IMPACT OF IMPROPER LANDUSE CHANGES ON FLASH FLOOD AND RIVER SYSTEM-A CASE OF SG PUSU

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ABSTRACT

The impact of landuses can cause significant changes in the hydrological regime of a river basin. Sg. Pusu is a recent example in Malaysia, which is going through indiscriminate changes in the landuses. This study was conducted in response to the recent severe flash flood occurred on 4th June, 2014 due to high rainfall intensity of 82.4 mm/hr which lasted about 2 hours. The flooding depth varied from 0.3 to 1.0 m and the flash flood duration was about 1.5 hours. Although the duration was short but it damaged 12 cars, inundated 2 blocks of the hostels (Mahallah) and caused inconvenience to the staff and students of the campus. The drainage and river systems of the campus was functioning properly as the seven ponds and lakes constructed along the rivers and tributaries could reduce the peak flows coming from the upstream areas. However, due to improper land clearing from 2009 and onwards, the peak flows during the rain events have increased significantly, the lakes and ponds constructed by IIUM has silted up and lost their flow reduction ability. As a result the flash flood incidents have increased compared to the past records. The development activities in the upstream areas not only have increased the severity of flood in the campus but also caused sediment related water pollution turning the Sg. Pusu and its tributaries muddy all the time. Due to the improper land clearing activities in the upstream areas, the runoff peak flow and sediment load has increased tremendously, which the existing lakes, ponds, rivers, culverts and drainage system are unable to cope with. The river is also badly affected by the improper land clearing activities at the upstream areas. The Turbidity and TSS values at the river outlet during the dry day and rainy days are recorded as 1640 NTU and 1290 mg/L and 2510 NTU and 2400 mg/L, respectively. The aesthetic appeal of the river is very repelling due to high turbidity and muddy appearance of the river. As such, proper integrated river basin management with necessary supports from the people and authorities are badly needed to rehabilitate Sg. Pusu which flows through the IIUM Gombak Campus.

Keywords: landuse, flood, river basin, sediments, water quality.

INTRODUCTION

Vital ecological assets and many other important services are provided by healthy rivers upon which human lives are much depended (Postel and Richter 2012). However, landuse and landcover within the river basin plays vital role on the status of the rivers. Healths of the rivers are affected by the landuse changes and activities in the river basin. Improper and indiscriminate landuse changes and uncontrolled activities may cause severe damage to the rivers. According to Ganoulis (2003); Jungwirth *et al*. (2002) past flood control techniques adopted by human being is failing to ensure promised flood control due to improper landuse policies, alteration of climate and encroachment of floodplain. Studies on watershed management are important to identify how water quantity and quality within the catchment and the river which receives the runoff is affected due to human development activities on the land (Silva and Williams 2001). Land use generally refers to the activities of human beings in connection with the use of land and these activities alter the land cover pattern (Veldkamp and

Fresco, 1996). In the present world, land use patterns are extremely dynamic and come into equilibrium state very rarely (Niehoff *et al*. 2002). It may have impact on a global scale by the summation of all the local scale alterations. Numerous numbers of researches have given the conclusion that river flow quantity and quality are significantly dependent on geomorphology of the catchment basin and also climatic conditions. The tropical arid and semi-arid areas undergo huge impact on its aquatic ecosystems (Tafangenyasha, and Dzinomwa 2005). Because of rapid urbanization, many parts of the Europe were inundated causing damages to human lives as well as properties (Brath *et al*. 2006). According to Costa *et al.* (2003), annual mean discharge of a basin can be increased by 24% due to the destruction of 30% of its forest land. The runoff produced by convective storms with high rainfall intensity is likely to be much affected by land use rather than the runoff out of advective storms with low rainfall intensity (Niehoff *et al*. 2002). But they continued that due to the complexity of the land use changes, determining the magnitude of the impact on the

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quantity of flood water discharging into the river network still remains highly unpredictable. However, although several methodologies have been devised by the scientists to predict the change in runoff dynamics due to the change in land use pattern, the credibility of these models and methods are not so much strong from scientific point of view (Kokkenen and Jakemen 2002). River waters are susceptible to pollution by their corresponding watershed and protection is really difficult as it requires efforts at a whole regional level (Elbag 2006). There are basically two sources of pollution of river water: (1) Point sources e.g. sewage treatment effluent and (2) Non-point sources e.g. storm runoff from agricultural and urban land areas (Silva and Williams 2001). Describing stream water quality in connection with non-point sources is really a difficult task in most of the cases as it involves high rate of uncertainty (Baker 2003; Ahearn *et al*. 2005). Sear *et al*. (2010) have discussed sediment management methods which can be used to improve water quality and enhance conveyance capacity of the river system.

