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# River Regulation and its Impact on River Channel Planform Changes

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**Abstract:** River regulation is a process of alteration of stream flow for water resources and hydropower. Most regulation structures involved dams and weirs which are able to control the flow regimes for special requirements, i.e., agriculture, domestic and industrial power. This study examines channel geometry change in particular their planform characteristic due to intensive regulation by the Pangson and Semenyih reservoirs on the Langat river over the last 12 years. GIS-ArcInfo extrapolation analysis was used to quantify the geometry change. Superimposed topographical maps of pre (1973) and post regulated (1985) were successful to determined type and pattern of channel planform change. Examination of planform indices represented by three-point stations in the upland, intermediate and lowland reaches indicate that in general, channel sections tend to be straighter in the upland and become narrower with more meandering in the intermediate and lowland reach sections. These were proven quantitatively using Sinuosity Index (SINDX). In the upland reach, the SINDX was reduced to average 1.02-0.99 post-regulation while the others demonstrate the opposite trend.

**Key words:** Channel geometry, GIS, planform, sinuosity index, Langat river, reservoirsr

## INTRODUCTION

Regulation of rivers and streams throughout Langat river basin, Selangor Malaysia over the last 40 years altered channel planform and geometry. Specifically, regulation of the headwaters of Langat river commenced since 1981, involving the formation of the Pangson and Semenyih reservoirs. Since then, the channel geometry was modified intensely throughout the channel reach. Although, very little researches have been done to evaluate environmental impacts of river geometry, there is an increasing awareness among geomorphologists, hydrologists and land planners of the need to study their impact, more specifically on river channel planform. This study outlines the effects of stream regulations over the last 12 years (1973-1985) in the Langat river, Selangor. To study the changes, GIS-ArcInfo package was used for the detection of channel sinuosity between pre and post regulation.

## MATERIALS AND METHODS

The Langat river is one of the four major river systems in the state of Selangor namely Bernam, Selangor, Kelang and Linggi river. Based on multivariate land classification technique using the TWINSPAN (Two-way Indicator Species Analysis) computer analysis (Elfithri *et al*., 2011; Toriman, 2003), the Langat river has a basin area of approximately 1815 $km^2$. The floodplain based on floodplain areas mapped in 1995 was 508 $km^2$. Figure 1 shows the land class distribution based on three study reaches namely upland reach (land class 1), intermediate reach (composite land class 2 and 3) and lowland reach (land class 4).

The upland reach is located in the upstream valleys of Langat and Semenyih river. The landscape is influenced by the Titiwangsa range, characterized by the elevations between 100-200 m and a significant number of 200 m contours. The predominant topography in this reach is a steep slope associated with Serdang soil series. The presence of this soil series indicated that these areas are susceptible to surface erosion (Jaafar *et al*., 2005; Al-Ajlouni *et al*., 2007). Geologically, the upland reach is dominated by granitic rocks.

The intermediate reach covers the area between Hulu Langat, North of Mantin and East to Kuala Langat and contains the major urban areas within the catchment:Kajang, Cheras, Bandar Baru Bangi and

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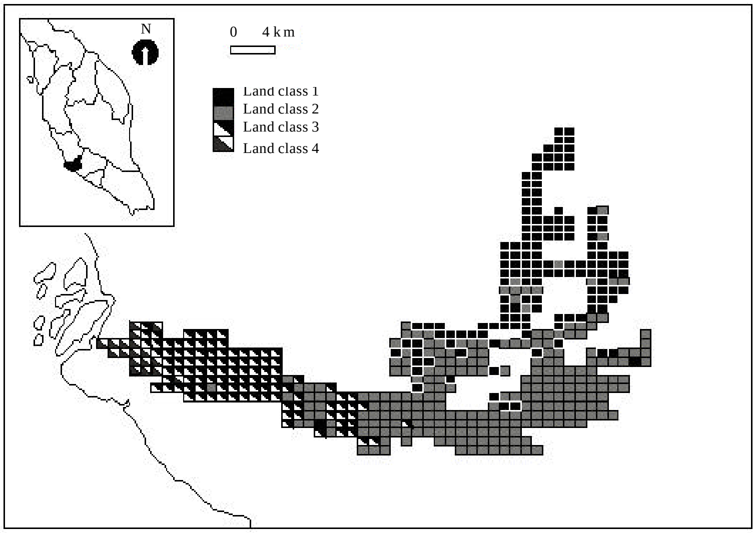


