International Journal of the Physical Sciences Vol. 6(21), pp. 4960-4976, 30 September, 2011
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS11.915
ISSN 1992 - 1950 ©2011 Academic Journals

Full Length Research Paper

Impact of land-use changes toward base-flow regime in Lui and Langat Dengkil sub-basin

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Accepted 5 August, 2011

Lui River and Langat-Dengkil River sub-basin are one of the large portions of Langat River catchment, known as the prime and important water source for Kuala Lumpur, Petaling Jaya, Shah Alam, Klang as well as domestic and industries usage in the Langat River basin itself. Unfortunately, the land-use change has greatly impacted the base-flow regimes particularly for the upstream area of Lui River sub-basin and downstream area of Langat-Dengkil River sub-basin. Base-flow separation method based on United Kingdom Institute of Hydrology (UKIH) smoothed minima method was adopted to estimate base-flow from daily stream-flow data. An index namely, base-flow index (BFI) is used to give the ratio of volume of base-flow (V_B) to the total stream-flow (V_A). The graph of yearly BFI time series has exhibited the unchanged or constant trends in Lui River sub-basin ranging from 0.3625 to 0.7184. In fact, downward trend in Langat-Dengkil River Sub-basin has vigorous fluctuation ranging from 0.2465 to 0.7356.The comparison of BFI in dry and wet period for both Lui and Langat-Dengkil River sub-basin was carried out for certain years (6 years for both cases for certain reasons) to identify the quantity of river's runoff derived from the stored sources particularly in dry period to sustain continuous flowing of water in the river. In order to analysis the low-flow regimes, technique 7-day 1-years (7Q1) was used for both Lui and Langat-Dengkil Sub-basin. The 7Q1 help to provide information of availability of water supply as well as robustness of the system particularly in drought period for both Sub-basins over the time.

Key words: Lui River, Langat-Dengkil River, base-flow separation, United Kingdom Institute of Hydrology, base-flow index, low-flow.

INTRODUCTION

The process of development and urbanization worldwide has shifted from rural to urban areas, and urban population growth has been uninterrupted and accelerating throughout the 20th century. By the year 2000, it is predicted that more than 50% (3200 million) of the world's population will have become urban dwellers, compared with less than 15% (only 200 million) at the turn of the century. That is the period from about ten years after a new century (Foster, 1990). The increase of urban population has led to further conversion of forest area (or increase rate of deforestation) to build house, car park, shopping centre, roads and so on. Arnell (2002) stated that the removal of forest cover from a watershed can result in significant hydrologic changes, including:

1. Decreased interception of rainfall by the tree canopy (net precipitation) where tree canopy can commonly intercept 10 to 20% of incoming precipitation,
2. Decreased evaporation,
3. Decreased rainfall interception by surface litter and
4. Increased runoff volumes (if 20 to 100% of the timber was removed corresponding to 5 to 30% increase of runoff yield).

In this context, a motivation for the hydrologists to study the hydrological components is raised (Othman and Naseri,

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Abbreviations: BF, Base-flow. **BFI,** base-flow index; V_B, volume of base-flow; V_A, volume of total flow; **ANN,** artificial neural network; **UKIH,** United Kingdom Institute of Hydrology; **Q,** stream-flow; **SW,** storm-flow; **DID,** Department of Irrigation and Drainage.

2011; Solaimani, 2011). Several researches have been developed for rainfall forecasting (El-Shafie et al., 2011a, b), rainfall-runoff modeling (El-Shafie et al., 2011c, d); and river inflow forecasting (El-Shafie and Noureldin, 2011). On the other hand, base-flow is considered as one of the important hydrological components. Several studies have been performed to estimate the values of this component (Citiroglu and Baysa, 2011).

Langat River Basin is one of the most important watersheds which supply water to two third of the state of Selangor including Kuala Lumpur, Petaling Jaya, Shah Alam, Klang as well as domestic and industries usage in the Langat River basin itself. The Langat Basin is chosen as one of the major areas for economic growth in Selangoras Kuala Lumpur International Airport, West Port at Klang, the Multimedia Super Corridor (MSC) and Putrajaya, all of which are situated in the Basin (Juahir et al., 2010). One of the factors that always relates to the incidence of disturbance on water supply is that decreasing of water resources results from the changes on land cover of water catchment and watershed, especially the exploitation of forest for non-agricultural purposes as well as urbanization (Othman, 2008). Hence, the research is conducted to study the relationship of the land-use change in the watershed area with changes of flow-rate in river as well as the availability of base-flow in the Lui and Langat-Dengkil sub-basin estimated from UKIH method.

As well known, stream-flow (Q) is composed of storm-flow (SW) or quick-flow and base-flow (BF). The former is mainly surface runoff and the latter is groundwater discharge to a stream. Stream-flow and the relative proportion of SW and BF in discharge vary with time and are affected by climate, mainly precipitation, and watershed characteristics, and by human activities, e.g. changes in land use (Zhang and Schilling, 2006). Storm-flow/quick-flow which represents the direct catchment response to rainfall events includes flow over the land surface (overland flow or runoff), rapid lateral movement in the soil profile (interflow) and direct precipitation onto the stream surface while base-flow is an important genetic component of stream-flow, which comes from groundwater storage or other delayed sources such as the shallow subsurface storage, lakes, melting glaciers and others (Smakthin, 2001).

Smakthin (2001) defined BFI as a non-dimensional ratio, referred to as the volume of base-flow divided by the volume of total stream flow, that is

$$BFI = \frac{V_B}{V_A} \quad (1)$$

where BFI is base-flow index, V_B is volume of base-flow, and V_A is volume of total flow.

In catchments with high groundwater contribution to stream-flow, BFI may be close to 1, but it is equal to zero for ephemeral streams. Ephemeral stream is a stream or part of a stream that flows only in direct response to precipitation; it receives little or no water from springs, melting snow, or other sources. In fact, ephemeral stream channel is at all times above the water table. BFI was found to be a good indicator of the effects of geology on low-flows and for that reason it is widely used in many regional low-flow studies (Smakhtin, 2001).

In this study, base-flow volume for both Lui and Langat River sub-basin are estimated via UKIH smooth minima separation method. Moreover, the extent in changes of base-flow regimes in base-flow index (BFI) and the 7-day 1 year low-flow as a result of land cover change in both Lui and Langat River sub-basin have also been assessed and evaluated. This research is significant because it studies in more details the land-use change towards the base-flow of groundwater in recharging river as water supply and it gives an overview of the availability of water resources supply for the current trends in the densely populated area of Langat Basin. Hence, this help in providing the information regarding sources of water particularly for water supply as well as the future water resource management so that water crisis does not occur especially in drought period.

METHODOLOGY

Prior to the determination of groundwater discharge rate represented by base-flow index (BFI), the base-flow separation entitled United Kingdom Institute of Hydrology (UKIH) method was adopted to separate base-flow from the total stream-flow hydrograph. The details relating to the study area and the method are described below.

Study area

Langat basin lies within the longitude of 101°17’ E to 101°55’E and latitudes of 2°40’ N to 3°17’N; there are four flow-rate gauging stations in the Langat River sub-basin located at Lui River (Kg Lui), Langat River-Kajang, Semenyih River-Rinching and Langat-Dengkil River (Figure 1). Langat River starts its flows from the main range (Banjaran Titiwangsa) at the east of Selangor State where the flow passes by four districts in Selangor State which include Hulu Langat District, Kuala Langat District, part of Sepang and Petaling District as well as some part of west region of Seremban in the State of Negeri Sembilan. The main tributary, Langat River flows about 182 km from the main range (Banjaran Titiwangsa) at the Northeast of Hulu Langat District in south-southwest direction, and drains into the Straits of Malacca. Langat River has 137 main tributaries such as Lui River, Semenyih River, Pongsun River, Reranang River, Labu River and Jenderam River.

