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DEVELOPING A CONCEPTUAL MODEL OF GEOMORPHIC CHANGE FOR CHANNEL MANAGEMENT PROPOSES: A CASE OF LANGAT RIVER BASIN

(Membangunkan Model Konsep Perubahan Geomorfik Bagi Tujuan Pengurusan Saliran: Kajian Kes di Lembangan Sungai Langat)

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ABSTRACT

This article examines channel changes using predictive model of geomorphic change in the Langat River catchment. River geomorphic change resulted from a number of variables control such as climate, geology, water discharge, sediment influx, the bed and bank characteristics, vegetation covers and human interference. Three variables found to be satisfied to develop the dynamic model of geomorphic change in the Langat River catchment namely channel flow regime, channel competence and catchment sediment production (QMAG, QVAR, SEDO, COMP). These computer-generated of conceptual model provides the basis forms to which any particular section of Langat River could be change as demonstrate by flow levels, morphological units and frequency of inundation linkages model in the selected section of Langat River. The model found to be useful in providing the information whereby morphology, local and regional hydraulic conditions can be discussed, described and quantifies. It also can be act as an alternative to river management system to guide planners and engineers involved in the management of the river or its surrounding corridor.

Keywords: Geomorphic Change, Conceptual Model, Langat River Basin, Flow Regime, River Management.

ABSTRAK

Artikel ini menilai perubahan saliran menggunakan model peramalan perubahan geomorfik di Lembangan Sungai Langat. Perubahan geomorfik sungai berpunca daripada beberapa pembolehubah seperti cuaca, geologi, luahan sungai, influk sedimen, ciri tebing dan dasar, litupan tumbuhan dan gangguan manusia. Tiga pembolehubah didapati sesuai bagi membangunkan model dinamik bagi perubahan geomorfik di Lembangan Sungai Langat, iaitu regim luahan aliran, keupayaan saliran dan pengeluaran sedimen lembangan (QMAG, QVAR, SEDO, COMP). Hasil analisis komputer bagi model konseptual ini menghasilkan bentuk asas di mana sebarang perubahan seksyen di sepanjang Sungai Langat boleh diperolehi sebagaimana didemonstrasikan oleh aras aliran, unit morfologi dan kekerapan kedalaman air di sepanjang Sungai Langat yang derdasarkan melalui model cantuman. Model ini didapati berguna dalam menyediakan maklumat di mana morfologi, keadaan hidraulik tempatan dan daerah boleh dibincang, diterang dan dianalisis secara kuantitatif. Ia juga boleh bertindak sebagai alternatif kepada pengurusan sistem sungai and jurutera yang terlibat di dalam pengurusan sungai dan di sekeliling koridornya.

Katakunci: Perubahan Geomorfik, Model Konseptual, Lembangan Sungai Langat, Regim Aliran, Pengurusan Sungai.

INTRODUCTION

An integrated approach to river basin development devolves upon recognition of the hydrological and geomorphological integrity of the fluvial system at the catchment scale (Downs et.al. 1991). This mutual interaction between hydrology and geomorphology determines the natural routes for surface waters and permits the re-distribution of sediment through erosion, transportation and deposition and, in so doing, provides the basis for a variety of plant and animals habitats. Therefore, the dynamics of river channel provides an interesting dilemma to those developing integrated river basin management schemes. The overall aims of this study was to fit into the holistic framework, through development of the capability to predict the geomorphological response to changing flow regimes in the Langat River system, hence providing information and protocols for environmentally sound management of these catchment. To achieve the aim, this article discussing the following topics namely:

- Description of the catchment background.
- Description of the contemporary morphology of the Langat Rivers.
- Construction of a conceptual model of channel change and on the basis of this model, identification of management requirement.
- Description of the dynamic factor of Langat River catchment.

