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# APPLICATION OF GIS FOR DETECTING CHANGES OF SUNGAI LANGAT CHANNEL

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**Abstract:** Recent environmental developments have stimulated interests in the restoration and conservation of the Sungai Langat in Selangor both to protect against flooding and to maintain river bank stability. In order to support restoration and rehabilitation works of Sungai Langat, sufficient information on physical river characteristics are needed. The use of Geographical Information System (GIS) to map active channels and to categorised the reach according to sinuosity indices over time is encouraging. Total channel length in year 1996 reduced by about 16% from 1973. Avulsion and cut-off were observed at least at six stretches along the river. The sinuosity index (SINDX) varies from 0.61 to 2.31 in 1973 and 0.04 to 2.31 in 1996. At downstream, the channel tends to be more stable and straighter with SINDX < 2.5. This trend of river channel changes can be used as basis for evaluating river restoration works.

**Keywords:** *Restoration; Geographic Information System; Channel Changes; Sinuosity Index.*

**Abstrak:** Pembangunan alam sekitar masa kini telah menyuntik minat dalam pemulihan dan pemuliharaan Sungai Langat di Selangor khususnya dalam konteks kawalan banjir dan menstabilkan tebing sungai. Dalam usaha untuk menyokong kerja-kerja pemuliharaan sungai di Sungai Langat, maklumat lengkap mengenai ciri-ciri fizikal sungai diperlukan. Aplikasi Sistem Maklumat Geografi (SMG) untuk memeta sungai-sungai aktif dan mengkategorikan ruas sungai mengikut indeks likuan didapati mengalakkan. Jumlah panjang sungai pada tahun 1996 menunjukkan pengurangan sebanyak 16% dari tahun 1973. Pembentukan avulsi sungai dan potongan terus telah dikesan di hampir enam regangan sepanjang sungai. Indeks likuan (SINDX) berbeza antara 0.61 ke 2.31 pada tahun 1973 dan 0.04 ke 2.31 pada tahun 1996. Di hilir, sungai didapati lebih stabil Dan lurus dengan nilai SINDX < 2.5. Hasil kajian ke atas corak perubahan morfologi sungai yang diperolehi boleh dijadikan asas di dalam kerja-kerja pemuliharaan sungai.