For the purpose of the research, two sub-basins out of four in Langat River Basin were chosen: Lui River sub-basin and Langat-Dengkil River Sub-basin. As observed, the closely and densely river networks are located in the high land area of up-stream of Langat River and reduce gradually as they move downstream. The Dengkil Gauging Station is downstream of Langat River (02°51’20’’N, 101°40’55’’E). On the other hand, the Lui Gauging Station is upstream of Langat River (03°10’25’’N, 101°52’20’’E). For both stations, daily mean flow-rate in the unit of (m^3/s) was recorded. Table 1 depicted the details of the gauge station of the study area.

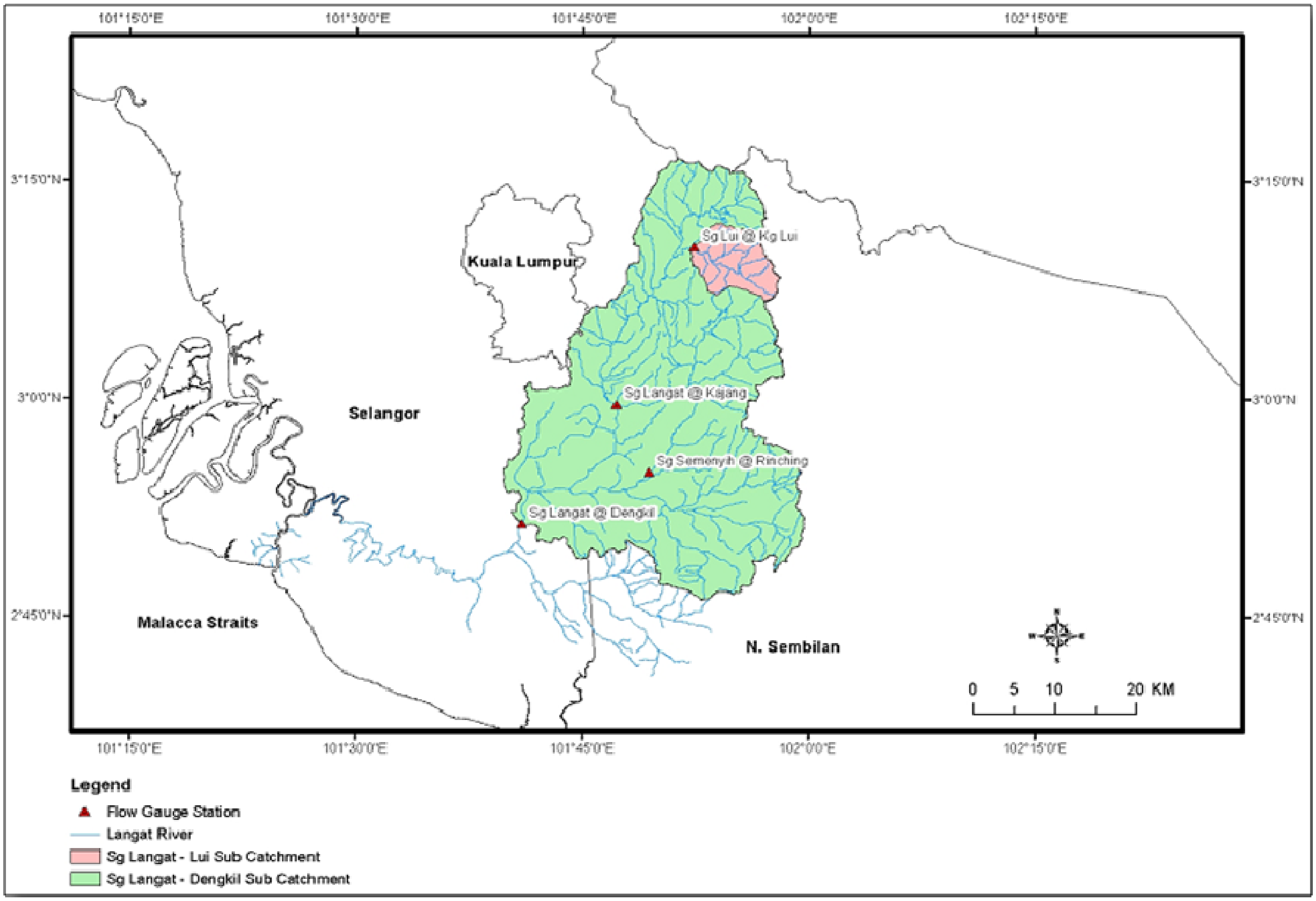

Figure 1. Study area of Lui and Langat-Dengkil sub-basin with gauging station.

Table 1. Gauging stations in Langat River Sub-basin.

Gauging station	Location coordinate		Area (km^2)	Duration
Station 3118445: Lui River	03°10'25''N	101°52'20''E	68.4	1972-2009
Station 2816441: Langat-Dengkil River	02°51'20''N	101°40'55''E	1,251.4	1965-2009

UKIH base-flow separation method

Base-flow (BF) is the main source of stream water during dry periods after the end of rain. As aforementioned, it is an important component of stream-flow, which comes from groundwater storage or other delayed sources such as the shallow subsurface storage, lakes, melting glaciers and others. So, BF is critical to the health of streams where continuous flowing of water is maintained. The UKIH base-flow separation is performed on the consecutive daily stream-flow time series data collected from Department of Irrigation and Drainage (DID) in the following procedure (Mazvimavi et al., 2004; Aksoy et al., 2009):

1. Divide the daily flow data into non-overlapping blocks of five days.
2. Mark and calculate the minima for each of these blocks, and let them be called q_1, q_2, q_3, q_t. where t = 1, n. If n is not a multiple of 5, then the final q_n can be ignored in the base-flow separation calculation.
3. For each block, the minimum daily flow is identified, and this forms the Q_1, Q_2, Q_3, Q_m series of minima.
4. Turning points among the Q_t are identified such that when the flow value is multiplied by 0.9 it is smaller than both neighbours, that is, Q_t is a turning point if $0.9Q_t < Q_{t-1}$ and $0.9Q_t < Q_{t+1}$ or $0.9Q_t <$ min (Q_{t-1}, Q_{t+1}). The multiplication factor, 0.9 has no physical meaning and is obtained after manual base-flow separation in the UK (Institute of Hydrology, 1980).
5. The turning points become base flow ordinates, and base flow values between turning points are linearly interpolated in time under the condition that the base-flow cannot exceed the total daily flow,