STUDY AREA

Langat River catchment is located in the southeast of Selangor State. It lies within the states of Selangor and Negeri Sembilan which encompasses the district of Hulu Langat, Kuala Langat, Sepang in Selangor and the other four mukims of Seremban in Negeri Sembilan. The area is situated within the latitude of 02^{o} 40M 15 N to 3^{o} 16M 15 and longitude of 101^{o} 19M 20 E to 102^{o} 01M 10 E with the total area approximately 2, 566 square kilometers (Figure 1).

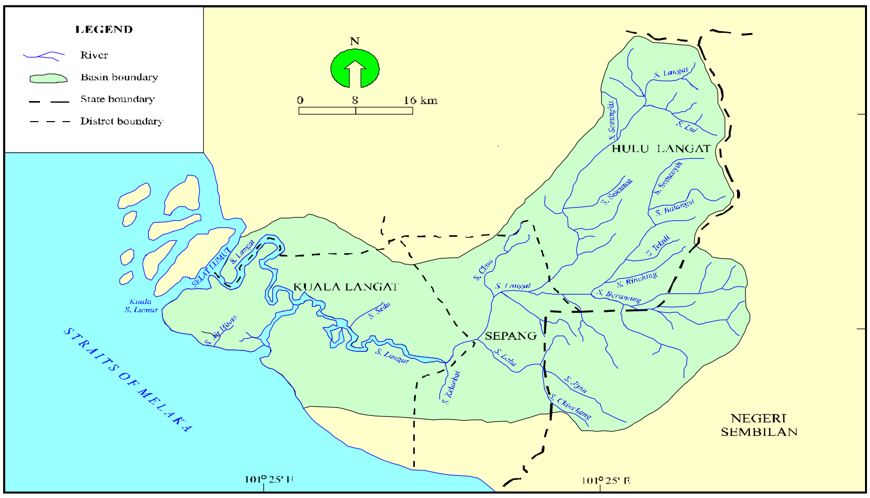


Figure 1: Langat River Catchment

The Langat River has a few tributaries. Among the main tributaries are Sungai Semenyih, Sungai Lui and Sungai Beranang. The upper basin is considered as the most important catchment forest which all the Langat water streams originate. Two reservoirs were located here, each at the upstream of Sungai Langat and Sungai Semenyih. Topographically, about 45 per cent of the catchment is steep mountainous country rising to heights of 1525m (Amir Hashim, et al. 2000). The remainder is hilly undulating land with swamps rising along the lower reaches of Langat River. Based on 1995 landuse map, approximately 25 per cent of the basin is covered by agricultural land, where mostly under rubber and oil palm. However, the mountainous areas are remain under virgin jungle. This upstream region consists of hilly dipterocarp catchment forest which has been to be maintained in order to protect the basin water resources. Two forests reserved were gazetted here namely Hulu Langat Forest Reserved (5, 018 ha) and Sungai Lalang Forest Reserved (6619 ha). Both catchment forests are important for Langat and Semenyih dams for sustaining and regulating stream flow at the intake point along the downstream of the Langat River.