There are a number of reasons for the flash flood in IIUM among which inadequate capacity of the existing river system to convey the high flow safely to the downstream areas; backwater flow due to constricted river sections; blockage of the drains and rivers by debris are among those directly related to the Pusu river. As a result, rehabilitation of the Pusu river is considered highly potential to protect the IIUM Gombak campus from flooding. In the recent past, the campus is not only affected by flash floods but also the river water quality has deteriorated badly due to uncontrolled sediment from the land clearing activities. The water of the river is always muddy with heavy sediments released from the catchments upstream of the campus areas. The amount of Suspended Solids (SS) is very much high in the river (Zainuddin *et al*. 2013). Also it is likely to happen that the components of the SS will cause siltation and thereby reducing the hydraulic capacity of the river or water body (Sturm 2001). The natural habitation of fish is hampered significantly due to excessive siltation and suspended solids disrupts the respiration of fish species by clogging their gills (Kramer 1987). Water quality acts as a limiting factor on which abundance and diversity of river ecology as well as how it can be used for recreational purposes depends (Paul and Meyer 2001). As such, the IIUM Gombak campus is not only hit by flash floods but also suffering from having a polluted river flowing through the heart of the campus giving bad impression to the local and international dignitaries and visitors. In urban areas, water quality of river is an issue of aesthetics and water quality improvement for river rehabilitation is paramount (Ellis 1996). In the past sediment management was addressed by river engineering, but now it is considered as a part of river rehabilitation (Wheaton 2005). Therefore, due to the very international status of IIUM, it is critical to mitigate the flash flood and river water pollution issues of the campus. As such, the main objective of this study was to investigate the causes of the recent flash flood at IIUM Gombak campus and causes of high turbidity and sediments in Sg. Pusu.

THE STUDY AREA

Location

The main campus of International Islamic University Malaysia is located at the District of Gombak, about 10 km towards the northeast of Kuala Lumpur. The campus is situated at the downstream part of Sg. Pusu and surrounded by hilly terrain. The university covers an area of 710 acres, which is about 2.8 km^2 (Hamsa and Azeez 2012).

Figure-1. IIUM Gombak campus (Source: Google earth).

Catchment description

The total catchment area of Sg. Pusu at the downstream boundary of IIUM Gombak campus is estimated to be about 12 km^2. The upper catchment is secondary forest with steep slopes. However, the middle portion of the catchment is undergoing huge land clearing activities. The IIUM Gombak campus is located at the downstream portion of Sg. Pusu, which is narrow and

shallow in nature. The Sg. Pusu meets Sg. Gombak at about 2.1 km downstream from the boundary of the campus.

The river system

The Pusu River system has a main stem and two other tributaries as shown in the Figure-2. The highest elevation at the upper catchment is about 428 m LSD and the average elevation at the downstream is about 85 m LSD. The main river (5.5 km) drains an area of 6.9 km^2, whereas the tributary Anak Sg. Pusu (3.2 km) and Batang Sg. Pusu (2.8 km) drains about 1.9 and 3.2 km^2 of catchment areas.