**Kata kunci:** *Pemuliharaan; Sistem Maklumat Geografi; Perubahan Saliran; Indeks Likuan.*

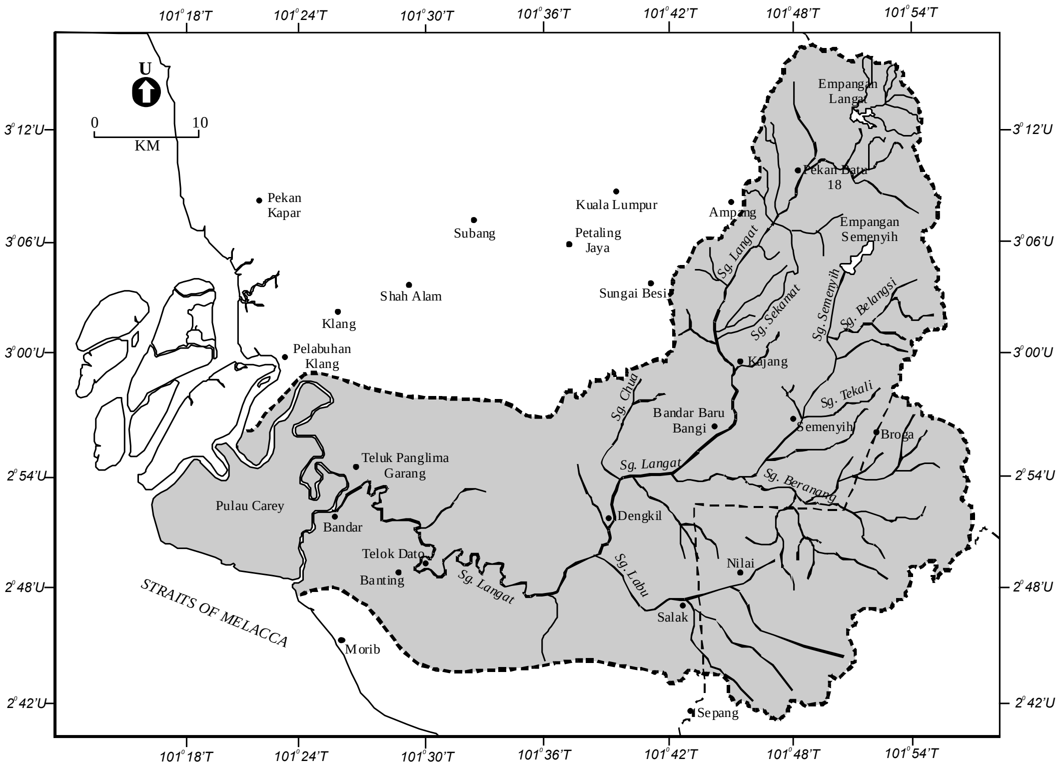
## 1. 0 Introduction

Rivers, in modern life play important roles to human being by providing fresh water, navigation, controlling local and monsoon floods and digesting effluent discharge from domestic and industrial sources. Many rivers especially in developing countries have been suffering from extreme erosion and sedimentation. Over a long term, sections of meander could shift toward the outer reach, causing damage to river riparian and floodplain stability. Natural factors, such as channel erosion together with anthropogenic activities have been identified as significant contributors to river channel dynamic (Knighton, 1985; Castaldini and Piacente, 1995). The linkages between geomorphological and anthropogenic factors on river channel dynamic have attracted interests amongst planners, researchers and scientists to study the trend and their implication on channel sinuosity over short, medium and long term. In Malaysia, studies on river channel changes were carried out directly with geomorphological and flow regime (Mohd Ekhwan and Baharuddin, 2003), hydrological and discharge characteristics (Aminuddin et al, 1999), bank properties (Haryati and Mohd Ekhwan, 2005) and combinations between climatic, soil and hydrological parameters (Mohd Ekhwan and Noorazuan, 2002).

Changes in the alignment of Sungai Langat were investigated by comparing maps showing the conditions in year 1973 and 1996. We used a combination of Geographic Information System (GIS), as a tool to identify reaches that have undergone changes and their relation to sinuosity indices. The results are useful to guide river restoration works and promote multiple benefits of biodiversity enhancement, cleaner water, and reduction of flood risk. The restoration of Sungai Langat is also in line with the government's commitment to subscribe to sustainable development and integrated catchment management.

## 2.0 Study Area

Sungai Langat is one of the four major river systems in the State of Selangor. The others being Sungai Bernam, Sungai Selangor and Sungai Kelang. The Sungai Langat stretches within the latitudes of 2$^{o}$ 40' 152"E to 3$^{o}$ 16' 15" N and longitudes 101$^{o}$ 19' 20" E to 102$^{o}$ 1' 10" E with a total basin area of approximately 1815 km$^2$. About 29% of the areas are on floodplains (Figure 1). The upper catchment is representative of the Langat hydrological region and classified under $L_1W_3$ which has massive rocks with potential runoff, between 1000 mm to 1500 mm (Law and Ahmad Jamaluddin, 1989). The average annual precipitation is 2316 mm with a range of 1800 to 3000 mm. The highest rainfalls are usually recorded in the months of October, November, December and April while the lowest is in June (mean 15 mm). The wet months coincide with the transition periods of the northeast and southwest monsoons, in March to April and October to November, respectively. Table 1 summarises the climatic conditions at Bangi Station from year 1985 to 2000.




Source: Topography map, 2001

Figure 1: The Sungai Langat Basin

Table 1: Summary of climatic data between 1985 and 2000 recorded at Bangi

| Climatic data | Annual | Unit | Average |
|---|---|---|---|
| Mean daily sunshine | 5.71 | hr $d^{-1}$ | 16 years |
| Mean daily temperature | 24.3 | $^{o}C$ | 16 years |
| Mean daily evaporation | 3.48 | mm $d^{-1}$ | 16 years |
| Mean daily relative humidity | 93.9 | % | 04 years |
| Mean daily wind speed | 1.59 | m $s^{-1}$ | 16 years |

In general, the topography of Langat basin is flat to undulating on the west and hilly to mountainous on the east and north. About 55 % of the catchment is classified as steepland with elevation up to 900 m above mean sea level.