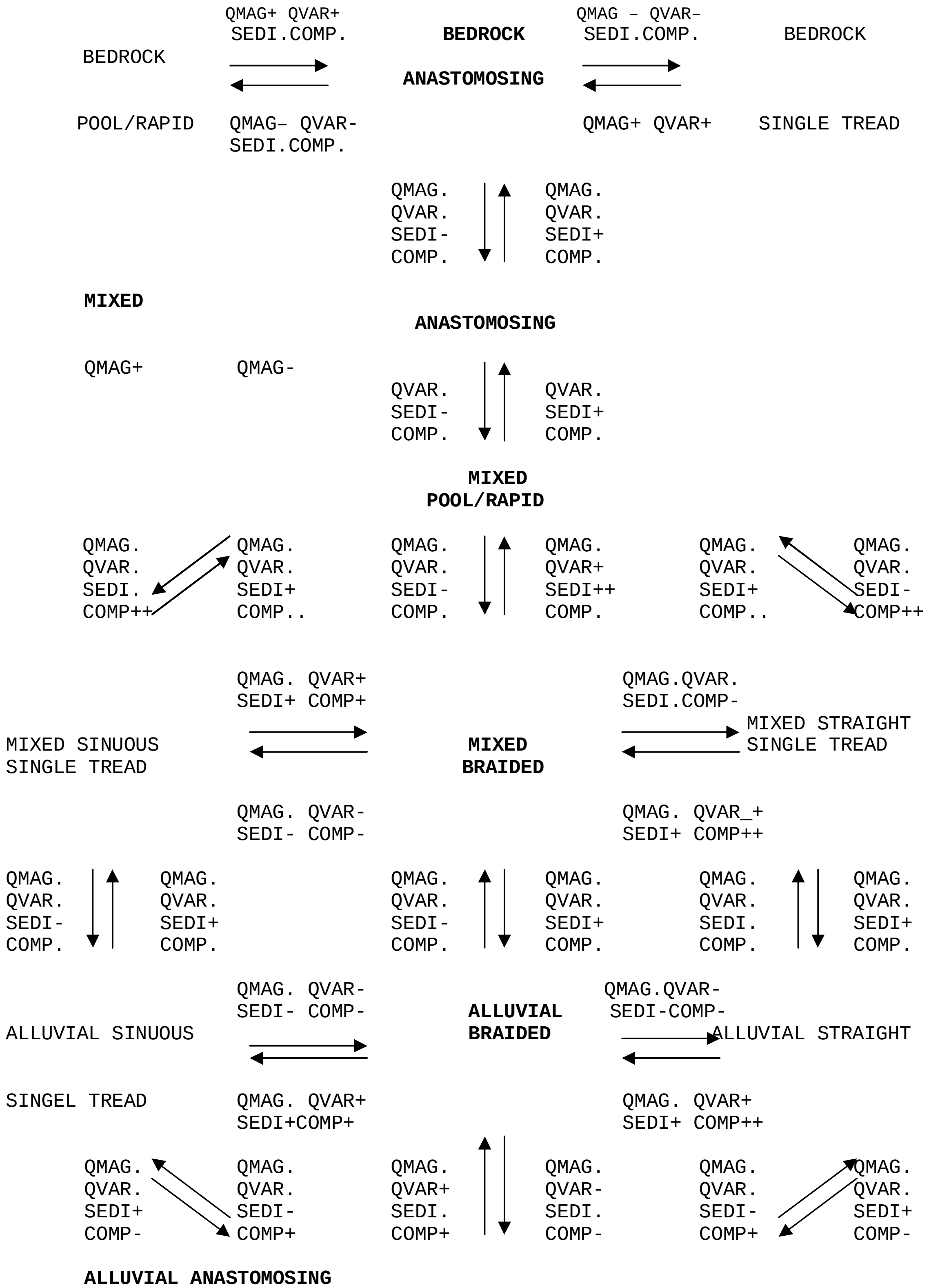
Soil cover is varied between highland and lowland areas. The average thickness of the soil can be expected to be 9m and it consists of coarse to fine sandy loam (Amir Hashim, et al. 2000). Studied by Sabry Mohamad (1997) shows that within the Tekali River, one of the Langat sub-catchment, 45 per cent of the soil consisted of coarse sand and another 30 per cent was clay. Common rocks in Langat Catchment include shales, sandstone and quartzite. In the highlands, granites of variable texture and composition are common.

METHODOLOGY

A conceptual Model For Change on The Langat River

Given the preliminary understanding of the structure and principal controlling variables operating on the Langat River, it is possible to conceptualise the impact that changes in the magnitude and variability of discharges, input of sediment and channel competence (QMAG, QVAR, SEDI, COMP respectively) will have on the geomorphological structure of the river. Based on this understood, the conceptual model of change of Langat River catchment is developed (Figure 2). To explain the conceptual model, it is useful to begin with the assumption that the main-channel is free of alluvium. As sediment accumulates progressively in the main-channel, the nature of the river changes from bedrock anastomosing through succesive channel types to an alluvial anastomosing system. Such a sequence of changes does not, however, take into account changes in controls other that sediment input. It is apparent that once the river has changed from bedrock anastomosing through mixed (bedrock and alluvial) anastomosing to a mixed pool-rapid character, changes follow a variety of sequences which could result in the development of one of many alluvial channel types. Depending on the relative changes in QMAG, QVAR, SEDI and COMP, the river may change from having a mixed pool-rapid character to sinuous, braided or single tread channel forms, all three of which may form entirely on alluvium.