Data availability

The catchment features and properties are available from the topographical and landuse maps. Satellite image provided by Google Earth was also used for the study. There are 5 active rainfall stations available around the catchment. However, no rainfall station is located within the catchment. There is no stream gauging station or water quality monitoring station located within the river system.
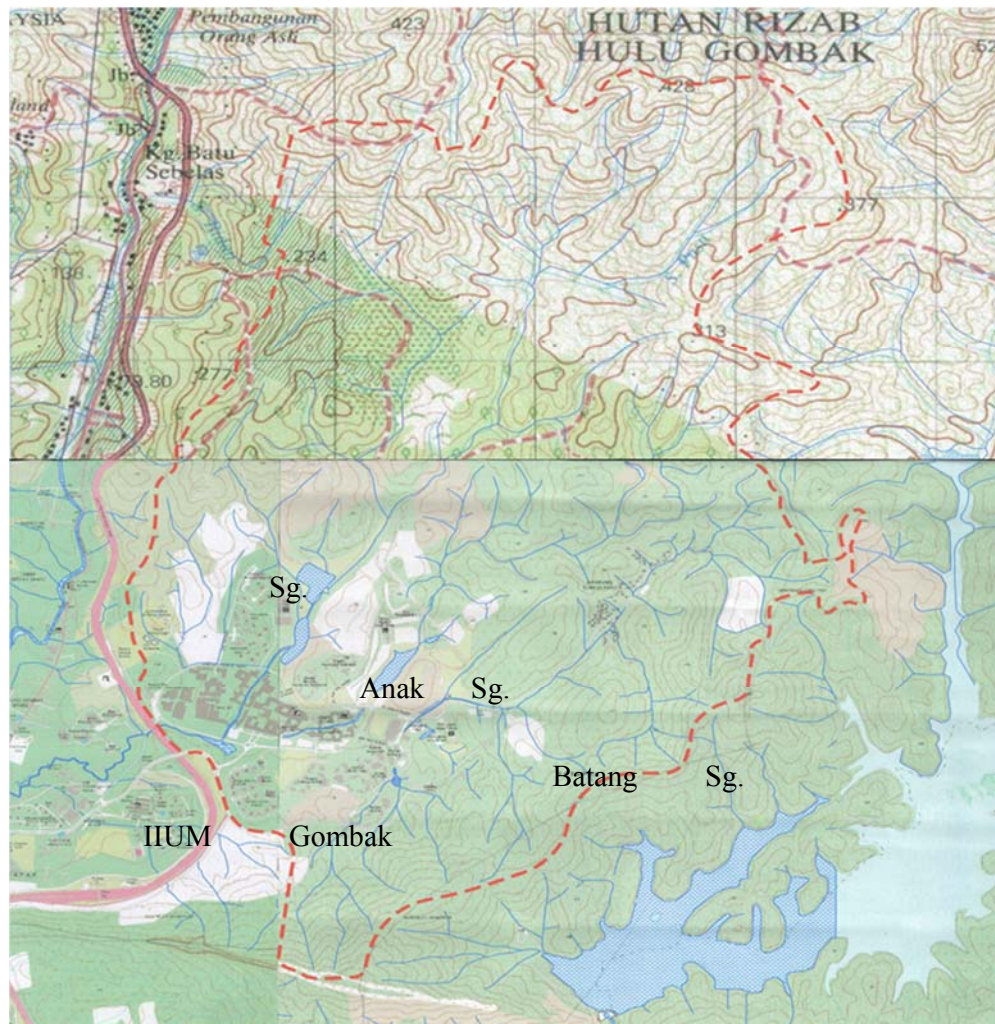
Figure-2. Topography and river system of Sg. Pusu catchment.

METHODOLOGY

Data collection

Relevant topographical data was collected from the Survey and Mapping Department of Malaysia. Printed map and digital terrain data was used for the relevant analyses. The rainfall data was collected from the Department of Irrigation and Drainage (DID), Malaysia.

The river water quality data was collected by grab sampling from the site.

Data analyses

The topographical information was gathered with the help of GIS and AutoCAD. The catchment boundaries were digitised by connecting the catchment divides. Rainfall data of 5-minute interval was collected from the DID and the rainfall intensity was calculated based on the

raw data. The intensity-duration-frequency values were calculated based on the equation given in new hydrological procedure HP-1, published by the DID Malaysia. The actual rainfall intensity was compared with the IDF values to determine the return period of the rainfall event that caused serious flood at IIUM Gombak Campus. As there are five rainfall stations, the mean IDF coefficients were calculated based on their individual coefficients and the mean values were used for the IDF.

Grab water samples were collected to evaluate the dry and rainy day water quality in the tributaries for selected important parameters. Dissolved oxygen (DO), total suspended solids (TSS), turbidity, chemical oxygen demand (COD) and ammoniacal nitrogen (AN) were tested for water quality status of the river. The samples were analysed in the field and laboratories as per the protocols accepted by standard methods (APHA 1998)

RESULTS AND DISCUSSIONS

Time of concentration
The estimated time of concentration for the whole catchment is about 1.1 hr. However, the peak flows from

the tributaries reaches the outlet of the IIUM Gombak campus at an early time within 40 to 55 minutes.