## 3.0 Methodology

Changes in Sungai Langat planform were assessed using two topographic maps. The first map, with 1:63360 scale, provides river conditions in year 1973 and the second with 1:50000 scale for 1996 conditions. The GIS–ArcInfo (Ver 3) extrapolation analyses were used to quantify changes in SINDX in the up-stream, mid-stream and down-stream reaches. The topography maps were first rectified to provide base line estimation of river planform changes between the two observation periods. Changes in channel planform were detected by superimposing the maps of year 1973 and 1996 (Figure 2). This technique provides evident on how the channel sinuosity is modified in size and position as the results of lateral erosion and sediments movement (Mohd Ekhwan, 2003). Digital scanning and on-screen digitizing techniques were applied to both maps. In this respect, all images covering up-stream, mid-stream and down-stream reaches were registered and saved in GIS-ArcInfo map projection. The procedure can be summarised into three stages:

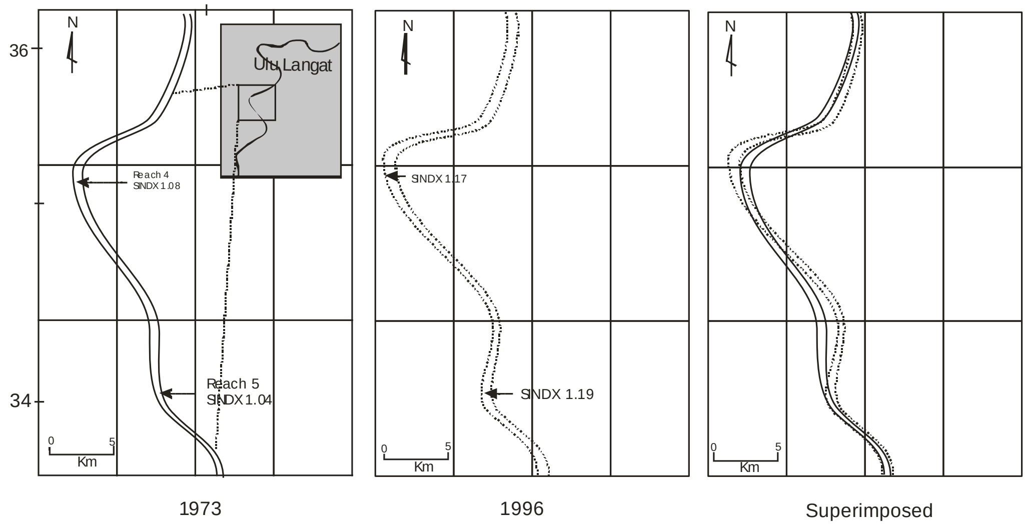



Figure 2: Superimposition technique between 1973 and 1996 topographical maps

*Stage one:* Scanning and downloading of images. The 1973 topo map was first scanned using a *Microtec* Digital Scanner with 600x1200 *dpi* resolution and saved in a *.jpg file. Digitised topo map of 1996, which was already available for the analysis, was saved as vector data into *CorelDraw10*. In the process of integrating them into the GIS database, all the scanned images were registered and imported into GIS-ArcInfo map projection on the UCS UNIX systems. The registration process is important for interfacing with location and orientation of stored maps and images.

*Stage two:* Manipulating the databases. The stream channel data in the vector format for different year were digitised on screen using GIS ArcInfo. The scales were adjusted to 1996's map (1:50000). At this stage, individual coverages were produced with point and line topology for each bankline using the 'generate' command in the ArcInfo-UCS UNIX system.

*Stage three:* Analysing the databases. The rectified 1973 and 1996 maps, both have similar scale, were superimposed to detect reaches which registered changes. These changes were stored as new themes for the subsequent sinuosity analysis. One of the advantages of using GIS is that highly accurate measurements between points can be obtained. It also provides a rapid and convenient technique to compare the rectified map (year 1973) with the base map (year 1996). Fixed reference points which could be identified from both maps were located and their co-ordinates were noted to the nearest 0.1m. The differences between the co-ordinates (base map minus rectified map) were determined for X and Y directions. However, errors during digitizing and rectification processes could still significant and these can be evaluated using equations (1) and (2).