The range of possible changes described by the conceptual model (Figure 2) is reversible. Further, it should be appreciated that, depending upon the variability of controls, changes in the river may reflect a progression through some or all of the river types included in the model (in an order determined by the variation in controls), or changes could simply be reflected in an oscillation of a river reach between two types of channel. The conceptual model provides the basis for predicting forms to which any particular section of river may change if there is a change in channel controls. For example, a mixed sinuous single thread channel may change to either mixed pool-rapid, mixed braided or an alluvial sinuous single tread channel. The conceptual model may be tested through studies of processes which also facilitate the determination of which conceptual change is more likely. The model also provides a theoretical insight into the geomorphological functioning of the Langat River system and highlights the following variables which must be investigated further in order to begin to quantify channel change on the Langat River:



QMAG= Discharge magnitude QVAR= Discharge variability SEDI= Sediment inputs
COMP= Channel competence += increase -= decrease .= no change

Figure 2: A Conceptual Model of Channel Change for The Langat River

RESULTS AND DISCUSSION

(a) Catchment Variables Control on The Langat River

The geomorphology and nature of changes to the physical state of any river result from complex interactions of a number of control factors that operate on scale ranging from the whole catchment, down to the scale of individual boulder outcrops in the river bed. In the Langat River catchment, these controls could included as a climate, geology, water discharge and sediment influx (both the main channel and from tributaries), the bed and bank characteristics, the development of vegetation along the rivers and the effects of human interference (Morisawa 1985) (Figure 3). A detailed discussion of each variable controls can be seen in Mohd Ekhwan (1998, 1999). These catchment control model is dynamic and be modified to define the principal dynamic variables that influence channel behavior. In case of Langat Catchment, channel flow regime, channel competence and catchment sediment production are considered as the major dynamic controls influencing geomorphological change (see figure 3). Factors such as geology are important, but have a static influence at the temporal scale in this study. For example, the underlying bedrock lithology affects the form of the river, but tectonic movement which probably occurs over periods of millions of years may be ignored for the purposes of prediction at timescales considered here. Table 1 stated change in the status of channel variables with temporal scale in the Langat River. The status of each channel variables is gives with reference to channel variable status developed by Schumm and Lichty (1965).

Other factors including soil cover, land-use patterns and catchment topography are also seen to influence the geomorphological dynamics of the Langat River. Similarly, there are a number of positive feedback mechanicms operating to control channel form, in particular vegetative growth on new sediments influences the evolution of the sedimentary unit. Siti Nazariah (1997) has demonstrated the link between vegetative succession and bar formation in the Rekoh River. Her successionary sequence from bedrock, through sand, and shrubs, to bamboo trees indicated a positive feedback mechanicm operating between progressive sedimentation and vegetative colonisation.

Table 1: Change in the status of channel variables with temporal scale in the Langat River

River variables	**Status of channel variables**		
	Geologic ($>10^3$ years)	**Modern (10^1 to 10^2 years)**	**Present (1 to 10 years)**
Time	independent	irrelevant	irrelevant
Geology	independent	independent	independent
Climate	independent	independent	independent
Vegetation (type and density)	dependent	independent	independent
Relief	dependent	independent	independent
Palaeohydrology	dependent	independent	independent
Mean Q of water and sediment	indeterminate	independent	independent
Channel morphology	indeterminate	dependent	independent
Observed Q of water and sediment	indeterminate	indeterminate	dependent
Observed flow characteristics	indeterminate	indeterminate	dependent