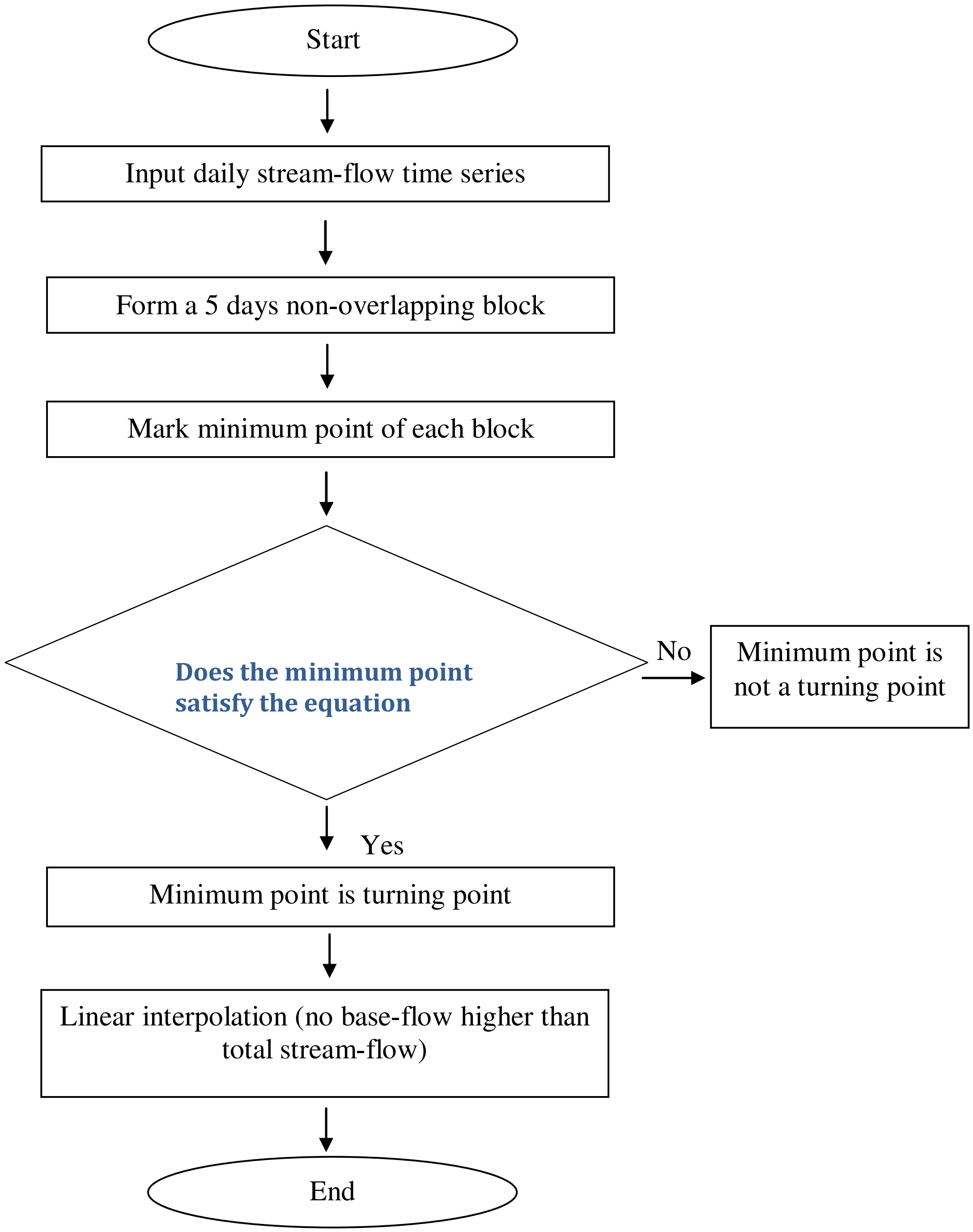

Figure 2. Flowchart of UKIH base-flow separation.

since base flow is part of the daily flow.

Determination of base-flow index (BFI)

The method of UKIH base-flow separation was done on each hydrograph throughout each year data for upstream area of Lui River sub-basin over 35 years from 1972 to 2009 (exclude 1996 and 1997 as it is identified as outlier), while for downstream of Langat-Dengkil sub-basin it was over 44 years, from 1965 to 2009 based on the procedure in Figure 2. Then, the volume of base-flow, V_B can be estimated and approximated by calculating area under the graph via the trapezium area formula:

$$V_B = \text{Trapezium} = \tfrac{1}{2}\,(a+b) \times h \qquad (2)$$

where a is turning point 1, Q_1 (m^3/s); b is turning point 2, Q_2 (m^3/s); and h is the time in day between the two turning points.

The volume of total flow/stream-flow, V_A can be simply calculated from the data collected from DID. Then, the BFI can be determined by a non-dimensional ratio whereby the volume of base-flow is divided by the volume of total stream flow (Equation 1). The BFI of each year of both upstream and downstream areas of Langat River sub-basin can be determined. As well known, the base-flow separation cannot start on the first day of the record, and similarly cannot finish on the last day. The start and end dates of the base-flow hydrograph must therefore be used in calculating the volume of flow beneath the base-flow hydrograph. For the same reason, BFI is sensitive to missing data as only one day may result in several days of data omitted from the base-flow separation. Interpolation can be used to fill in missing periods, providing these are short durations (Tallaksen and Van Lanen, 2004). The base flow index is used in this paper as a quantitative measure for base-flows by mathematical approximation.

RESULTS AND DISCUSSION

The base-flow index (BFI) in the study area of both upstream (Lui River Sub-basin) and downstream (Langat-dengkil sub-basin) area is focused on here. The BFI gives the ratio of volume of base-flow divided by the total stream-flow. The volume of base-flow is estimated by UKIH smooth minimal method from daily stream-flow data. Long-term base-flow responses of a catchment (Lui and Langat-Dengkil River Sub-basin) particularly in land-use and land cover (LULC) changes is studied via graph plotting of yearly BFI time series. BFI is a number between zero and one; increasing values indicate an increasing ratio of base-flow to total stream-flow by delayed sources such as the surface water storage, shallow subsurface storage, connected lakes, wetlands and groundwater storage (Arnell, 2002). The comparison of BFI in dry and wet period for both Lui and Langat-Dengkil River sub-basin is carried out as well for certain year (6 year for both cases) to identify the quantity of river's runoff derived from the stored sources particularly in dry period to sustain continuous flowing of water in the river. The separation and arrangement of each dry and wet period in Lui and Langat-Dengkil River sub-basin is drawn and classified in each of the graph. Subsequently, the analyses of the low-flow regimes by the technique of 7-day 1-years (7Q1) will be discussed. The 7Q1 helps to provide information of the trend of low flow in Lui and Langat-Dengkil sub-basin over the time and the identification of an extreme value of 1-day average flow that occurs (on average) once a year throughout the time of the study.

Base-flow index (BFI) for Lui River Sub-basin

The base-flow index (BFI) of Lui River sub-basin, from 1972 to 2007 of 35 years of study (excluding 1996 and 1997), is illustrated in Table 2. The BFI of Lui River sub-basin is observed ranging from 0.3625 to 0.7184. Average base-flow volume of 23,574,197 m^3 is estimated while 41,034,912 m^3 of total flow volume is recorded. There are 1681 missing data or equivalent to 13.15% of total recorded data set for 35 years because the flow-rate gauging station is faulty or broken down. The volume of base-flow, V_B is obtained based on the UKIH base-flow separation method and trapezium approximation.

As noted from Table 2, the average Lui River Sub-basin's BFI is 0.5616 of the total of 1 where high groundwater contribution to stream-flow occurs. This implies that 56.16% of water in the river is contributed by groundwater storage and/or shallow subsurface storages while the other 43.84% of river flow is made of quick-flow or storm-flow from rainfall events. This quantity of base-flow volume is important to maintain background level of a river, as well as the health of the river where continuous flowing of water in the river can be assured for the reason of water supply.

A graph of BFI versus time is plotted from the year 1972 to 2009 in order to visualize the long-term base-flow response of a catchment in Lui River sub-basin as depicted in Figure 3. The BFI trend of the Lui River sub-basin has almost no changes or is constant through time with the line gradient of just merely 0.0001 or almost negligible. The statistical analysis has shown that the coefficient of determination (R^2) is 0.0001, coefficient of correlation (R) is 0.01 (little if any correlation), the standard deviation of annual BFI for the whole period is 0.09 which approximates to the stable range of BFI (0.04) recommended by UKIH (1980). The analysis is not significant at 0.05 level of significance. The insignificant result may be due to the numerous missing data, especially the data of 1996 and 1997 which cannot be used as a result of it been identified as outlier.

The BFI of Lui River sub-basin, remaining in the constant trends, has a very close relationship with the land-use and land cover (LULC) changes. The land-use status in Lui River sub-basin for the year 1990, 2001 and 2009 is shown in Table 3 with 6,880.23 ha of the total size of the sub-catchment. Types of LULC have been classified into eight categories which include forest, mangrove, oil palm, agriculture, grassland, bare land, urban and water bodies. The forest LULC remained as the dominant in the Lui River sub-basin with the value of 4,671.90 ha in the year 1990; it decreased to 4208.42 ha in the year 2009 which is always more than 60% of overall land cover. Hence, the originality of the land status remains as in the past, which in turn leads to the constant BFI.