Hydrological analyses
As rainfall is the main driving force to cause storm runoff and flood, rain gauging stations surrounding the IIUM Gombak campus (Figure-3) were identified from the DID's website and the rainfall data of 4th June, 2014 was collected from DID's data bank for calculations and analyses purpose. Five automatic rain gauging stations (3217001 at Ibu Bekalan Km. 16 Gombak, 3217002 at Empangan Genting Klang, 3217003 at Ibu Bekalan Km. 11, Gombak, 3217003 at Kg.Kuala Seleh and 3217005 at Kg. Kerdas) are located around Sg. Pusu Catchment. There is no station located within the Campus or Sg. Pusu catchment itself. It was revealed that there was rainfall recorded at the stations highlighted yellow in Figure. Meaning that the rain occurred in Sg. Pusu and surrounding catchments but not at the downstream areas, as the station 3217300 was totally dry. The rainfall summary of 4th June, 2014 is given in Table-1. The rainfall related calculations and findings are reported in the following Sections.
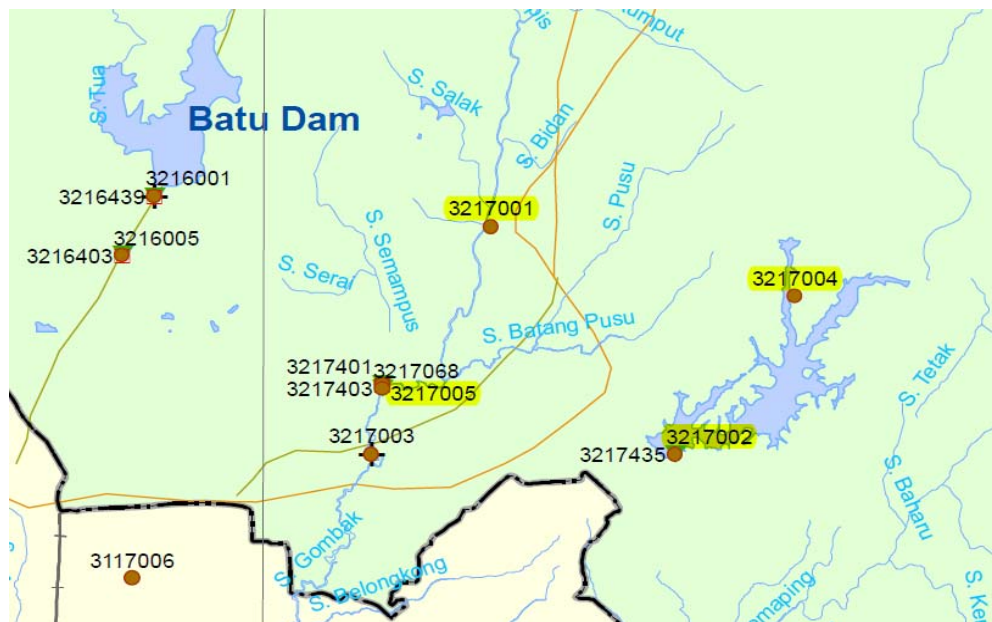
Figure-3. Locations of the rainfall stations near IIUM Gombak campus (Source: DID).

Table-1. Summary of the rainfall event on 4th June, 2014.

Stn. No.	Rain started	Rain ended	Rainfall duration (hr)	Total rainfall (mm)	Max hourly rainfall intensity (mm/hr)
3217001	2:05 PM	4:35 PM	2.50	89.6	83.3
3217002	2:10 PM	4:40 PM	2.50	99.5	87.3
3217003	No Rain	No Rain	Dry	No Rain	-
3217004	1:55 PM	4:25 PM	2.50	88.9	66.8
3217005	1:45 PM	3:40 PM	1.92	66.1	56.0

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I-D-F curves for Sg. Pusu catchment

The design rainfall intensity-duration-frequency (I-D-F) curves of various return periods (Figure) were calculated based on the revised Hydrological Procedure (HP) of DID, Malaysia. The I-D-F values were calculated based on the regression coefficients proposed for the five automatic rainfall stations around Sg. Pusu (Table-2). The coefficients of Table 2 was used to produce the I-D-F curves (Figure-4) to calculate the return period of the rainfall intensity occurred on 4th June, 2014.