Fig. 1: Langat floodplain land distribution based on upland, intermediate and lowland reaches

Dengkil. The topography is steeper in proximity to areas of upland reach and flattens in proximately to lowland reach. Crop cultivation, mainly oil palm estates predominates with this covering approximately 40.6% of the total area. Meanwhile at lowland reach is characterized by bordering coastal areas, generally close to intertidal sands or muds and is found particularly around Banting, Jugra and South of Klang town. The topography is fairly flat, although short steep slopes are common in areas of Jenjarum and Bukit Cheeding. Near to the coastal zones, wetland forest, mainly mangrove (Bakau) with local species such as *Nipah* and *Gelam* predominate.

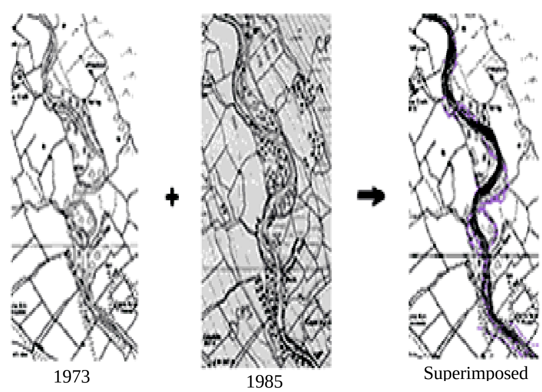


Fig. 2: Example of superimposed map (1973 and 1985) of the lowland reach of Langat river

## RESULTS AND DISCUSSION

To ascertain how the channel planform changes were related to flow regulation in the Langat river, two different periods, representing both pre and post regulation were selected for analysis. The GIS-ArcInfo extrapolation analysis was used to quantify the changes represented by a change in sinuosity index at upland, intermediate and lowland reaches. Two rectified databases, namely a 1973 and the 1985 topographical maps provide base line estimation of river planform changes between both periods. Planform change can be observed by comparing maps (from different time periods) of the same stretch of river and overlaying them using a Geographical Information System (GIS). This technique provides evident and indicates how the channel sinuosity changed size and position indicating a transfer of erosion and process of sediments over time (Toriman *et al*., 2010; Toriman, 2010; Mokhtar *et al*., 2010; Islam *et al*., 2010). To assess channel planform change, sequential maps were used and compiled. The method of compilation involved superimposition for two different topographical maps dates 1973 and 1985 (Fig. 2). Digital scanning and on-screen digitizing techniques were applied to both sets of map. In this respect, all images representing upland, intermediate and lowland reaches were registered and saved in GIS-ArcInfo map projection. The registering process is important to inform the computer where the maps and images are stored and oriented.

Having two different scales issued (1:163, 360-1973 and 1:50, 000-1985) both scales need to be rectified. Basically, digital rectification is the process of registering the digitized outline of the river channel to the base map (in this case, the 1985 topographical map). Once rectified both maps having a uniform scale was superimposed to identify change in Sinuosity Index (SINDX). During rectification process, two types of error were identified. Firstly, the Systematic Error (SE) which was calculated using the Eq. 1:

$$S = \frac{\sum x}{n} \quad (1)$$

If S = 0, then the errors are random. If however, a systematic error has been introduced into the data (most likely during map rectification) then the value of S will give the amount of shift which has taken place. The second error involved the Root Mean Square (RMS) error and this is calculated by the Eq. 2:

$$r = \sqrt{\frac{\sum x^2}{n}} \quad (2)$$

Where $x_1, x_2, \ldots, x_n$ are the error at n reference points. This value is the average amount by which co-ordinates of the same point (or tics) on the two maps will deviate. This error must be considered when taking measurements of change that have occurred between the two map dates. With GIS accuracy between rectified maps could be measured with the base map by fixing a geo-reference points which could be identified both on the base map and the rectified map.