As noted, agriculture constituted the second largest of the LULC in Lui River sub-basin with the value of 2,201.94 ha in the year 1990; it increased to 2,420.46 ha in the year 2001 and to 2,480.36 ha in the year 2001. Other land-uses such as mangrove, oil palm, bare land and water bodies emerged and were developed in the year 2009. The four stated land-uses represent a very small area in Lui sub-basin which is approximately 46.85 ha or 0.68%. In addition, urban development shows an increasing trend, but it was very slow in the year 1990,

Table 2. Base-flow Index for Lui River Sub-basin.

Year	Volume of base-flow, V_B (m^3)	Volume of total flow, V_A (m^3)	BFI	Missing data
1972	14,271,682	26,880,768	0.5309	88
1973	29,725,704	41,377,824	0.7184	0
1974	17,287,992	31,923,936	0.5415	45
1975	12,630,168	28,918,080	0.4368	119
1976	7,583,544	20,920,896	0.3625	85
1977	9,220,392	24,666,336	0.3738	18
1978	19,659,672	36,229,248	0.5426	0
1979	19,933,776	38,029,824	0.5242	0
1980	23,744,016	42,608,160	0.5573	0
1981	32,556,168	51,557,472	0.6315	0
1982	34,329,096	53,520,480	0.6414	8
1983	23,001,408	34,554,816	0.6656	48
1984	37,099,296	61,617,888	0.6021	24
1985	35,944,560	56,504,736	0.6361	0
1986	33,471,792	59,205,600	0.5653	79
1987	41,310,000	60,396,192	0.6840	0
1988	33,852,816	52,166,592	0.6489	0
1989	16,062,883	23,428,224	0.6856	38
1990	18,798,480	32,867,424	0.5719	110
1991	33,376,536	57,885,408	0.5766	6
1992	20,698,546	39,329,280	0.5263	37
1993	29,733,091	50,645,952	0.5871	13
1994	31,429,814	48,596,544	0.6467	11
1995	24,035,616	38,657,088	0.6218	93
1998	8,876,304	23,290,848	0.3811	206
1999	8,421,408	15,743,808	0.5349	125
2000	34,255,224	60,859,296	0.5629	31
2001	8,606,088	18,885,312	0.4557	21
2002	28,384,344	49,746,528	0.5706	41
2003	18,263,880	34,275,744	0.5329	121
2004	30,174,768	52,838,784	0.5711	137
2005	4,743,360	8,260,704	0.5742	106
2006	13,634,050	28,562,976	0.4773	44
2007	33,301,886	46,621,440	0.7143	11
2008	28,123,848	65,320,128	0.4306	0
2009	32,128,877	60,362,496	0.5323	16
Average	23,574,197	41,034,912	0.5616	

where there was only 5.22 ha; and it continued to increase to 109.44 ha in the year 2001 and 146.53 ha in the year 2009 which is less than 3% of overall land cover. But this rapid urbanization by conversion of permeable land surface to impermeable through the construction of rooftops, sidewalks, driveways, roads-covered by impenetrable materials such as concrete, blacktop, and mortared brick or stone has been accompanied by localized dramatic hydrologic changes. To have better illustration and visualization of LULC, Figure 4 shows the changes in the years 1990, 2001 and 2009 respectively in Lui River sub-basin as well as the changes of land-use in Lui River sub-basin in 1990 and 2009.

Base-flow Index (BFI) for Langat-Dengkil River sub-basin

The Base-flow Index (BFI) of Langat–Dengkil River sub-basin is illustrated in Table 4. According to the 44 years study from 1965 to 2009 in the Langat–Dengkil River sub-basin, the fluctuation of BFI is observed ranging from 0.2465 to 0.7356 with the range of 0.4891. Average base-flow volume of 428,892,875 m^3 is estimated while

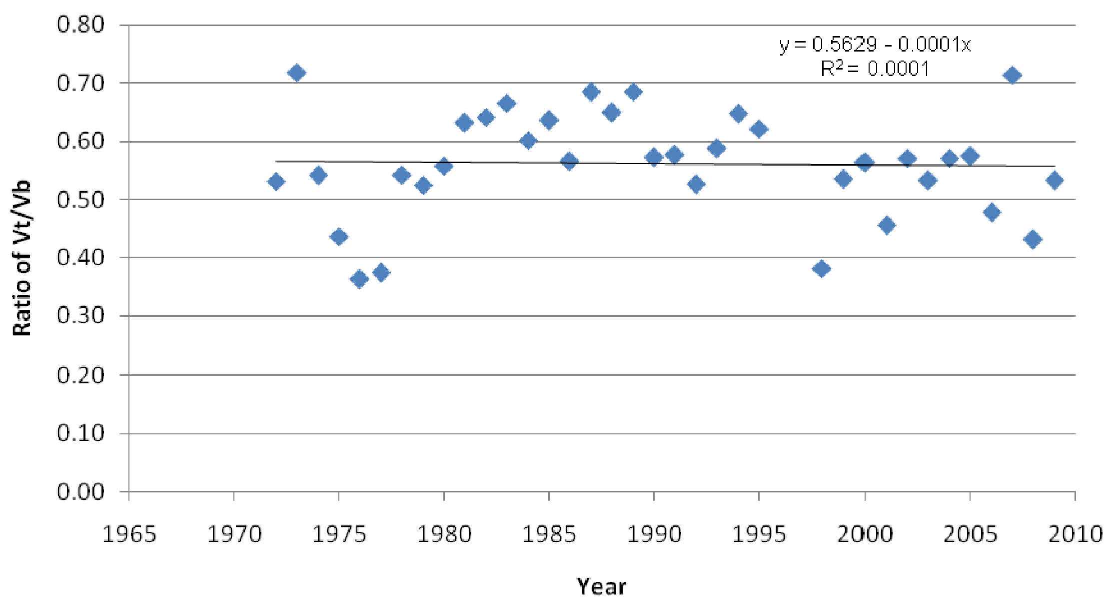

Figure 3. BFI for Lui River sub-basin for the year 1972 to 2009.

Table 3. Land-use status in Lui River Sub-basin for year 1990, 2001 and 2009.

Land use	1990		2001		2009	
	Hectare	Percentage	Hectare	Percentage	Hectare	Percentage
Forest	4,671.90	67.90	4,349.16	63.21	4208.42	61.12
Mangrove	-		-		0.16	0.002
Oil palm	-		-		2.69	0.039
Agriculture	2,201.94	32.00	2,420.46	35.18	2480.36	36.02
Grassland	1.17	0.02	1.17	0.02	3.35	0.049
Bareland	-		-		43.14	0.627
Urban	5.22	0.08	109.44	1.59	146.53	2.128
Water bodies	-		-		0.86	0.012

Source: EOC, UKM (2011).

857,470,560 m^3 of total flow volume is recorded. There are 2696 missing data equivalent to 16.78% of total recorded data set for the 44 years period of time because of the fault or break down of flow-rate gauging station. The consequences of the missing data will likely and highly affect the amount of base-flow volume due to the changes in the location of turning point when plotting graphs.

As noted in Table 4, the average BFI for the Langat–Dengkil River Sub-basin is 0.5005 which is half of the total of 1 (high groundwater contribution to stream-flow). This implies that 50.05% of water in the river is contributed by groundwater storage and/or shallow subsurface storages while the other 49.95% of river flow is made of quick-flow or storm-flow from rainfall events including flow over the land surface (overland flow or runoff), rapid lateral movement in the soil profile (interflow) and direct precipitation onto the stream surface. This quantity of base-flow volume is important to maintain background level of a river, generally by seepage from groundwater storage or known as ground-water recharge. Recharge is sometimes referred to as groundwater runoff in which water infiltrates the soils and then soaks into aquifer system by natural methods. Also, recharge can be defined as groundwater discharge because it discharges base-flow to the streams. This infiltration does not include very shallow waters that drain from the soil into ditches to feed streams immediately after a rain event. In fact, water draining only from saturated soils and bedrock, long after a rainfall which feeds the stream system is only referred as base-flow (Debarry, 2004).