Table-2. I-D-F coefficients for the design rainfall of Sg. Pusu Catchment.

Stn. No.	I-D-F coefficients			
	λ	κ	θ	η
3217001	66.328	0.144	0.230	0.859
3217002	70.200	0.165	0.290	0.854
3217003	62.609	0.152	0.221	0.804
3217004	61.516	0.139	0.183	0.837
3217005	63.241	0.162	0.137	0.856
Mean	64.779	0.152	0.212	0.842

Return period of 4th June rainfall event

Based on the rainfall recorded at the surrounding stations (Figure 3 and Table 1), the mean highest hourly rainfall on 4th June was 79.1 mm/hr. Compared to the I-D-F curves given in Figure the rainfall was equivalent to 11-year return period. This indicates that due to significant change in the upstream catchment landcover and hydrology rainfall intensity of small return period also can cause flood in the downstream areas of Sg. Pusu including the IIUM Campus.

Hydraulic assessment

The seven ponds constructed by the IIUM were effective in reducing the peak flow during the rainfall events. However, due to high sediments from the land clearing activities the ponds, including the rivers are silted up. Therefore, the flood attenuation capacity of the ponds has reduced tremendously. The conveyance capacities of the river sections are also reduced. Culverts at several places are partially blocked by sediments. Thus the actual hydraulic capacity of the conveyance and storage facilities are reduced drastically. The situation is so bad that desilting has become an annual necessity to avoid recurrence of flash floods in the campus. The maximum hydraulic capacity of Sg. Pusu at the boundary of the IIUM Gombak campus is calculated to be about 30 m^3/s. Any flow higher than that capacity will cause backwater effect and flash flood in the upstream of the outlet. As such, it is necessary to ensure that the ponds, weirs, culverts and other hydraulic structures function as designed.

Water pollution issues

In the recent years the Pusu River is not only being affected by high runoff quantity but more seriously affected by poor quality of water with high sediment contents. The main water quality issue of the recent years is the murky water due to high turbidity and sediments. Grab water samples were collected from various locations of the river system (Figure-2). Out of three main tributaries, the main stem of Sg. Pusu is mostly affected due to sand mining activities just outside the boundary of the IIUM campus. Though the sand mining is being done with license from the relevant authorities, the way the sands are cleaned are not proper. That is why the turbidity and TSS value of the water released from the silt traps of the sand cleaning process were increased from 36 NTU and 40 mg/L to 3410 NTU and 3020 mg/L, respectively (Table-3). Value of these parameters increased further during the rainy days due to discharge of more sediments with the increased stormwater runoff. The other parameters such as COD did not increased significantly during the rainy days, while the DO slightly increased and the ammoniacal nitrogen reduced due to the dilution effect. Water qualities of the two other tributaries were not as bad as that of the main stem of the river. However, the water quality trend during the dry and rainy days in the tributaries were similar. The high flow during rainy days caused high sediment, turbidity, DO and COD values but low concentration of ammoniacal nitrogen and pH due to the effect the storm runoff.
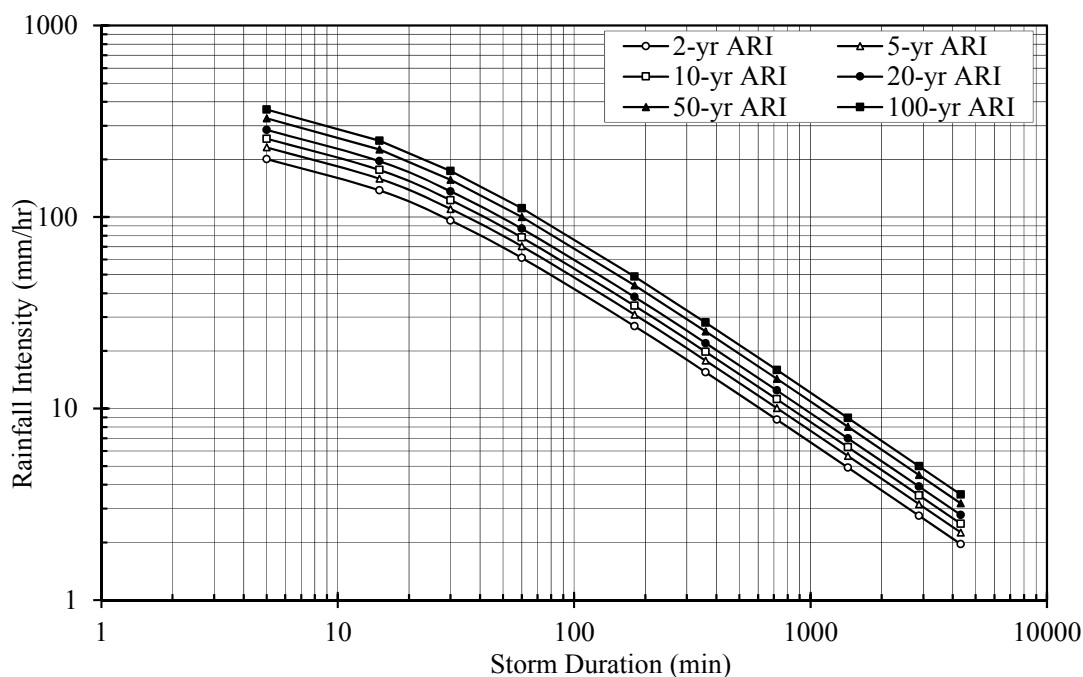
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Figure-4. Mean I-D-F curves for Sg. Pusu.

