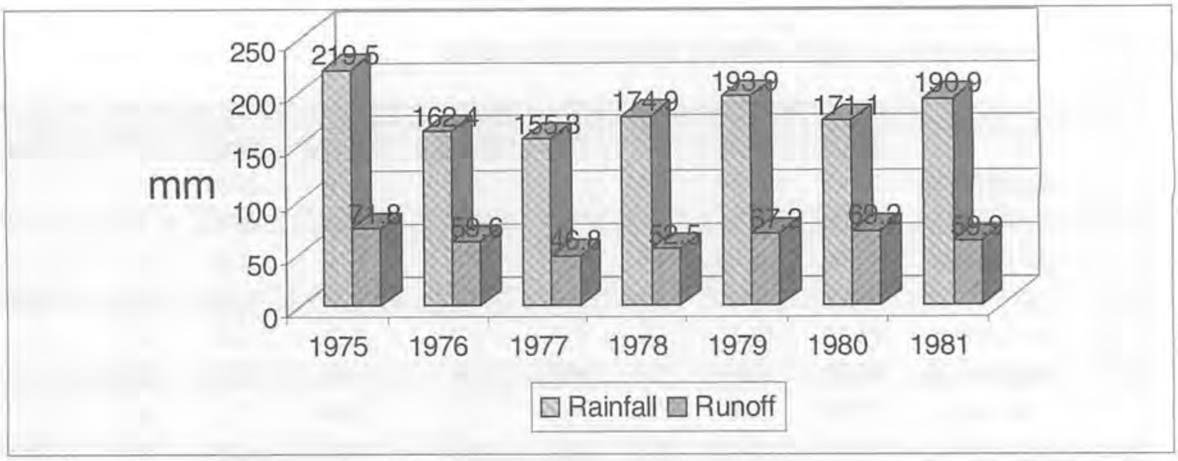

Figure 3: Rainfall and runoff distribution for the Rinching sub catchment from 1975 to 1981

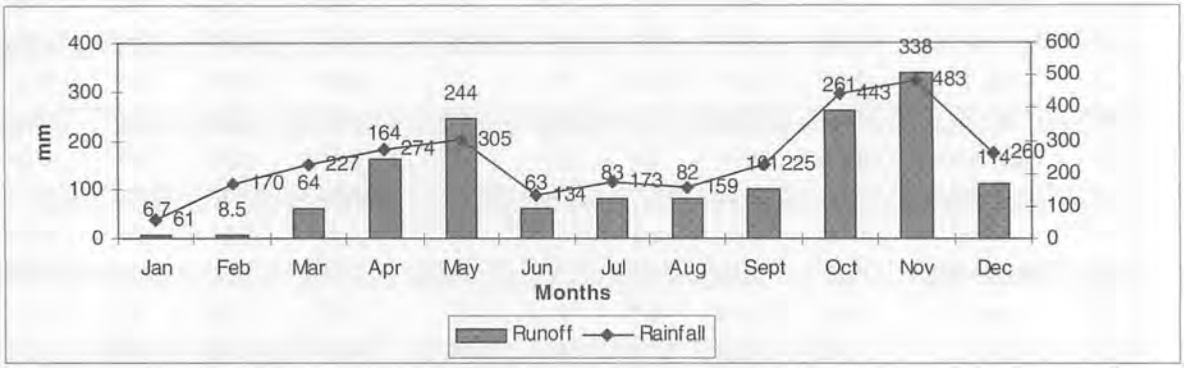

Figure 4: Distribution of 1993 rainfall and runoff at the Rinching Station

for a medium size sub-basin. For a small size sub-basin its length ratio is slightly higher, ranging from 0.5 to 5.

4. Bifurcation ratio (Rb): The distribution of bifurcation ratio in the Semenyih River ranges from 1.1 to 7.0 for a medium sub-basin (Sg. Rinching has the highest value) and from 0.8 to 6.0 for a small size sub-basin. The shape of the Semenyih River Basin is oval shaped. Based on the bifurcation ratio values, the Semenyih River Basin can be categorized as a normal homogenous basin.

5. Drainage density (Dd): The distribution of the drainage density (Dd) values in the Semenyih River ranged from as low as 1.4 to 5.0 km/km^2 for a small sub basin (Sg. F) and between 1.4 to 2.4 km/km^2 for a bigger size sub basin as Sg. Hulu Semenyih or Sg. Batangsi. The Dd of Sg. Batangsi is slightly higher than that for Sg. Hulu Semenyih because the landform in the upstream area of Sg. Batangsi consists of primary forests.