A long-term base-flow response of a catchment (Langat-Dengkil River Sub-basin) was studied thoroughly

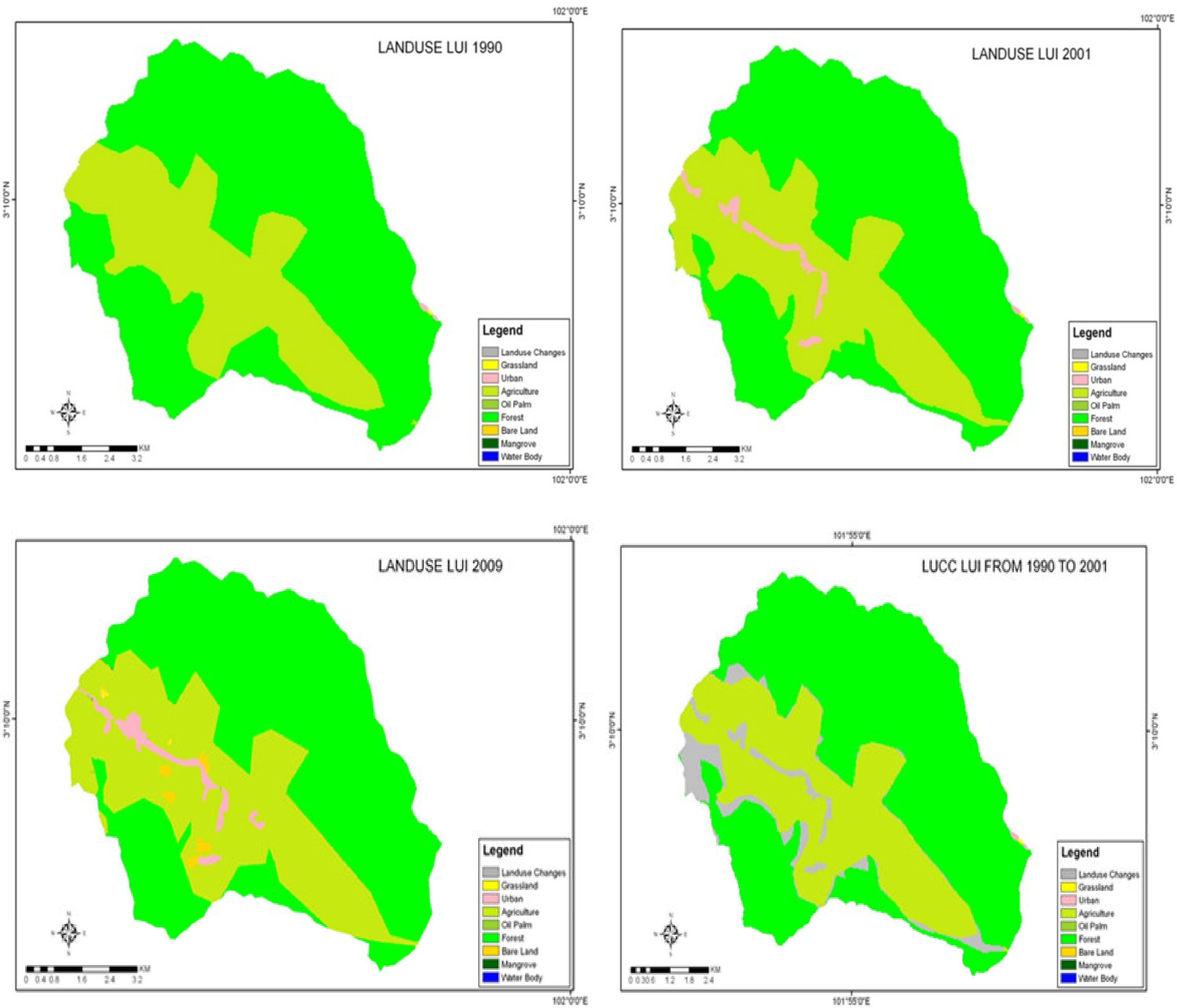

Figure 4. Land-use and land cover changes in Lui River sub-basin from 1990 to 2009. Source: EOC, UKM (2011).

from 1965 to 2009 where the graph of yearly BFI time series is plotted as depicted in Figure 5. It is noted that the BFI of the Langat-Dengkil River sub-basin shows the downward trend through time. The BFI line is very steep and the gradient is much larger (0.0051) if compared to the Lui River sub-basin which is only 0.0001 or about 5000% in difference. In addition, the result of simple regression shows that the coefficient of determination (R^2) is 0.2461, coefficient of correlation (R) is 0.50 (moderate correlation), the standard deviation of annual BFI for the whole period is 0.14 which is near the stable range of BFI (0.04) recommended by UKIH (1980); and the analysis is significant (δ=0.0005) at 0.05 level of significance.

Based on the decreasing trend of BFI, it is expected to fall in the near future due to unending and rapid urbanization and the land-use and land cover (LULC) changes in the catchment by the increases of impervious surfaces such as roofs and roads, compaction of soils, modifications of vegetation and so on. As aforementioned, land-use is classified in the same way with the classification of Lui River sub-basin which comprises

Table 4. Base-flow index for Langat–Dengkil River Sub-basin.

Year	Volume of base-flow, V_B (m^3)	Volume of total flow, V_A (m^3)	BFI	Missing data
1965	728,850,312	1,114,368,192	0.6540	0
1966	718,368,264	1,168,772,544	0.6146	0
1967	867,581,928	1,283,770,944	0.6758	0
1968	575,637,840	938,988,288	0.6130	0
1969	555,538,824	871,065,792	0.6378	62
1970	214,098,552	415,742,112	0.5150	87
1971	51,644,304	112,279,392	0.4600	271
1972	338,047,992	638,270,496	0.5296	27
1973	500,653,872	797,586,048	0.6277	20
1974	437,965,704	1,055,883,168	0.4148	13
1975	340,093,080	923,692,896	0.3682	98
1976	737,637,192	1,141,452,000	0.6462	54
1977	374,461,056	510,035,616	0.7342	87
1978	493,544,664	670,959,936	0.7356	34
1979	556,588,584	895,982,688	0.6212	0
1980	494,846,366	763,048,512	0.6485	14
1981	600,189,782	926,970,912	0.6475	0
1982	439,367,328	727,909,632	0.6036	162
1983	430,318,008	819,649,152	0.5250	0
1984	703,856,304	1,298,600,640	0.5420	15
1985	434,725,056	861,312,960	0.5047	16
1986	462,347,352	820,471,680	0.5635	35
1987	400,461,667	826,418,592	0.4846	6
1988	247,753,080	741,030,336	0.3343	100
1989	414,993,456	995,033,376	0.4171	119
1990	206,406,144	403,645,248	0.5114	102
1991	200,738,995	765,644,832	0.2622	170
1992	169,122,168	600,577,632	0.2816	124
1993	206,859,096	777,146,400	0.2662	53
1994	152,314,344	551,976,768	0.2759	98
1995	195,891,048	794,727,936	0.2465	72
1996	313,876,296	909,456,768	0.3451	17
1997	687,308,976	1,191,719,520	0.5767	55
1998	448,018,128	725,801,472	0.6173	85
1999	268,100,928	625,859,136	0.4284	240
2000	582,493,550	1,025,744,256	0.5679	113
2001	124,921,440	211,264,416	0.5913	209
2002	351,348,451	693,004,896	0.5070	11
2003	334,931,760	631,283,328	0.5306	102
2004	384,838,517	1,448,112,384	0.2658	23
2005	246,965,760	696,922,272	0.3544	0
2006	626,866,906	1,449,251,136	0.4325	0
2007	582,443,784	1,385,256,384	0.4205	0
2008	513,667,008	1,133,859,168	0.4530	0
2009	576,243,979	1,245,625,344	0.4626	2
Average	428,892,875	857,470,560	0.5005	

forest, mangrove, oil palm, agriculture, grassland, bare land, urban and water bodies with total sub-catchment size of 125,145.18 ha (Table 5).