Table-3. Grab water quality data of Sg. Pusu.

ID	Flow (m3/s)		DO (mg/L)		pH		Turb (NTU)		TSS (mg/L)		COD (mg/L)		AN (mg/L)	
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
1	0.052	2.02	6.50	7.11	6.83	6.91	81	1470	80	1440	11	14	0.22	0.14
2	0.071	1.49	5.84	6.51	6.88	6.96	109	928	110	900	21	23	0.47	0.26
3	0.037	0.68	6.22	7.35	6.90	6.67	72	937	70	910	13	18	0.33	0.17
4	0.124	2.35	6.39	6.81	6.71	6.89	68	1040	60	1030	17	22	0.25	0.14
5	0.091	3.59	7.17	7.30	7.09	7.01	36	781	40	760	6	14	0.01	0.01
6	0.214	3.88	6.41	7.37	6.69	6.55	3410	4120	3020	4010	35	42	0.42	0.31
7	0.373	4.17	5.63	7.12	6.58	6.57	3060	3380	2400	3300	41	39	0.43	0.25
8	0.520	5.92	5.16	7.64	6.61	6.72	2070	2910	1910	2840	32	40	0.51	0.34
9	0.068	1.81	6.11	7.31	6.82	6.50	32	494	30	470	18	21	0.19	0.08
10	0.630	7.83	4.82	6.40	6.98	6.61	1640	2510	1290	2400	28	33	0.52	0.21

Actions taken by IIUM

Prompt actions were taken by the University Management to clear the campus of flood debris. The Star on-line news media praised the action taken by the university and reported on 7 June, 2014 that mess caused by the flood at the International Islamic University Malaysia's (IIUM) campus in Gombak has been cleared quickly. The IIUM also has taken initiative to remove the sediments from the lakes and ponds to regain the storage capacity of the facilities (Plate 1), which will help reduce the peak flow in the rivers passing through the campus. However, the lakes will be quickly filled up during the next heavy rainfall if the upstream developing areas do not have proper sediment traps as required by MSMA and other Authorities.

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Plate-1. Re-excavation of pond 5 at IIUM.

The IIUM has been trying its level best to resolve the Sg. Pusu related issues, as the muddy river was giving negative image to the visitors, let alone the students and staffs. Several meetings were held with the relevant authorities (DID, DOE, Majlis, Land Department, Forest Department, LUAS, etc.) to curb the sediment pollution released from the upstream land clearing activities.

