Stormwater quality modeling for upscaling MSMA stormwater management ecohydrology

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Abstract. Langat River is 180 km length has a total catchment area of 2,350 km$^2$. The Langat River is classified as Class II in the upstream, and as the water flows downstream the quality degrades to Class III and IV. This degradation is caused by the rapid and uncontrolled urbanization in the contributing catchment of the river. The characteristics of the river and its contributing catchment are modeled using Model for Urban Stormwater Improvement Conceptualisation (MUSIC) in order to rehabilitate the river and enhance its Water Quality Index (WQI) to Class II. The historical rainfall data was obtained from DID for the period from 1974 to 2012. This paper presents the effects of various BMP Components on rehabilitating the water quality of the river. In addition, the minimum amount of river flow required for protection of the habitats and the river’s ecology has been assessed during the dry seasons. The outcomes of this study suggest the most appropriate Best Management Practices that can be used as solutions for the river’s rehabilitation. Simulations and modeling result found out that a configuration of wetlands, bio-retention systems and ponds are capable to reduce pollutants loadings such as TSS, TP and TN by 85.1%, 69.1% and 37.5% respectively.

1. Introduction
Langat River is one of the main rivers in the state of Selangor, and starts from Titiwangsa Range in Gunung Nuang and flows into the Strait of Malacca. It has a total length and catchment area of 180 km and 2350 km$^2$ respectively. The focused study area covers a stretch of 2 km of the river with its respective 20.6 km$^2$ catchment area, located at Taman Tasik Bangi 3. It is believed that unsustainable human activities in the catchment of the Langat River have resulted in degradation of the river’s water quality. Within the catchment there have been several mega projects in the catchment of Langat River, e.g. development of new federal government administrative capital, Putrajaya and the Kuala Lumpur International Airport, KLIA and other mega projects [1]. In addition, this river is not only used as main source of potable water but also is mean to serve other purposes, for example recreational, fishing and irrigation [2] and hence it is vital to have clean water at this river. It is however important to mention that the catchment of this river falls under the semi-residential urban area and due to presence of pollutants in the water of this river, it cannot be used for recreational purposes as well, which consequently impacts its tourism values.

Sg Langat is high in turbidity due to the fact that the river bank is unprotected which causes the erosion of the soil along the river bank. Exposed and unprotected soil along the river bank will be eroded laterally [3]. High turbidity causes a decline in fishery resources and has adverse effect on ecology and aquatic environment of the river. In addition it is said that the river’s water quality has deteriorated due to increase of socio-economic activities. It has been found that the previous practices...
of “end-of-pipe” solutions are not effective in treatment of stormwater and the current popularized practices of urban stormwater management focus on the source control. The sources of pollutions in the Langat River are 58% from industrial discharge, 28% from domestic sewage from treatment plants, 12% from construction projects and 2% from pig farming. The pollutants in Langat River are point source pollutants, such as manufacturing industries and sewage treatment plants and non-point source pollutants, such as runoff from livestock and pig farms, urban area, agricultural land and solid waste dumpsites. It was found that the typical pollutants of Langat River are organic matters, sediments, Ammonical-Nitrogen, Phosphate-Phosphorus, oil and grease, Phenol, Iron (Fe), Lead (Pb), Copper (Cu) and Cadmium (Cd). Therefore, this study is crucial to investigate balanced ecosystem low flow analysis in order to ensure that a minimum quantity of streamflow exists to protect habitat during a drought situation [3].

2. Study Area
The study area covers a length of 2 km with a respective 20.6 km2 catchment area, located at Taman Tasik Bangi 3, near Universiti Kebangsaan Malaysia, UKM. Figure 1 shows the location of the study area.

![Figure 1. Location of the study area](image)

3. Methodology
The raw data required for this study are collected from DID, and DOE and MPK Bangi. The raw data collected from DID were rainfall data of station 2917001 from 1974 to 2012, for various durations and river flow data for 1 hour and 1, 7 and 30 days were collected for primary analysis and generation of IDF curves, temporal patterns, flow duration curves and low flow analysis. The raw data collected from DOE were the water quality data for better understanding of the river’s quality characteristics. This study conducts hydrological analysis and Low flow analysis was also conducted to evaluate the river condition during dry season. The water quality and quantity simulations were carried out using MUSIC software. The simulation result will be used to formulate the best strategies of the up-scaling MSMA stormwater management ecohydrology.