Equation (1) provides the systematic error (*s*) which is defined as (Law and Fisher, 1992),

$$s = \frac{\sum x}{n} \tag{1}$$

where *x* is error at *n* reference point. If *s* = 0, then the errors are random. However, if *s* were introduced, most likely during map rectification, then the value of *s* indicates the degree of channel 'shift' that has taken place. Secondly, the Root Mean Square Error (RMSE) was calculated as (Law and Fisher 1992),

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n}} \tag{2}$$

where $x_i$ *is* the error at *n* reference point. RMSE provides the average error by which co-ordinates of the same point (or *tics*) on the two maps deviate. Such errors must be considered when measuring a shift in the channel alignment over the observation period. With GIS, the accuracy of the rectified maps could be measured against the base map by fixing several geo-reference points. The differences between the co-ordinates (base map minus rectified map) were determined in both X and Y directions. The measurement errors for 1973 and 1996 topo maps are presented in Table 2.

Table 2: Rectification errors of the 1973 and 1996 maps

| Error Type | *s* | | RMSE | |
|---|---|---|---|---|
| Direction | X | Y | X | Y |
| Error between 1973 and base map (m) | 0.13 | 0.18 | 0.57 | 1.42 |

Digital rectification is a process of registering the digitized outline of the river channel to the 1996 base map. Once rectified, both maps will have similar scale, and can be superimposed to detect changes in SINDX using the following formula:

$$SINDX = \frac{Channel\ Length\ (L)}{Valley\ Length\ (Z)} \tag{3}$$

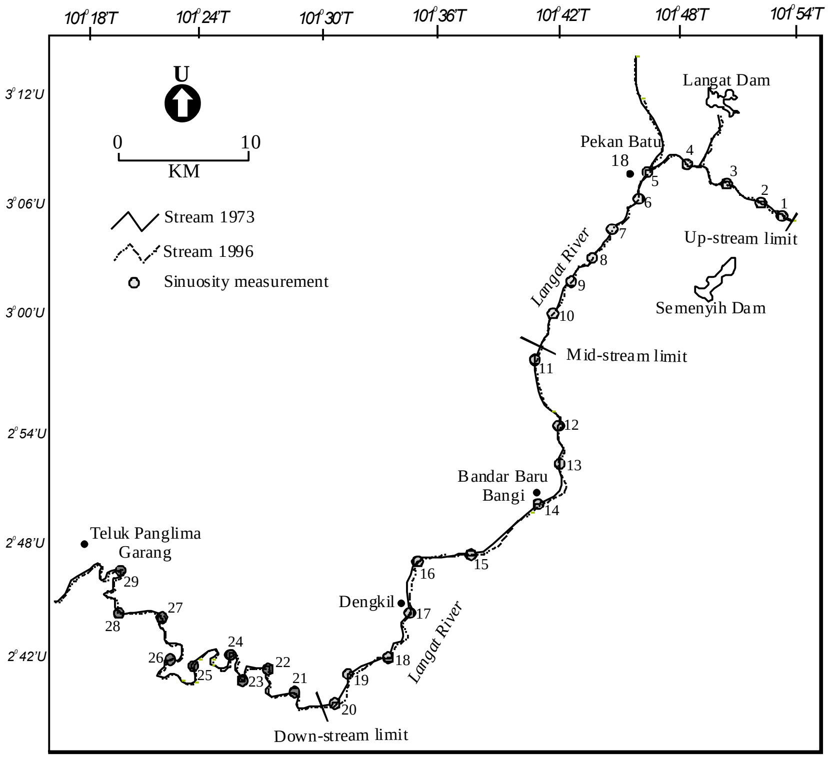
In measuring SINDX, the whole stretch of the river was first sectioned into five km reaches (Figure 3). The valley line was then digitised as a straight line from the starting point to the end point of each reach whereas the channel length was measured following the meander along the thalweg of the channel. The calculation of SINDX was carried out in the ArcInfo file.

## 4.0 Results and Discussion

For each reach, the SINDX values in 1973 and 1996 are presented in Table 3 (up-stream), Table 4 (mid-stream) and Table 5 (down-steam). In the context of channel dynamics, SINDX is important as indicator for channel response to natural and anthropogenic activities, hence could facilitate restoration and conservation works (Rosgen, 1996). It is also a useful indicator of stream type and how the stream channel slope is adjusted to that of the valley slope. Further description on SINDX values of each study reach is addressed below.