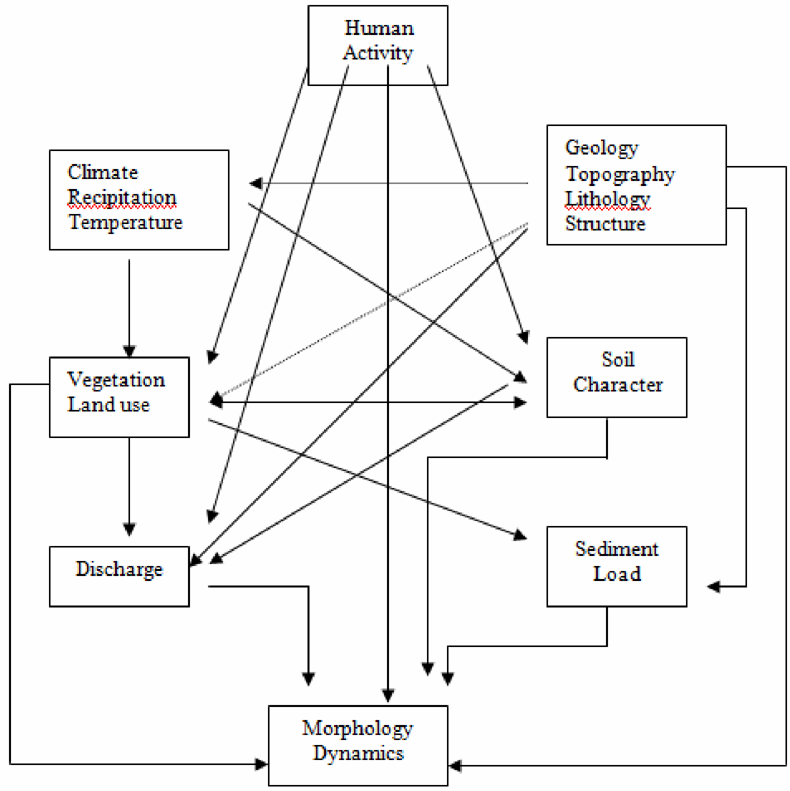


Figure 3: Generalised catchment factors that influence fluvial geomorphological dynamics in the Langat Catchment (modified from Morisawa 1985)

(b) Recent Changes in Catchment Controls

Increased development pressure on the region as a result of social, political and economic factors has resulted in changes in environment pattern in the Langat Catchment (Jamaluddin 2000), which are the primary factors resulting in altered catchment hydrology and sediment production. Existing and projected water demands for instance, have been quantified by Noorazuan (2000). His study stated that for total domestic water requirement for Langat Catchment, it is projected to be around 208 MLD by the year 2010 and will exceed 335 MLD by the year 2025.

Afforestation in the Langat River catchment has resulted in an estimated 21 per cent reduction in the MAR (Jamaluddin et al. 1998). The projected increase in water demand by domestic, industrial and irrigation will further reduce existing low base-flows, impacting on the river ecosystem during low-flow periods.

Dynamic Factor Analysis in The Langat River catchment

(a) Hydrological Regime

Detailed information on the Langat River hydrology is required to describe the natural and anthropogenic induced variability in the flows experienced in the river. It also allows these flows to be analysed using statistical methods, producing a quantitative description of the flow regime. Gauging station at Dengkil found to be satisfied due to prolong and good historical flow record, extending back to 1974.

Generally, the Langat River exhibits flow variability on a number of temporal scales, namely monthly and seasonally, due to mainly changing precipitation patterns and flow regulation operates at upstream the Langat and Semenyih Rivers. Previous flow records indicate that Langat River flow is not constant through out the years observing. Noorazuan (1998) was compiled the average monthly discharge for Langat River at Dengkil gauging station from the period 1974-1990. The average mean monthly flow is presented in Figure 4. It is observed that the river flow began to increase drastically up to the month of November. The lowest flow is observed in August which is also the driest month in the year. The peak flow in the year occurred from November to December, during the onset of north-east monsoon.