4. Results and Discussion
This paper assesses the quantitative and qualitative behaviour of Langat River and its catchment in order to find solutions for rehabilitating the river. The hydrological analysis show the annual flows and mean annual floods for this river are 35 m3/s and 300 m3 /s respectively. The river’s quality current situation and condition was modelled by using MUSIC for qualitative analysis and assessment of effectiveness of various Best Management Practice components. Based on the land use map, the model was set up by dividing the catchment into three sub-catchments, three different Junctions (J1, J2 and J3) and one Receive Node were created for the model. The percentage reduction of each pollutant was simulated by MUSIC model under the two scenarios of with and without BMPs. The assessed
pollutants were TSS, TP and TN. Different trials with different components, sequences and sizes were introduced to find the best fitting solution in terms of pollution reduction. The BMP components proposed for this area are 2 wetlands, 2 bio-retention systems and 1 new pond as an additional to the available pond at the study area (see Figure 2). The runoff from the catchment is passed through these systems for filtration and removal of pollution. Table 1 shows the percentage reduction of the pollutants with the proposed BMPS components simulated by MUSIC model.

Table 1. Percentage reduction of the pollutants for three different Junctions used for simulation of Langat River under this study

| Junction | Parameter          | Unit  | Source | Residual Load | (%) Reduction |
|----------|--------------------|-------|--------|---------------|---------------|
| 1        | Flow               | (ML/yr) | 7210  | 6750          | 6.50          |
|          | Total Suspended Solids | (kg/yr) | 1060000 | 158000 | 85.10 |
|          | Total Phosphorus | (kg/yr) | 2440 | 755 | 69.10 |
|          | Total Nitrogen    | (kg/yr) | 18700 | 11700 | 37.50 |
|          | Gross Pollutant   | (kg/yr) | 174000 | 0 | 100.00 |
| 2        | Flow               | (ML/yr) | 7230  | 6760          | 6.40          |
|          | Total Suspended Solids | (kg/yr) | 1060000 | 160000 | 85.00 |
|          | Total Phosphorus | (kg/yr) | 2450 | 760 | 69.00 |
|          | Total Nitrogen    | (kg/yr) | 18700 | 11700 | 37.40 |
|          | Gross Pollutant   | (kg/yr) | 174000 | 0 | 100.00 |
| 3        | Flow               | (ML/yr) | 24200 | 23200 | 4.20 |
|          | Total Suspended Solids | (kg/yr) | 3680000 | 1110000 | 69.80 |
|          | Total Phosphorus | (kg/yr) | 8370 | 3730 | 55.40 |
|          | Total Nitrogen    | (kg/yr) | 63100 | 46700 | 25.90 |
|          | Gross Pollutant   | (kg/yr) | 572000 | 0 | 100.00 |

From the modelling result, the reduction of TSS and TP percentages have reached the MSMA targeted percentage while Total Nitrogen percentage is slightly below the target [10]. Figure 3 shows the hydrograph generated by MUSIC and the maximum runoff is 20 m$^3$/s and the minimum runoff is 0.2 m$^3$/s. This value 0.2 m$^3$/s (minimum runoff) is also adequate for the minimum flow required in the dry seasons.

![Figure 2. BMPs components in MUSIC model](image2.png)

![Figure 3. Daily Flow hydrograph generated by MUSIC](image3.png)

It is also important to ensure a healthy river which has the ability to rehabilitate itself and contain a balanced ecosystem. Therefore, a Low Flow Analysis was conducted in this study to ensure a minimum flow in the river to protect the habitats within the river ecosystem process. Gumbel and Log-Pearson method were used for generation of low flow curves and compared with the graphical
method. Based on Hydrological Procedure 12 (HP 12) the study area was categorized under Region RC3 and RE3. By comparing the outcome of Low Flow Curves in Figure 4, and Flow Duration Curves in Figure 5, it can be seen that the minimum flow required for the revival of the beneficial ecosystems present in the river is equivalent to 20 years return period. Result from Flow Duration Curve shows that for 100% dependable flow (100% of the time the flow equal or exceeded) the discharge value of 2 m$^3$/s. This value is well above the minimum required flow in the dry seasons for river water quality protection purposes.

**Figure 4.** Low Flow Analysis for Sungai Langat at Dengkil (HP 12 Method)

**Figure 5.** Daily Flow Duration Curve (FDC) at Dengkil Station

### 5. Conclusion

Langat River’s quality simulation was carried out by MUSIC and a number of BMP components were proposed. These components are two wetlands, two bio-retention systems and two ponds. The simulation results indicated that the Flow reduction values vary from 4.2% to 6.5%, TSS reduction ranges from 69.8% to 85.1%, TP reduction ranges from 55.4% to 69.1% and TN reduction ranges from 25.9% to 37.5%. Total Suspended Solid and Total Phosphorus percentage reduction have reached the MSMA targeted range while Total Nitrogen percentage is slightly below the target, due to the fact that Nitrogen removal is slightly difficult. The hydrological analysis shows annual flows and mean annual floods for this river are 35 m$^3$/s and 300 m$^3$/s respectively When assessing the reliability of low flow the Sg Langat river shows 100% dependable flow of 2 m$^3$/s more than the minimum required for environmental flow protection of the river.

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