Two aspects of discussion were undertaken in order to examine channel planform changes due to river flow regulation along the Langat river. Firstly, involves analyzing a flow pattern from the pre and post regulation. Discussions were emphasis on the discharge and water level pattern over the period study. Secondly, involves analyzing channel Sinuosity (SINDX). This was obtained by measuring the channel sinuosity using Eq. 3:

$$\text{Channel sinuosity} = \frac{\text{Channel length (L)}}{\text{Valley length (Z)}} \quad (3)$$

The process of sinuosity measurement involves dividing the reach into 5 km reaches and measuring sinuosity by digitizing the valley line as a straight line from the starting point to the end point of each reach and digitizing the channel length line as a meandering line along the thalweg of the channel. In this respect, the calculation of sinuosity index was carried out in the Excel file.

**Response of channel flow to channel regulation:** The retention time of water behind a dam and its gradual release downstream results in the reduction of peak discharges and regulation of the flow regime. In the case of Langat river, reduction of peak discharges is achieved not only by the storage of flood waters in the reservoir volume but also through the storage provided by the rise in water-level above the overflow weir. Reduction in the magnitude of mean annual flood has been recorded below the Langat dam namely at Dengkil gauging station (02°59'00" N 101°52'00"E).

Over 17 years (1974-1990), only 35% (6 no. of occurrences) along the years that exceeded current water levels. It can be seen from Fig. 3 that the discharge was reduced by almost 60% in post regulated. The post regulated shows peak discharge exceeded 150 $m^2$ $sec^{-1}$ occurred once in November, 1983 compared to four no. of occurrences in pre-regulated period.

**Response of channel sinuosity to flow regulation:** For each 5 km reach, the Sinuosity Index (SINDX) dated 1973 and 1985 were computed and tabulated in Table 1-3. In the context of channel dynamic, SINDX plays an important role as an indicator for the channel response, it also a primary indicator of stream type as well as an indication of

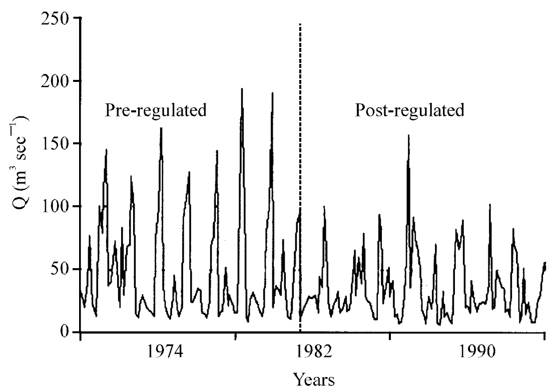


Fig. 3: Response of channel flow to channel regulation

Table 1: Change in SINDX values in the upland reach

| Reach no. | 1973 map (Pre-regulation) | 1985 map (Post-regulation) |
|---|---|---|
| 1 | 1.13 | 1.10 |
| 2 | 1.07 | 1.03 |
| 3 | 1.08 | 1.05 |
| 4 | 1.08 | 1.17 |
| 5 | 1.04 | 1.19 |
| 6 | 1.07 | 1.00 |
| 7 | 1.04 | 1.38 |
| 8 | 1.05 | 0.04 |
| 9 | 1.03 | 1.38 |
| 10 | 0.61 | 0.59 |
| Average | 1.02 | 0.99 |
| Highest | 1.13 | 1.38 |
| Lowest | 0.61 | 0.04 |
| SD | 0.52 | 0.40 |
| CV | 50.90 | 40.40 |

Table 2: Change in SINDX values in the intermediate reach

| Reach no. | 1973 map (Pre-regulation) | 1985 map (Post-regulation) |
|---|---|---|
| 11 | 1.64 | 1.64 |
| 12 | 1.34 | 1.37 |
| 13 | 1.92 | 1.92 |
| 14 | 1.84 | 1.84 |
| 15 | 1.05 | 1.02 |
| 16 | 1.22 | 1.26 |
| 17 | 2.13 | 2.08 |
| 18 | 1.94 | 1.89 |
| 19 | 1.73 | 1.77 |
| 20 | 2.02 | 2.09 |
| Average | 1.68 | 1.69 |
| Highest | 2.13 | 2.08 |
| Lowest | 1.05 | 1.02 |
| SD | 0.36 | 0.36 |
| CV | 21.40 | 21.40 |