CONCLUSIONS

Due to rapid changes in the catchment, hydrology and morphology of the Sg. Pusu has changed drastically. Removing sediments from the lakes and rivers will not improve the flood situation and river water quality issues of the campus. As such, one of the immediate actions to be taken is to conduct a thorough investigation to assess the hydrologic, hydraulic and morphologic behavior of the catchment and the river system flowing through the IIUM Gombak campus. The internal drainage system also need to be reassessed to check its adequacy under the new catchment response and adaptability to the climate change. Therefore, the flood management committee (which has necessary expertise to tackle flood issues) should be appointed as a consulting team to conduct hydrologic, hydraulic, drainage and river morphologic analyses to come up with alternative flood mitigation measures at IIUM Gombak campus. Detail survey need to be conducted to acquire the existing data on the catchment, drain, river and lake systems. Hydrologic and hydraulic models should be used to simulate various scenarios and to come up with the sustainable flood mitigation measures. It is also necessary to have effective dialogues with the law makers, community leaders and representatives of the land owners to find ways to minimize the negative impacts on the flow quantity and quality in the river system.

REFERENCES

Ahearn, D. S., Sheibley, R. W., Dahlgren, R. A., Anderson, M., Johnson, J., and Tate, K. W. 2005. "Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California." Journal of Hydrology 313(3): 234-247.

APHA. 1998. Standard Methods for the Examination of Water and Wastewater. 20th Ed., American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF), the USA.

Baker, A. 2003. Land use and water quality. Encyclopedia of Hydrological Sciences.

Brath, A., Montanari, A. and Moretti, G. 2006. Assessing the effect on flood frequency of land use change via hydrological simulation (with uncertainty). Journal of Hydrology. 324(1): 141-153.

Costa, M. H., Botta, A. and Cardille, J. A. 2003. Effects of large-scale changes in land cover on the discharge of the Tocantins River, Southeastern Amazonia. Journal of Hydrology, 283(1), 206-217.

Elbag Jr, M. A. 2006. Impact of Surrounding Land Uses on Surface Water Quality, Worcester Polytechnic Institute.

Ellis, J. 1996. Urban watercourses: Ecological sustainability and restoration, Natural Environmental Research Council, Swindon, UK.

Ganoulis, J. 2003. Risk‑based floodplain management: A case study from Greece. International Journal of River Basin Management 1(1): 41-47.

Hamsa, K. and A. Azeez. 2012. Analysing traffic elements in International Islamic University Malaysia by revealed preference approach."

Jungwirth, M., et al. 2002. Re‑establishing and assessing ecological integrity in riverine landscapes." Freshwater Biology. 47(4): 867-887.

Kokkonen, T. and A. Jakeman. 2002. Structural effects of landscape and land use on streamflow response." Environmental foresight and models: a manifesto: 303-321.

Kramer, D. L. 1987. Dissolved oxygen and fish behavior. Environmental Biology of Fishes 18(2): 81-92.

Niehoff, D., Fritsch, U. and Bronstert, A. 2002. "Land-use impacts on storm-runoff generation: scenarios of land-use change and simulation of hydrological response in a meso-scale catchment in SW-Germany. Journal of Hydrology 267(1): 80-93.

Paul, M. J. and J. L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics: 333-365.

Postel, S. and B. Richter. 2012. Rivers for life: managing water for people and nature, Island Press.

Sear, D. A., *et al*. 2010. Guidebook of applied fluvial geomorphology, Thomas Telford.

Sliva, L. and D. D. Williams. 2001. "Buffer zone versus whole catchment approaches to studying land use impact on river water quality. Water research 35(14): 3462-3472.

Tafangenyasha C. and T. Dzinomwa. 2005. Land-use impacts on river water quality in lowveld sand river systems in south-east Zimbabwe. Land Use and Water Resources Research 5: 3.1-3.10.

Sturm, T. W. 2010. Open channel hydraulics, McGraw-Hill Higher Education.

Tafangenyasha, C. and T. Dzinomwa. 2005. Land-use impacts on river water quality in lowveld sand river systems in south-east Zimbabwe. Land Use and Water Resources Research 5: 3.1-3.10.

Veldkamp, A. and L. Fresco. 1996. CLUE: a conceptual model to study the conversion of land use and its effects." Ecological modelling 85(2): 253-270.

Wheaton, J. M. 2005. Review of River Restoration Motives and Objectives. Unpublished Review, Southampton, UK 12.

Zainudin, Z., *et al*. 2013. "Pollution load management to improve water quality of Sg. Pusu.