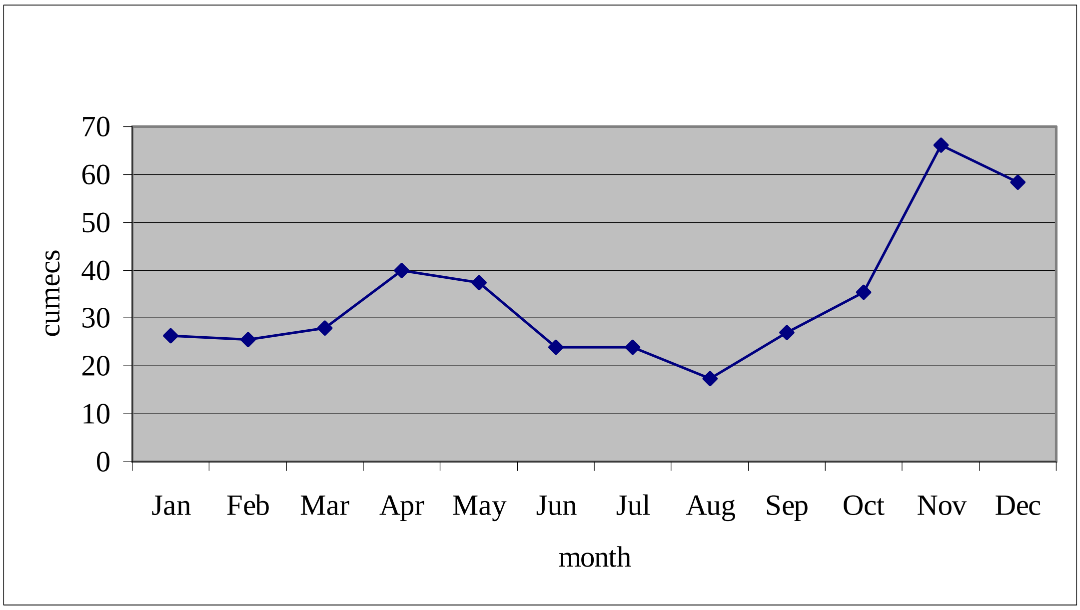


Figure 4: Mean monthly flow of Langat River at Dengkil Station

Flow duration characteristic was also calculated (Table 2) to generate the frequency of inundation data for each cross-section in the Langat River. In Figure 5, the curve represents the hydrograph of the mean value of the flows arranged in order of magnitude. It is estimated that the monthly mean discharge of 35 cumecs is exceeded 50 per cent during 17 years record, while 20 per cent of the time will have a estimated mean flow of 48 cumecs.

Table 2: Flow duration curve for Langat River at Dengkil Gauging Station

Class mean Q	**Class interval**	**No. of occurance**	**Accumulated**	**% time the flow is exceeded**
10	0-20	86	202	100
30	20-40	79	116	57.4
50	40-60	20	37	18.3
70	60-80	10	17	8.4
90	80-100	6	7	3.5
110	100-120	1	1	0.5

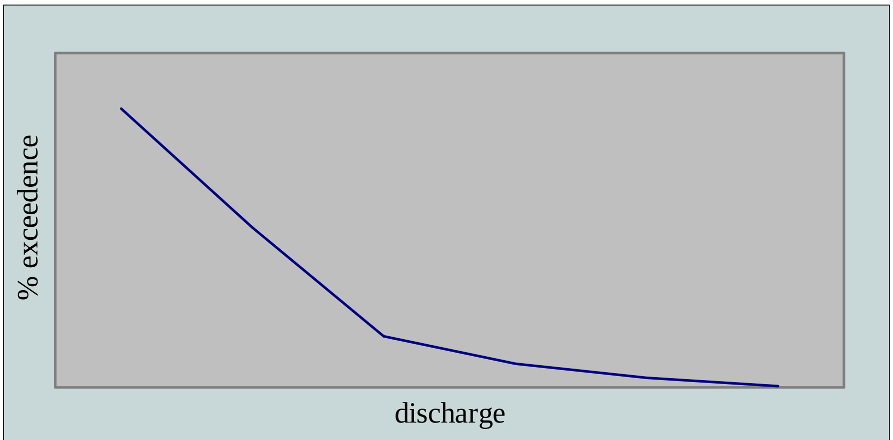


Figure 5: Flow duration curve for Langat River at Dengkil

Combining the local stage-discharge and flow frequency information and assuming that the water surface remained horizontal across the main-channel for all flows, enables the generation of frequency of inundation data for each cross-section measured at LA 03^{O} 01' 75", and LO 101^{O} 46' 10"(Figure 6). Two sets of results were calculated based on the annual maximum flood series data and daily average flow data obtained at Dengkil gauging station.