The land-use for agriculture remain as dominant in the Langat-Dengkil River sub-basin with the value of 59,150.34 ha (47.27%) in year 1990 decrease to

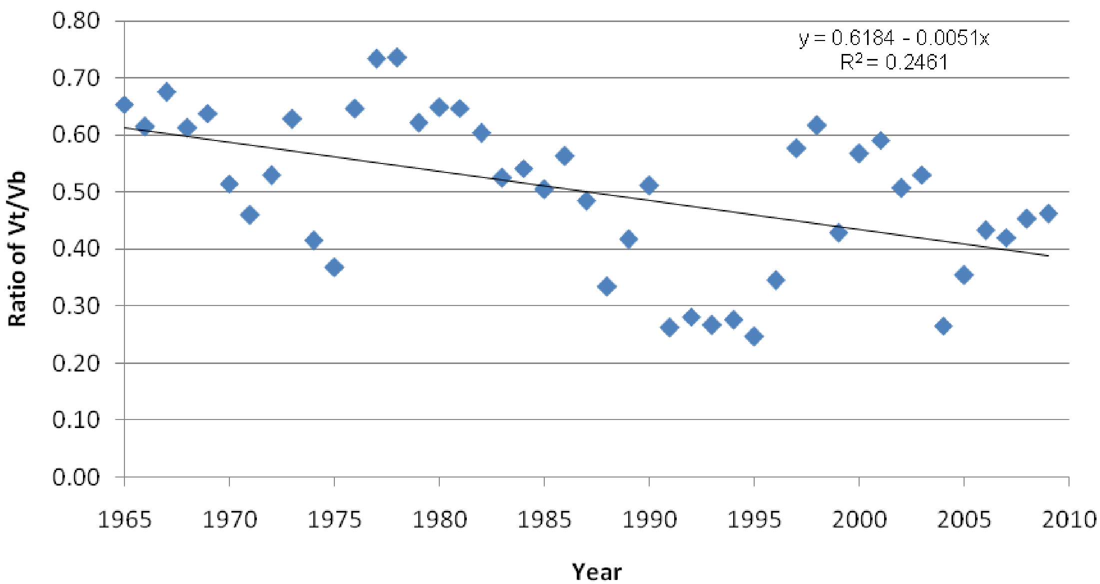

Figure 5. BFI for Langat-Dengkil River sub-basin for the year 1965 to 2009.

Table 5. Land-use status in Langat-Dengkil River sub-basin for year 1990, 2001 and 2009.

Land use	1990		2001		2009	
	Hectare	Percentage	Hectare	Percentage	Hectare	Percentage
Forest	45,389.16	36.27	41,100.75	32.84	39,866.48	32.16
Mangrove	15.84	0.01	1.62	0.00	64.94	0.05
Oil palm	8,025.03	6.41	7,635.87	6.10	1,317.85	1.06
Agriculture	59,150.34	47.27	47,941.29	38.31	46,636.59	37.62
Grassland	2,620.08	2.09	1,985.22	1.59	1,456.72	1.18
Bareland	5,287.86	4.23	3013.11	2.41	2,218.24	1.79
Urban	3,374.55	2.70	22,234.77	17.77	30,722.41	24.78
Water bodies	1,282.32	1.02	1232.55	0.98	1,691.01	1.36

Source: EOC, UKM (2011).

47,941.29 ha (38.37%) in the year of 2001 and further reduced to 46,636.59 ha (37.62%) in year 2009. The amount of total area reduction is same as that of the second larger type of land cover, that is, the forest. Since 1990, about 5,522.68 ha (4.41%) of forest have been cut down until now for the purpose of development from 45,389.16 ha in year 1990 to 39,866.48 ha in year 2009. The urban development shows a rapidly increasing trend, where in year 1990 there is only 3,374.55 ha (2.70%) and it continue to increase to 30,722.41 ha (24.78%) in year 2009. In the time period of 19 years, there has been 22.08% conversion of land cover into urban. It is expected to increase due to the increase of the population in Langat-Dengkil Sub-basin. The lowest and second lowest of land-use in Langat-Dengkil River sub-basin (<2% coverage) is both mangrove and water bodies. Water bodies includes mining sites, quarries, pits, excavation sites, lake, dams and water recreation centre.

Figure 6 shows the changes in year 1990, 2001 and 2009 respectively in Langat-Dengkil River sub-basin as well as the changes of land-use from 1990 and 2009 in Langat-Dengkil River sub-basin. The conversion of agricultural, forest, grass, and wetlands to urban areas usually comes with a vast increase in impervious surface, which shift away from infiltration reduces groundwater recharge, lowering water tables. This both threatens water supplies and reduces the groundwater contribution to stream-flow, which can increase in the volume and rate of surface runoff and decreases in ground water recharge and base-flow or dry stream beds during periods of low flow (Tang et al., 2005). Therefore, base-flow is critical in determine the healthiness of streams where continuous flowing of water in the river is required to maintain particularly for water supply.