Table 3: Change in SINDX values in the lowland reach

| Reach no. | 1973 map (Pre-regulation) | 1985 map (Post-regulation) |
|---|---|---|
| 21 | 2.01 | 2.03 |
| 22 | 1.24 | 1.22 |
| 23 | 1.67 | 1.67 |
| 24 | 2.22 | 2.22 |
| 25 | 1.91 | 1.92 |
| 26 | 1.67 | 1.67 |
| 27 | 1.54 | 1.54 |
| 28 | 2.31 | 2.31 |
| 29 | 1.86 | 1.86 |
| Average | 1.82 | 1.83 |
| Highest | 2.31 | 2.31 |
| Lowest | 1.24 | 1.22 |
| SD | 0.34 | 0.34 |
| CV | 18.70 | 18.60 |

how the stream channel slope is adjusted to that of the valley slope. Description of SINDX values from each study reach is addressed.

**SINDX analysis for the upland reach:** In general, SINDX values were relatively low. During pre-regulation period, the lowest (0.61) was in reach 10 while the highest recorded in reach 1 (1.13). The 1973 topographical map indicates SINDX tends to be higher in the upper and lower sections but decreased in the middle section. Meanwhile, the 1985 topographical map (post-regulation) shows, over 50 km of the upland reach, six reaches registered a decreased in SINDX value namely reaches no. 1, 2, 3, 6, 8 and 10, implying more straighter than pre-regulation period. The lowest (0.04) was in reach 8 while the highest SINDX (1.38) recorded at reaches 7 and 9 (Table 1). Figure 4 shows an example of meandering change as examined at the upland reach of Langat river.

**SINDX analysis for the intermediate reach:** The basic summary statistics for the SINDX at each both map editions are shown in Table 2. General patterns of the SINDX in the intermediate reach were slightly higher than in the upland reach. In the 1973 pre-regulation map, the highest value of SINDX appeared to reach 17 (2.13) while the lowest value, 1.05 appeared to reach 15. Meanwhile in the 1985 post-regulation map, highest value of SINDX recorded in reach 20 (2.09) and the lower of 1.02 was recorded in reach 15. Rate of SINDX changes showed an increase between maps (reaches 12, 16, 19 and 20) and a reduction of between 0.03-0.05 in reaches 15, 17 and 18. Only three reaches (11, 13 and 14) registered no changed over the time period. The decrease of SINDX at reaches 17 and 18 is believed to relate to increase in Q as these reaches are located at the confluence between the Langat and Sepang/Semenyih river tributary.

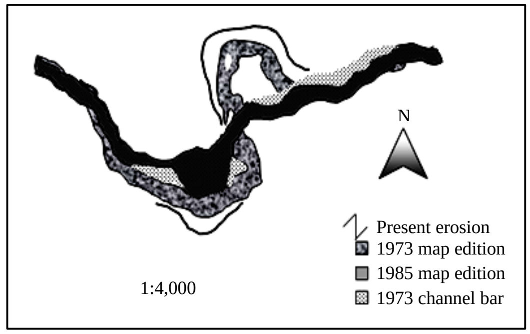


Fig. 4: Change in sinuosity as measured in reach 20 (Intermediate section)

Representative sinuosity change was taken from the development of meander extension as observed in grade coordinates 2821-2721 at Ladang brooklands, Labohan Dagang (reach 20). At this site, the SINDX value demonstrates a net increase in the post-regulation from about 2.02-2.09 (Fig. 4).

**SINDX analysis for the lowland reach:** Table 3 lists SINDX values and their changes over times. As expected, the SINDX values generally tend to be higher (up to 2.31 reach 28) in the lowland reach. Prior regulation, the highest value was 2.31 recorded in reach 28 while the lowest, 1.24 was observed in reach 22. Post regulation indicates highest SINDX value recorded at reach 28 (2.31) and the lowest was also similar reach (22) as recorded in pre-regulation map. Compared with the upland and intermediate reaches, the average value in the lowland reach seems to be higher simply because of relatively stable plan and profile. Table 3 shows the change in SINDX values in the lowland reach. As indicated, only three reaches appeared changes in SINDX namely reach no. 21, 22 and 25.

