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Preliminary analysis of recession flow characteristics of granitic catchments

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Abstract: Even though granite formation in Peninsular Malaysia has been generally known as poor aquifers, their ability to sustain river flow during periods of less or no rainfall has not been generally evaluated. Obviously, quantitative assessment about groundwater storages and their releasing rates especially during dry weather period form the basis for development and optimal utilization of our water resources.

The magnitude and variability of recession flows from a catchment depend upon many factors. However it has been commonly assumed that recession flows are less dependent upon precipitation and intensity distribution than physical storage of a catchment. Since, characteristically, these flows are more or less steady, it has been a common practice to represent them by general mathematical models. In this study an attempt has been made to evaluate the recession flow characteristics of two granitic catchments viz Sungai Lui (68.1 km^2) and Sungai Semenyih at Kg. Rinching in Selangor, (225 km^2). Both catchments have similar characteristics for soil cover which is derived from weathered granite or granite parent material

Basically, slopes of individual recession hydrographs were determined and based on selected 39 and 49 recession hydrographs for Sg. Semenyih, and Sungai Lui respectively, it was found that the average recession coefficient for the Sg Lui and Sungai Rinching is 0.0463 and 0.0315 day^{-1} respectively. The exponential function model used to the described the recession flow of the two rivers was $Q_t = Q_o e^{-\alpha t}$, where a is the recession coefficient.

Abstrak: Formasi granit di Semenanjung Malaysia diketahui umum sebagai akuifer yang kurang baik. Namun, maklumat tentang keupayaan formasi berkenaan sebagai penyumbang kepada aliran sungai semasa ketiadaan hujan atau kemarau panjang tidak diketahui dengan jelas. Penilaian secara kuantitatif terhadap simpanan air tanah dan kadar pelepasannya ke sungai terutama di musim kering merupakan asas kepada pembangunan dan penggunaan optimal sumber air.

Magnitud dan perubahan alir rosotan dari sebuah kawasan lembangan bergantung kepada banyak faktor. Walaubagaimana pun, andaian umum ialah alir rosotan kurang bergantung kepada pertaburan curahan dan keamatan hujan tetapi lebih kepada simpanan fisikal kawasan lembangan. Oleh kerana ciri-ciri aliran rosotan boleh dikatakan mantap, adalah menjadi kebiasaan ianya diwakili dengan model metamatik. Dalam kajian ini percubaan telah dilakukan untuk menilai ciri-ciri alir rosotan yang mewakili dua buah kawasan lembangan iaitu Sungai Lui (68.1 km^2) dan Sungai Semenyih (225 km^2). Kedua kawasan lembangan ini mempunyai ciri permukaan tanah yang sama iaitu terbitan dari granit terluluhawa atau bahan granit induk.

Pada asasnya, cerun setiap hidrograf rosotan ditentukan dan berdasarkan kepada 39 hidrograf rosotan bagi Sungai Semenyih dan 49 bagi Sungai Lui, didapati purata koefisien rosotan bagi Sungai Lui ialah 0.0463 $hari^{-1}$ dan Sg Semenyih ialah 0.0315 $hari^{-1}$. Model fungsi exponen yang diguna bagi menghuraikan alir rosotan bagi kedua sungai berkenaan ialah $Q_t = Q_o e^{-\alpha t}$, di mana a ialah koefisien sorotan.

INTRODUCTION

The natural unregulated flow of a river is influenced by a variety of catchment characteristics namely geology, climate and topography (Riggs, 1964). It is however, generally accepted that geology exerts a considerable influence upon level of low flow or recession flow. A number of researcher have noted the close correspondence between geology and the rate of change of flow as illustrated by recession curve (Kunkle, 1962).

At the beginning of a dry season or periods between isolated storms, the yield of water from a catchment usually diminishes with time. During such periods, without further replenishment, most of the water that reaches down stream users is essentially recession flows. It has been commonly assumed that the flow is less dependent on rainfall intensity and distribution (Linsley *et al.*, 1975), but instead more dependent upon physical storage of a catchment. The objective of this preliminary study is to analyse the recession flow characteristic of granitic catchments and a general mathematical relation suitable for all recession flow of the catchment will be proposed.

STUDY AREA

Both study catchments are located in the Langat River Basin, Selangor (Fig. 1). The Sungai Lui catchment with area of 68.1 km^2 is located in the upper part while Sungai

Semenyih at Kg. Rinching with area of 225 km^2 is located at the lower part of the Langat River Basin. Both catchments have similar characteristics for soil cover which is derived from weathered granite or granite parent material.

Sungai Lui catchment is fairly undulating with hills rising to about 275 m above sea level while Sungai Rinching catchment is 90% hilly and mountainous rising to a maximum height of about 610 m.