6. Stream frequency (F): The stream frequency estimation for the Semenyih River ranges between 1.18 to 4.49 for a medium size sub-basin and from 0.73 to 3.54 for a small size sub-basin. Among the four big sub-basins in the Semenyih Basin (based on an area >20 km^2), Sg. Lalang has the highest stream frequency (2.27) and it is the only stream in the basin which has a rapid flow feature.

7. Length of overland flow (Lb): Most of the streams, which are located in the eastern flank of Semenyih River has longer overland flow length because the position of the Semenyih River does not mirror the image of the basin. To illustrate, the length of Sg. Batangsi (located in the east bank) is 19.95 km but the length of Sg. Tekala (located in the west bank) is only 7.60 km. The overland basin length value ranges between 2 to 19.95 km for a medium size sub-basin and from 0.95 to 2.47 km for a small size sub-basin.

8. Relief (H); Generally, the highest relative relief occurs on the eastern flank of the Semenyih Basin. The relief condition of each sub-basin ranges between 24 to 848 meter for a medium size sub-basin and from 20 to 225 meter for a small size sub-basin

9. Relief ratio (Rr); The relief ratio of each sub-basin ranges between 0.007 to 0.02 or 0.7% to 2% for a medium size sub-basin and from 0.008 to 0.15 or 0.8 % to 15% for a small size sub-basin.

Table 1 shows the morphometric characteristics of the Semenyih River which covers an area of 266.60 km^2 consist of 36 sub basins with 13 medium size sub basins and 23 small size sub basins. These 36 sub basins were merged and formed as a dendritic pattern which is believed that at an early stage, before the dendritic pattern was formed, there are other drainage patterns in the basin. For example, folds in the metamorphic rocks located in north and south regions produced a trellis drainage system whereas a rectangular pattern was observed in granitic rocks in the middle area which was influenced by fault and joint systems. According to Zernitz (1977), a dendritic pattern develops as a result of several structural conditions and is usually produced in homogenous rocks.

HYDROLOGIC FEATURES

Two hydrologic variables i.e. rainfall and runoff were selected to evaluate their dominance in the relationship between surface runoff and infiltration during certain particular years. The mean monthly rainfall from 1975 to 1981 at the Rinching Station ranged from 155.3 mm to 219.5 mm with an average of 181.1 mm, while the mean monthly runoff ranged from 46.8 mm to 71.8 mm with an average of 61 mm (Fig.3).

The hydrologic response (runoff/rainfall) for these particular years ranged from 0.30 to 0.40 with an average of 0.34, meaning that less than 34% of the rainfall had turned into surface runoff and more than 66% transformed into evapotranspiration, interception and infiltration.

The 1993 mean monthly rainfall ranged from 61 mm to 483 mm with an average of 242 mm whereas the mean monthly runoff ranged from 6.7 mm to 338 mm with an average of 127 mm (Fig.4).

The hydrologic response (runoff/rainfall) for 1993 ranged from 0.05 to 0.75 with an average of 0.45, meaning that less than 45% of the rainfall had turned into surface runoff. Surface runoff occurs when the rainfall rate exceeds the infiltration capacity over a permeable soil surface and the amount is dependent on total rainfall and percentage of vegetative. The 1975-1981 and 1993 rainfalls data would indicate that developments in the basin in the latter year have resulted in reduced vegetative cover and increased soil permeability.

DISCUSSION AND CONCLUSIONS

Correlation of nine morphometric parameters and hydrological variables show that the infiltration rates in the Semenyih Basin is more dominant than surface runoff. The reasons are: firstly, the development of geological structures such as bedding, joint and fault systems by previous tectonic events. Secondly, the variation of drainage density values which is related to the surface landform of the basin. Thirdly, water penetration into the ground due to weathered materials of the surface landform, and fourthly, based on the hydrological properties. The length of overland flow and relief conditions for most of the river tributaries in the basin such as Sg. Lalang, Sg. Batangsi, Sg. Tekala, Sg. Rinching and Sg. Saringgit significantly contribute to the water yield and sufficiency of the Semenyih River flow. The Semenyih Dam which is located upstream of the Semenyih River is fed by water from Sg. Hulu Semenyih, Sg. Kesuma and Sg. Rephen as well as from sub surface or base flow. Logging activities in the surrounding area of the basin must be monitored and controlled especially in the water catchment area in order to prevent erosion and sedimentation impacts and to maintain the water level in the dam.

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