## CONCLUSION

From the results, there are two points of interest. Firstly, the role played by the Langat and Semenyih dams in regulating the flow below the reservoir. The result demonstrates by a declining in the number of times Q exceeded the 150 cumecs in the post-regulation period. This result agreed with other researchers (Petts, 1977; Castaldini and Piacente, 1995; Knighton, 1984) which postulated that reservoir construction would decrease discharge and flow velocity. Secondly, change in channel geometry as demonstrated by a change in SINDX values at the upland, intermediate and lowland reaches. Examination of planform indicates that in general, channel reaches tend to be straighter in the upland reach and narrower with more meandering in the intermediate and lowland reach. Although, this study not discuss in terms of sediment content, of course, reservoir construction would effects sediment budget in the downstream site of the Langat river. It is believed that flow regulation effects reduction in sediment load and the input of sediment from tributaries. It can be concluded that in reality, channel response to flow regulation are complex processes, so that the rate and direction of response may vary both with regard to time and in different parts of channel reach. In the context of Langat river within the 12 years time span, the increase rates of SINDX values in the intermediate and lowland reach indicate channel tends to be more meandering, this means change in bend Radius (R), channel wavelength (L) and meander belt width (B).

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## REFERENCES

Al-Ajlouni, M.F., R.A. Rahman, A.G. Rafek, M. Mokhtar and N. Ezlin, 2007. Advisory system software for aquifer storage and recovery in langat basin UKM campus as case study (IWRMAS). Int. J. Soft Comput. Appl. London, 2: 50-55.

Castaldini, D. and S. Piacente, 1995. Channel Changes on the Po River, Montova Pronince, Northern Italy. In: River Geomorphology, Hickin, E.J. (Ed.). John Wiley and Sons, New York, ISBN: 9780471955313, pp: 193-209.

Elfithri, R., M.E.B. Toriman, M.B. Mokhtar and H.B. Juahir, 2011. Perspectives and initiatives on integrated river basin management in Malaysia: A review. The Social Sci., 6: 169-176.

Islam, S., B.S. Ismail M. Barzani, G.M.E. Toriman and A.R. Sahibin, 2010. Assessment of land use and land cover changes in the tasik chini catchment area, Pahang, Malaysia using the GIS. Adv. Environ. Biol., 4: 404-413.

Jaafar, O., S. Mastura, S. Abdullah and O.A. Karim, 2005. Urbanisation and its impact on catchments runoff. Proceedings of the 2nd International Malaysia-Thailand Conference on Southeast Asia Studies, UKM Bangi.

Knighton, D., 1984. Fluvial Forms and Processes. Edward Arnold, London.

Mokhtar, M.B., M.E.H. Toriman and A.A. Hossain, 2010. Social learning in facing challenges of sustainable development: A case of Langat River Basin, Malaysia. Res. J. Applied Sci., 5: 434-443.

Petts, G.E., 1977. Channel Response to Flow Regulation: The Case of the River Derwent. In: River Channel Change, Gregory, K.J. (Ed.). John Wiley and Sons, London, ISBN: 9780471995241, pp: 145-164.

Toriman, M.E., 2003. The Application of Multivariate Land Classification Model to the Langat Floodplain Survey. In: Urban Ecosystem Studies in Malaysia: A Study of Change, Hashim, N.M. and R. Rainis (Eds.). Universal Publishers, Florida, ISBN: 9781581125887, pp: 229-247.

Toriman, M.E., 2010. Assessing environmental flow modeling for water resources management: A case of SG. (River) Pelus, Malaysia. Nature Sci., 8: 74-81.

Toriman, M.E., P. Abdullah, M.B. Mokhtar, M.B. Gasim and O. Karim, 2010. Surface erosion and sediment yields assessment from small ungauged catchment of Sungai Anak Bangi, Selangor. The Malaysian J. Anal. Sci., 14: 12-23.