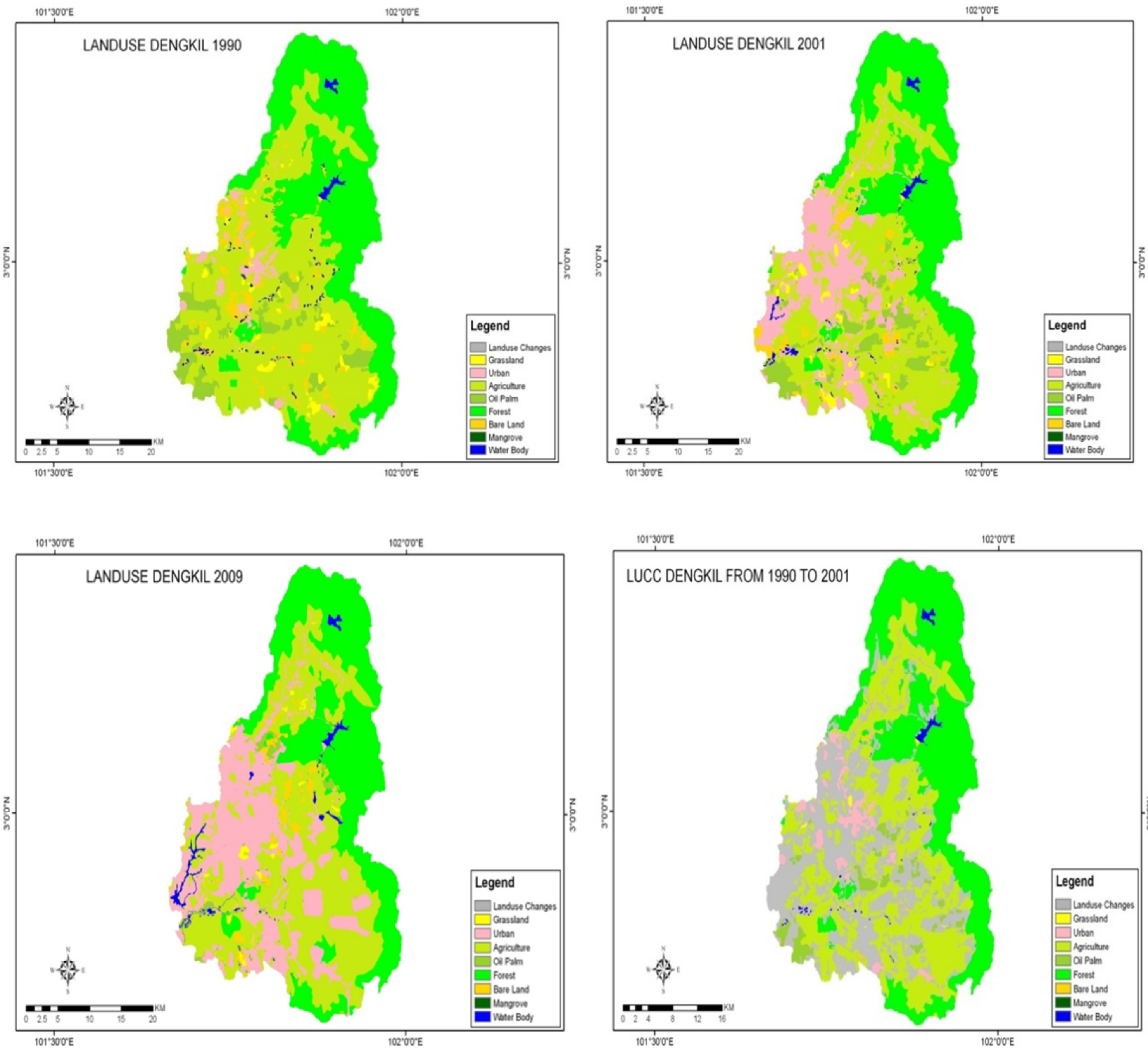

Figure 6. Land-use and land cover changes in Langat-Dengkil River sub-basin from 1990 to 2009. Source: EOC, UKM (2011).

Lui River Sub-basin dry and wet period analysis

For the analysis of dry and wet period in Lui River Sub-basin, selected six years data is used in the analysis which is year 1973, 1981, 1988, 1991, 2008 and 2009 out of 35 years of study. The main reasons these data sets are chosen because (i) there is no missing data (if there is, it is less than 20), (ii) the day of drought and wet can be identified and determined easily, (iii) sufficient quantity of turning points particularly for very short period of drought or wet day and (iv) analysis of BFI during the dry and wet period for certain period of time such as every 5 years,10 years or even longer depends on the availability and completeness of data sets. From the observation in Figure 7, most of the year (1973, 1981, 1991 and 2009) has two times of dry and wet period in the analysis, only the year of 1988 and 2008 has only one dry and wet period. This is mainly due to there is no another obvious

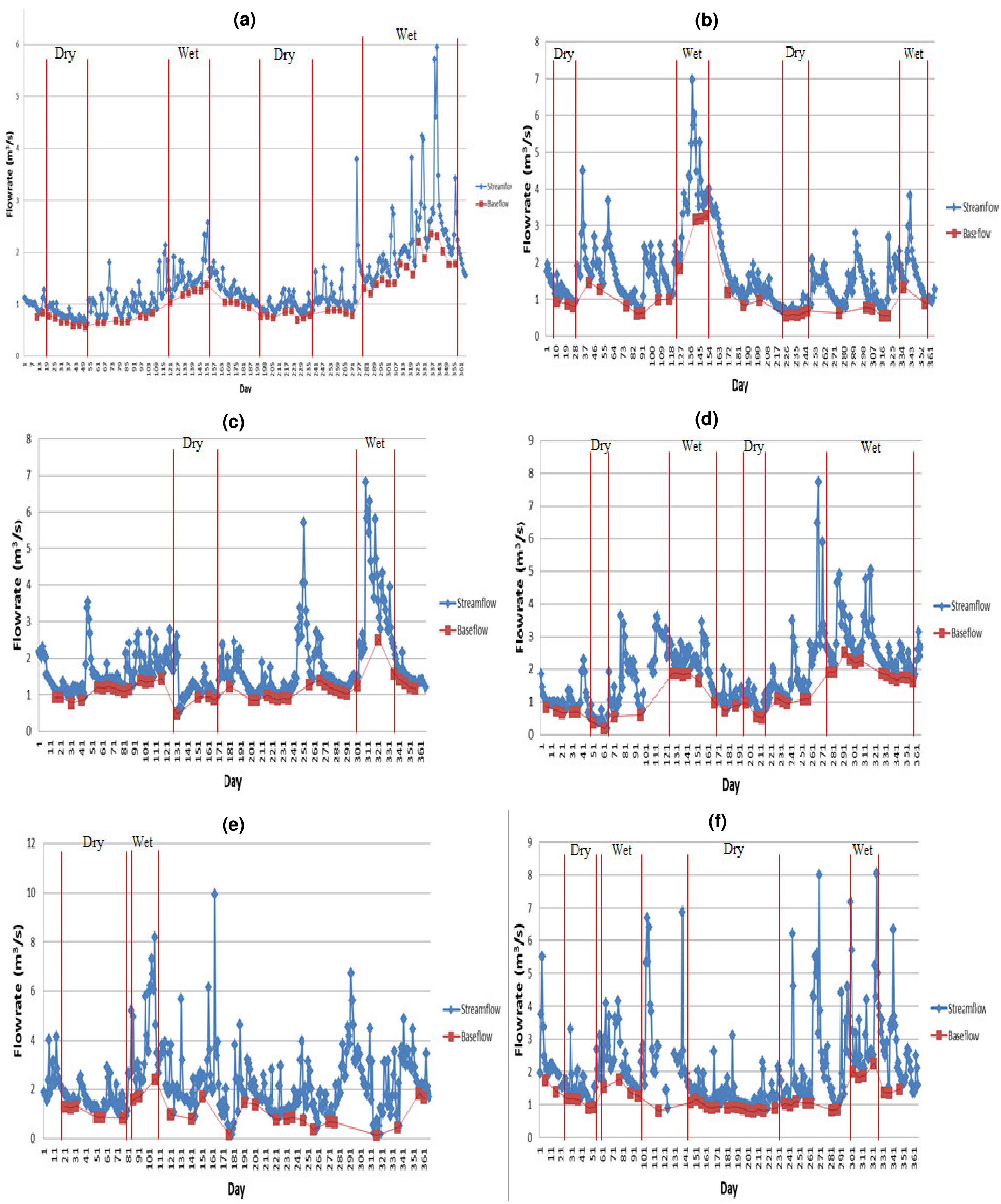

Figure 7. Dry and wet period for Lui River sub-basin in year (a) 1973, (b) 1981, (c) 1988, (d) 1991, (e) 2008 and (f) 2009.

dry and wet period that can identify on the graph. The duration of day used in the classification is range between 15 to 90 days and this number of days largely depends on the respective conditions and it cannot be fixed from case to case.

Average BFI value for the drought of the selected year (0.6149) is larger than during the wet period (0.5702) for selected year of data set. Also, BFI during each dry period is always larger than the following wet period, except for the year of 1991. It is because there is six missing data in the year 1991 which has affected largely on BFI value as BFI is sensitive to missing data. Only one day of missing data may result in several days of data omitted from the base-flow separation. The highest BFI for the dry period is 0.7382 in year 1981 (11/Jan-31/Jan) while the lowest is 0.4269 in year 1991 (20/Feb-6/Mac). For the wet period, the BFI is in between 0.3861 to 0.6944 over the year of study. The year 2008 and 2009 is chosen simply because the most recent BFI value in response to dry and wet period can be evaluated. The dry period has larger BFI indicates that the flow during the dry season of the year, the stream-flow discharge is composed entirely of base-flow. On the other hand, in the wet season, the discharge is made of base-flow and quick-flow/storm-flow where it is the relative large portion as compared to base-flow.