METHOD

To conduct the analysis, average daily streamflow data for the water year of 1970–1981 and 1981–1991 for Sungai Semenyih at Kg. Rinching and Sungai Lui respectively was summarized from Hydrological Data of Streamflow Records published by Drainage and Irrigation.

Data reduction

The initial analysis was to select individual recession hydrographs, necessary for further analysis (Fig. 2). Unimportant recessions were eliminated according to the following criteria:

i. Definition of a recession hydrograph. A set of data points that exhibit more-or-less steady recession was considered as a recession event. Recession that demonstrated extensive fluctuations were excluded.

ii. Duration of each recession. It was decided that at least 10 days interval was to be the minimum duration of a recession event retained for analysis.

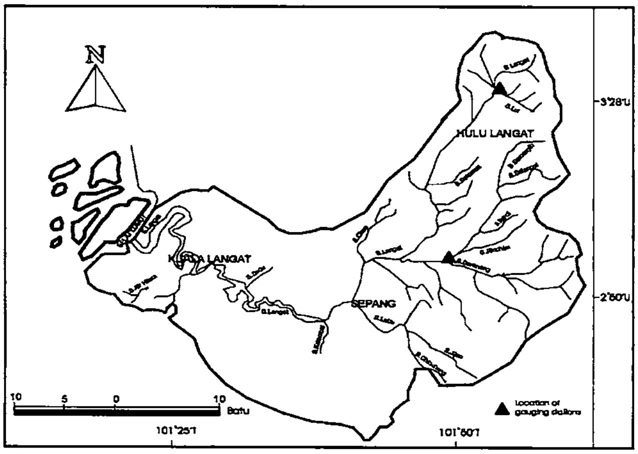

Figure 1. Study catchment.

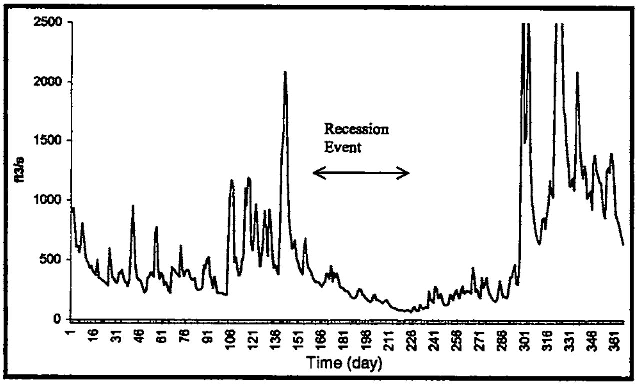

Figure 2. An example of a recession event used in the analysis.

Hydrograph analysis

The form of streamflow depletion from a catchment, depicted by the receding side of a hydrograph can be represented by different equations (Hall, 1968; Toebes and Strang, 1964). However, the most common one is of the form of a simple exponential function:

$$Q_t = Q_0 e^{-\alpha t} \qquad (1)$$

where, Q_t is the discharge after a time period t; Q_0 is the initial discharge recession; α is the recession coefficient (day^{-1}); and t is the time interval between Q_t and Q_0 in days

The above equation can be transformed into a linear function when plotted on semi-log paper, with discharges on logarithmic scale and time on arithmetic scale. In this study this approach was used. Each recession hydrograph was plotted on semi-log paper, with recession coefficient a being its slope:

$$\alpha = \frac{\text{Log } Q_o - \text{Log } Q_t}{0.4343\ (t - t_0)}$$

DISCUSSIONS

A total of 39 and 50 recession hydrographs for Sungai Semenyih at Kg. Rinching, and Sungai Lui respectively were analysed (Tables 1 and 2). Example of the recession event chosen for the study is shown in Figure 2. Generally each recession demonstrated straight plots with some exhibiting more than two slopes. Only the lower slope which truly represent low flow characteristic was used in this analysis.

The results indicated that the average recession coefficient a, for the Sungai Lui and Sungai Semenyih at Kg. Rinching is 0.0463 and 0.0315 day^{-1} respectively. The variation of the recession coefficient has a physical explanation.

Based from previous studies (e.g. Kunkle, 1962), the recession coefficient of order 10^{-2} reflects rapid drainage characteristics. The smaller Sungai Lui catchment seems to recede faster as compared to the larger Sungai Semenyih at Kg. Rinching catchment. However, even though the size of both catchments differ by more than three folds, the variability of recession flow due to area differences is rather small.

CONCLUSION

Preliminary analysis of recession flow characteristics for Sungai Lui and Sungai Semenyih at Kg. Rinching catchments, both representing the granitic formation can be represented by $Q_t = Q_0 e^{-0.0463t}$ and $Q_t = Q_0 e^{-0.0315t}$ respectively. The recession coefficients of both catchments reflects rapid drainage characteristics. The results also indicate that the variability of recession flow due to area

Table 1. Recession coefficient, α for Sungai Lui.