### *4.1 SINDX analysis in the up-stream reaches*

The up-stream reaches stretch from the Langat Dam to 50 kilometers downstream of Sungai Langat. In general, the SINDX values are low. In 1973, the lowest (0.61) was in reach 10 while the highest (1.13) in reach 1. The condition in 1973 indicates that SINDX tended to be higher in the upper and lower sections but decreased in the middle section. Meanwhile, in 1996, along the 50 km section in the up-stream, six reaches registered decreases in SINDX values, i.e. reaches no. 1, 2, 3, 6, 8 and 10. This implies a straighter river alignment than in 1973. The lowest SINDX (0.04) was in reach 8 while the highest (1.38) in reaches 7 and 9 (Table 3).




Source: Topography maps, 1973 and 1996

Figure 3: Location of sinuosity measurement points

Table 3: Changes in SINDX values in the up-stream reaches

| Reach No. | Year 1973 | Year 1996 |
|---|---|---|
| *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 |
| S.D | 0.52 | 0.40 |
| C.V. | 50.9 | 40.4 |

### *4.2 SINDX analysis for the mid-stream reaches*

The summary statistics of SINDX values for the mid-stream reaches are presented in Table 4. In general, the SINDX values in the mid-stream reaches were slightly higher than in the up-stream reaches. In 1973, the highest SINDX value was obtained in reach 17 (2.13) while the lowest (1.05) in reach 15. The SINDX values reduced slightly in 1996 with a maximum of 2.09 in reach 20 and the lowest (1.02) in reach 15. Rate of changes in the SINDX between 1973 and 1996 showed increases in reaches 12, 16, 19 and 20 and reduced between 0.03 and 0.05 in reaches 15, 17 and 18. Only three reaches, i.e. 11, 13 and 14 registered no change over the observed period. Lower SINDX values at reaches 17 and 18 are believed to be attributed to a greater river flow as these reaches are located at the confluence of the Sungai Langat and Sungai Sepang/Sungai Semenyih tributaries. As demonstrated by Hooke and Redmond (1992), an increase in flow is expected to decrease the sinuosity.

A representative sinuosity change was taken from the development of channel avulsion as observed in grade coordinates 2821 to 2721 at Ladang Brooklands, Labohan Dagang (reach 20). At this site, the SINDX value demonstrates net increases, from 2.02 to 2.09 between year 1973 and 1996.

Table 4: Changes in SINDX values in the mid-stream reaches

| Reach no. | Year 1973 | Year 1996 |
|---|---|---|
| *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 |
| S.D | 0.36 | 0.36 |
| C.V. | 21.4 | 21.4 |

### *4.3 SINDX analysis for the down-stream reaches*

Table 5 lists SINDX values and their changes over times in the down-stream reaches. In 1973, the highest SINDX value was 2.31, recorded in reach 28 while the lowest, 1.24 was observed in reach 22. Reach 28 registered the same SINDX value of 2.31 in 1996 and reach 22 maintains its lowest value. By comparison, the down-stream reaches are more stable than the up-stream and mid-stream reaches although the average SINDX value in the down-stream reach seems to be higher. This is because of the relatively more stable plan and profile. As can be seen in Table 5, only three reaches showed changes in SINDX, i.e. reaches no. 21, 22 and 25.

Changes in channel geometry along the Sungai Langat are evident as demonstrated by the SINDX values in the up-stream, mid-stream and down-stream reaches. Examination of planform indicates that in general, channel reaches tend to be straighter in the up-stream. Towards mid-stream, the reaches become slightly bigger but narrower at the meander sites. Meanwhile the down-stream reaches exhibit broader cross section and wider meandering sections. The increase rates of SINDX values in the mid-stream and down-stream reaches indicate that the channel tends to be more meandering and probably with less discharge than before. On the other hand, a decrease in SINDX value has a converse effect which suggests changes in bend radius, channel wave length and meander belt width.