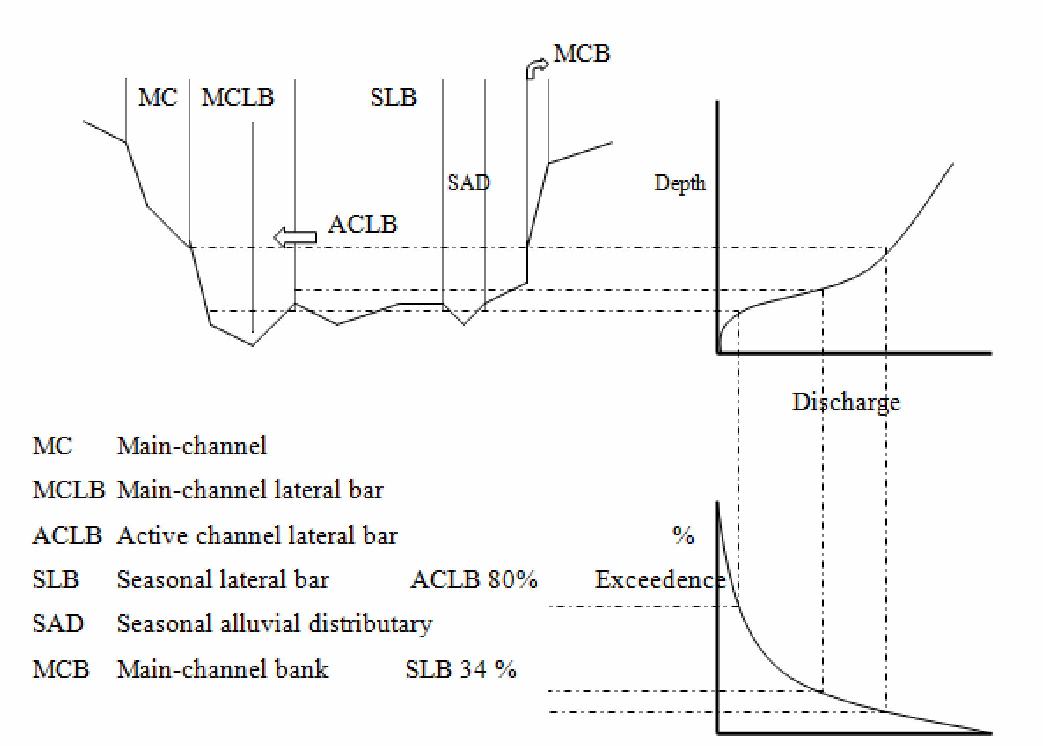


Figure 6: Model of the links between flow levels, morphological units and frequency of inundation

(b) Sediment Production

Catchment sediment production has been identified as a principal factor determining channel form and dynamics in the Langat River. Evidence of channel change from various authors all report an increase in the sediment visible in the river (Mykura 1992, Sabry Mohamad 1987, Mohd Ekhwan 2000), which is a consequence of the increased degradation of the catchment. Studied by Mohd Ekhwan (1998) indicates that sediment production in the main-channel is high. Using USLE (Universal Soil Loss Erosion) model shows that average erosion rate are varied from 76.4 tan/ha/year for palm oil estates to 382.5 tan/ha/year in urban areas (Table 3). Sediment analysis at Langat River shows that the maximum sediment concentration was 89, 574 mg/l whereas at Semenyih was 49, 530 mg/l, respectively.