Year	t_0	t_1	t_1-t_0	Q_0	Q_1	α
1981	2	29	27	1.95	0.95	0.027
	68	91	23	1.4	0.69	0.031
	160	189	29	3.49	0.92	0.046
	209	229	20	1.22	0.66	0.031
	264	278	14	1.54	0.7	0.056
	307	320	13	1.41	0.62	0.063
	342	363	21	3.82	0.93	0.067
1982	17	36	19	0.81	0.44	0.032
	157	187	30	2.06	1.21	0.018
	238	272	34	2.85	0.71	0.041
	334	365	31	5.36	1.84	0.035
1983	2	110	108	2.14	0.59	0.012
	146	157	11	1.75	0.73	0.08
	166	186	20	2.39	0.96	0.046
	259	300	41	3.26	1.17	0.025
	317	345	28	4.11	1.97	0.026
	349	365	16	3.22	1.42	0.051
1984	52	85	33	3.49	1.23	0.0316
	87	101	14	6.22	2.23	0.0735
	108	120	12	2.52	1.06	0.0722
	153	196	43	5.44	1.12	0.0368
	202	250	48	3.55	0.99	0.0266
	262	289	27	3.46	1.17	0.0402
	356	366	10	4.24	2.06	0.0722
1985	1	38	37	1.72	1.16	0.0106
	68	96	28	2.9	1.07	0.0356
	147	185	38	4.7	1.01	0.0405
	203	226	23	2.05	1.06	0.0286
	319	338	19	6.5	2.85	0.0434
	345	365	20	5.7	3.53	0.0240
1986	5	30	25	2.97	1.66	0.0235
	107	118	11	3.34	1.68	0.0625
	318	365	47	4.49	1.5	0.0233
1987	7	53	46	1.72	1.16	0.0086
	143	192	49	2.27	1.49	0.0086
	230	253	23	4.22	1.6	0.0421
	274	292	18	2.69	1.81	0.0220
	304	333	29	4.8	1	0.0541
	335	357	22	1.31	1.11	0.0075
1988	4	32	28	2.3	0.86	0.0351
	49	82	33	2.67	1.23	0.0235
	191	230	39	2.19	0.96	0.0211
	264	293	29	2.63	1.21	0.0267
	310	366	56	5.83	1.19	0.0284
1991	2	62	60	1.76	0.32	0.0253
	114	154	40	3.23	1.82	0.0143
	157	181	24	2.85	0.88	0.0490
	272	283	11	3.35	2.15	0.0403
	286	304	18	4.74	2.47	0.0362
	318	360	42	3.51	1.82	0.0156

differences is rather small. As the shape and characteristics of a recession curve depend largely on the physical storage of a catchment (Linsley *et al.*, 1975; Szilagyi *et al.*, 1998), factors related to the type of aquifer porosity, recharge from other aquifers etc. may need to be investigate further in order to explain the small differences in recession constant for such a different topography of both catchments.

Table 2. Recession coefficient, α for Sungai Semenyih.

Year	t_0	t_1	t_1-t_0	Q_0	Q_1	α
1970	23	71	48	468	195	0.018
1971	27	53	26	885	434	0.027
	97	116	19	488	266	0.032
	259	281	22	605	173	0.016
1972	5	25	20	616	284	0.039
	199	226	27	159	226	0.013
1973	3	55	52	383	139	0.019
	171	208	37	520	289	0.016
1974	1	29	28	639	324	0.024
	76	95	19	326	179	0.032
	149	187	38	436	186	0.022
	210	244	34	363	127	0.031
	276	313	37	541	211	0.025
1975	20	35	15	395	177	0.054
	165	179	14	446	255	0.040
	225	242	17	554	285	0.039
	285	298	13	277	41	0.147
1976	2	55	53	428	149	0.020
	122	151	29	534	207	0.033
	195	225	30	254	147	0.018
	338	354	16	703	287	0.061
1977	65	98	33	213	117	0.018
	194	212	18	241	149	0.027
1978	25	38	13	297	167	0.044
	204	221	17	259	179	0.022
	272	289	17	141	99	0.021
1979	9	29	20	251	133	0.032
	134	145	11	490	239	0.065
	175	190	15	341	240	0.023
	218	233	15	341	219	0.031
1980	9	54	45	281	151	0.014
	92	112	20	1120	210	0.084
	167	197	30	617	202	0.037
	291	317	26	992	349	0.040
1981	7	32	25	561	219	0.041
	63	87	24	403	119	0.051
	172	246	74	401	130	0.015
	266	283	17	308	171	0.035
	304	321	17	274	206	0.017

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