Table 5: Change in SINDX values in the down-stream reaches

| Reach no. | Year 1973 | Year 1996 |
|---|---|---|
| *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 |
| S.D | 0.34 | 0.34 |
| C.V. | 18.7 | 18.6 |

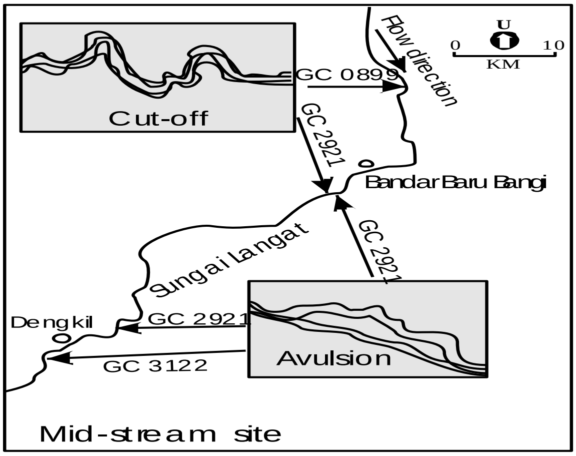
### *4.4 Implication to river restoration and conservation*

The channel changes along the Sungai Langat as indicated by the SINDX values were attributed to natural erosion and a combination of anthropogenic factors. Our results confirmed those findings elsewhere (e.g. Hooke and Redmond, 1992; Lawler, 1993; Petts, 1998; Mohd Ekhwan, 2003). Erosion normally occurred in the form of lateral bank and bank scouring which can be seen at most reaches with SINDX > 1.5. In Sungai Langat, erosion occurred in combination with scouring process which later develops into channel avulsion and cut-off (Figure 4). At least six locations along the Sungai Langat exhibited channel avulsion and cut-off (Table 6). Scouring is a major problem in natural channels and rivers. The process could induce bank instability and destroy bank vegetations (Large, 1996). At GC 3122 and GC 2921 (Figure 4), the reaches were affected by channel revetment for river bank protection. In these particular reaches, the scouring occurred due to changes in the river flow following the construction of a flood mitigation structure, about 20 m from the sites that had undergone avulsion. In addition, the bank has sandy sub-soils, hence is unable to recover quickly from bank collapse and erosion. The installation of a rectangular concrete for restoring the streambank has improved the reach conditions with a healthy growth of bank vegetation.

Within the 23 years interval, considerable amounts of vegetation along the riverbank were apparently lost. Based on the land use map, about 55% of the vegetation covers were lost or converted to other land use. Restoration works have been going on for quite sometime with the installation of environmentally friendly materials for river bank revetment. Since 2001, four bank protection works were carried out by the Drainage Irrigation Department (DID) stretching about 35.3 kilometers. The aim was to restore the meanders and the natural dynamics, improve the conditions of flora and fauna and ensure high river water quality.

Table 6: Causes of channel changes along the Sungai Langat

| Grade coordinate/ location | Types of change | Causes of change |
|---|---|---|
| GC 3122 | avulsion | Sungai Langat flood mitigation project (phase 1) |
| GC 2921 | avulsion | Urbanisation and river schemes |
| GC 2720 | migration | Urbanisation and river schemes |
| GC 2921 | cut-off | Erosion process and river bypass project |
| GC 0899 | artificial cut-off | Agricultural and irrigation scheme |
| GC 1092 | natural/artificial avulsion | Flood embankment |
| GC 2218 | Bankfull depth | River sand mining |




Source: Topography map, 1996

Figure 4: Type of channel changes along the mid-stream of the Sungai Langat

## 5.0 Conclusion

The dynamics of Sungai Langat as indicated by changes in the sinuosity index (SINDX) shows more active channel processes in the up-stream and mid-stream reaches. The use of topography maps and ArcInfo GIS to estimate spatial and temporal SINDX changes has been encouraging. The technique allows rapid detection of channel changes over time. The calculated SINDX values range from 0.14 to 2.16, and 1.25 to 3.11 in 1973 and 1996, respectively. Over this period, the channel became straighter in the up-stream. The middle stream became slightly bigger but narrower at the meander whereas the down-stream has broader cross section with wider meandering sections. Information on SINDX values especially on the long term trend can be used as basis for assessing the effectiveness of river restoration work and monitoring various river functions. By applying both engineering and biological approaches, the extent of lateral erosion and bank scouring can be minimized.

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