Table 3: Soil erosion at Langat Catchment as Estimated by USLE model

Land use	**No. of grid square**	**Average erosion (tan/ha/year)**
Forest	87	38.86
Urban	28	382.5
Rubber estate	40	122.6
Palm oil estate	71	76.4
Mix cultivation	31	96.7

(c) Management Implication

The study on the geomorphological response to changing flow regime of the Langat River system provides a descriptive basis for the interface between hydrology and biotic response to changing flow regime. This study provides the communication system whereby morphology (physical habitat) and local and regional hydraulic conditions can be discussed, described and quantifies.

The existing geomorphology and the nature of changes in the Langat River result from the complex interaction of water discharge and sediment, the development of the vegetation along the rivers and the effects of human activity (dams, water usage, etc.). The processes and their interaction need to be understood in order to quantify change in the rivers in response to changes in different contributing conditions.

Channel management applications are based upon the assumption that rivers within each channel class (bedrock anastomosing, mixed anastomosing, mixed pool-rapid, alluvial barided and alluvial single tread) react similarly to any disturbances. Therefore, case studies can be used to determine the potential response behaviour of numerous other, similar, rivers. Mohd Ekhwan (2000) for instance uses this logic of geomorphological change to develop a standard geomorphological approach for the appraisal of river studies in Johor River, Trengganu River and Langat River, respectively. In conjunction with temporal series of aerial photo-based interpretation, the model can be tested in the ground to identified river planforms which suspectable to changes. Management interpretations of sensitivity to disturbance, recovery potential, sediment supply, bank erosion potential, the influence of vegetation on bank stability and river restoration can be also identified using the model geomorphic change developed to particular river.

As river managers increasingly recognise that rivers are not simply 'watercourses', but involve the interrelated movement of water and sediment within a dynamic river channel. This model can be act as an alternative to river management system and to guide planners and engineers involved in the management of the river or its surrounding corridor. This model however, needs to be polished in order to provide good information of river channel change. In case of Langat River, it is recommended that detailed study of the surface-subsurface flow interaction in ephemeral systems should be carry out in conjunction with this model. The result may gives better predict water volumes necessary to restore such systems to a state of perennial flow. The model can also intergrate with ecological knowledge in order to establish geomorphological/ecological response linkages.

CONCLUSION

The original aims of the research study have been achieved. A comprehensive description and structuring of the geomorphology of the Langat River is proposed. Patterns of temporal change have been investigated and change theory established. A conceptual channel change model is suggested for the Langat River. In conclusion, it can be noted that:

1. Changes to the catchment control factors are occuring in the Langat River catchment as a result of flow variability and anthropogenic influence, in the form of land degradation and water abstraction for industrial and domestic use.

2. Land degradation and sediment production are high, particularly in the urban areas. This sediment is contributing to an increase in the area of sedimentary deposits observed in the Langat River using USLE model.

3. Five principle channel types have been observed on the Langat River, these are bedrock anastomosing in the upstream channel, mixed pool-rapid, mixed anastomosing, alluvial braided and alluvial single tread.

4. The principle catchment control factors responsible for channel change in the Langat River are discharge magnitude, discharge variability, local channel sediment transport capacity and lateral sediment inputs.

5. Geological influence on the form of the Langat River is apparent, however this factor is static at the temporal scale of this study.

6. Only the principal dynamic controls on channel form are considered in the conceptual model of change, other factors are also influencing, and being influenced by geomorphological change, including riparian vegetation. Such factors have not been explicitly considered in the present study as the models proposed are too coarse to warrant their inclusion. Refinement of these models necessitates further investigation into these factors at the earliest opportunity.

7. The conceptual model provides a theoretical framework that describes the possible geomorphological change pathways for the Langat River. Specific study reach was applied in the cross section of LA 03^{O} 01’ 75”, and LO 101^{O} 46’ 10”. However, the result gives a general idea about channel change along the Langat River. In the river

management point of view, the model can be help the managers to understand how to manage the rivers from the broad perspectives but under control variables.

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