Langat-Dengkil River sub-basin dry and wet period analysis

For the analysis of dry and wet period in Langat-Dengkil River Sub-basin, selected six years data is used in the analysis which is year 1965, 1979, 1987, 1996, 2008 and 2009 out of 44 years of study. The selected year acts as the representative data for the whole basin where the pattern of catchment response to dry and wet period can be identified and illustrated. The main reasons these data sets are chosen is simply the same as the reasons mentioned previously. In facts, the year 2008 and 2009 is selected simply because the most recent BFI value in response to dry and wet period can be assessed and evaluated. The duration of day used in the classification is range between 15 to 80 days.

As observed in Figure 8, most of the year (1965, 1979, 2008 and 2009) has two times of dry and wet period in the analysis, only the year of 1987 has only one dry and wet period and less one wet period in the year 1996. In year 1987, the year of low discharge persist for the duration of 226 days before the beginning of peak or high discharge occurs. The absence of one wet period occur in year 1996 primarily due to the missing data occur in the day of 243 to 246 which leads to the changing of turning point. The changes of turning points have leads to the omitted peak base-flow recharge as it cannot be considered in the BFI calculation. Average BFI value of the selected year for the drought (0.5790) is larger than during the wet period (0.4432) for selected year of data set. Also, BFI during each dry period is always larger than wet period, except for the year of 1965 at the 28 Oct -26 Dec. The highest BFI for the dry period is 0.7935 in year 1987 (12/Jan-1/Apr) while the lowest is 0.4254 in year 1996 (19/Sept-2/Oct). For the wet period, the BFI is in between 0.1915 to 0.7450 over the year of study.

The estimated average amount of base-flow volume in the Langat-River sub-basin is notified as larger if compared to Lui River sub-basin as the latter is the part of the Langat-Dengkil River sub-basin (dry period: 27,707,479 m^3>2,292,015 m^3; wet period: 115,462,286 m^3>5,726,246 m^3). In facts, average BFI in Langat-Dengkil River sub-basin for both dry and wet period is always smaller than the Lui River sub-basin where 0.5790<0.6149 for BFI in dry period and 0.4432< 0.5702 for BFI in wet period as Figure 9. Also, the fluctuations in the Langat-Dengkil Sub-basin is more rigorous as compared to Lui River sub-basin in both BFI dry and wet period with the range BFI = 0.3681 for dry in Langat-Dengkil > BFI = 0.2675 in Lui river and the range of BFI = 0.5535 for wet in Langat-Dengkil > BFI = 0.3083 in Lui river. This is again related to the rapid urbanization occur in the downstream area of Langat-Dengkil River Sub-basin. Smakhtin (2001) states that modification of land use over large parts of a catchment which may contribute to changes in the infiltration and/or evaporation characteristics, as well as modifications to the amount of groundwater recharge.

According to Smakhtin (2001), BFI was found to be a good indicator of the effects of geology on low-flows and for that reason is widely used in many regional low-flow studies. This have been further highlighted by Tallaksen and Van Lanen (2004), values of index range from above 0.9 for a permeable catchment with a very stable flow regime to 0.15-0.2 for an impermeable catchment with a flashy flow regime (often have higher flow-rates and more quick rises and falls in water level).Hence, the overall catchment of upstream and downstream has characterized as the partially permeable with equally stable flow regime. The trends and the low flow study will be further discussed in ‘low-flow analysis’.

Low-flow analysis

World Meteorological Organization, WMO (1974) defines low flow as flow of water in a stream during prolonged dry weather while Smakhtin (2001) defines low flows as actual flows in a river occurring during the dry season of the year and it is a seasonal phenomenon, and an integral component of a flow regime of any river. To analyses the low-flow regimes of the both Lui and Langat-Dengkil Sub-basin, the technique of 7-day 1-years (7Q1) low flow is used. The other hydrologically-based design low flow methods are 7-day 10-year low flow (7Q10) and 7-day 2-year low flow (7Q2). The purpose

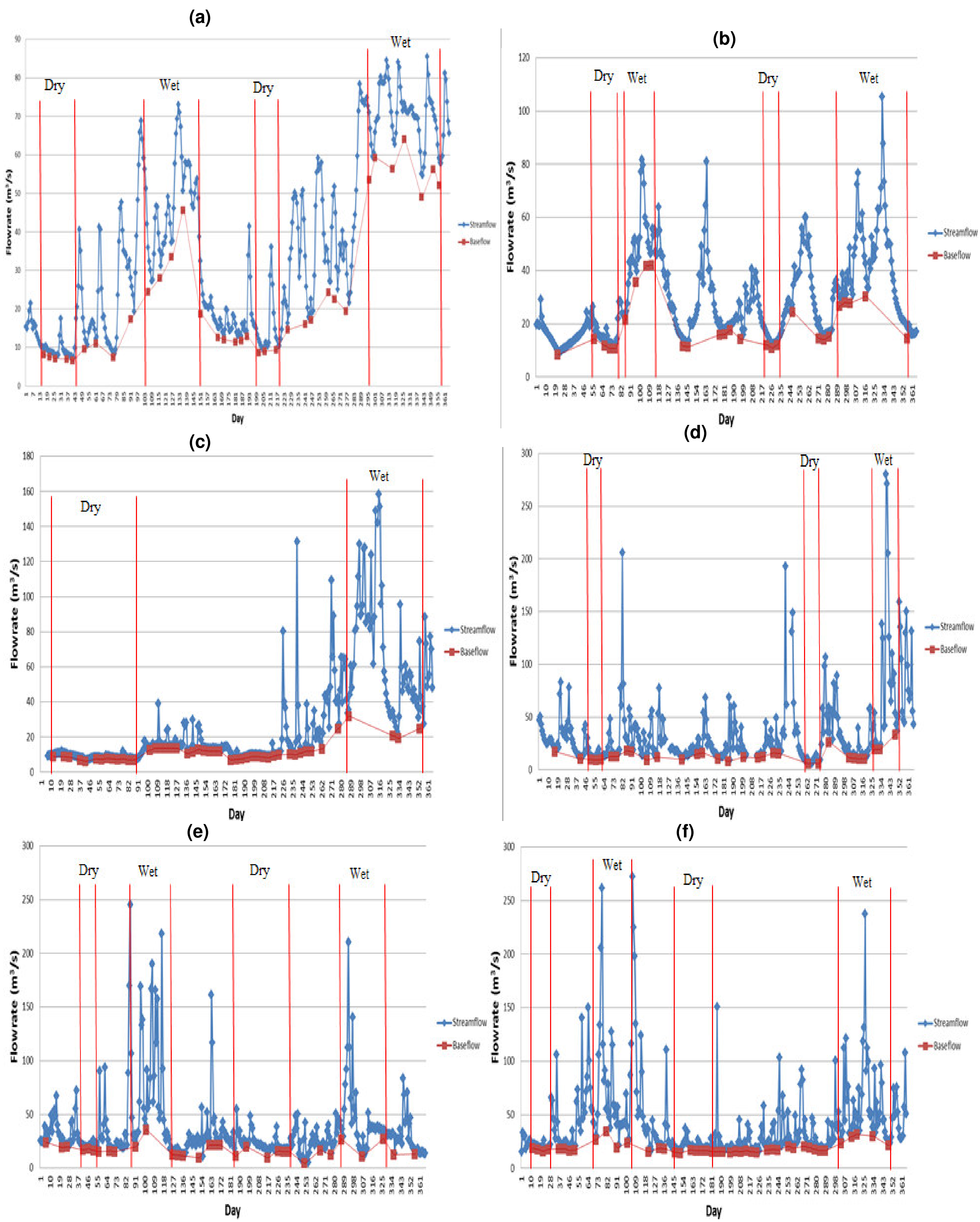

Figure 8. Dry and wet period for Langat-Dengkil River sub-basin in year (a) 1965, (b) 1979, (c) 1987, (d) 1996, (e) 2008 and (f) 2009.

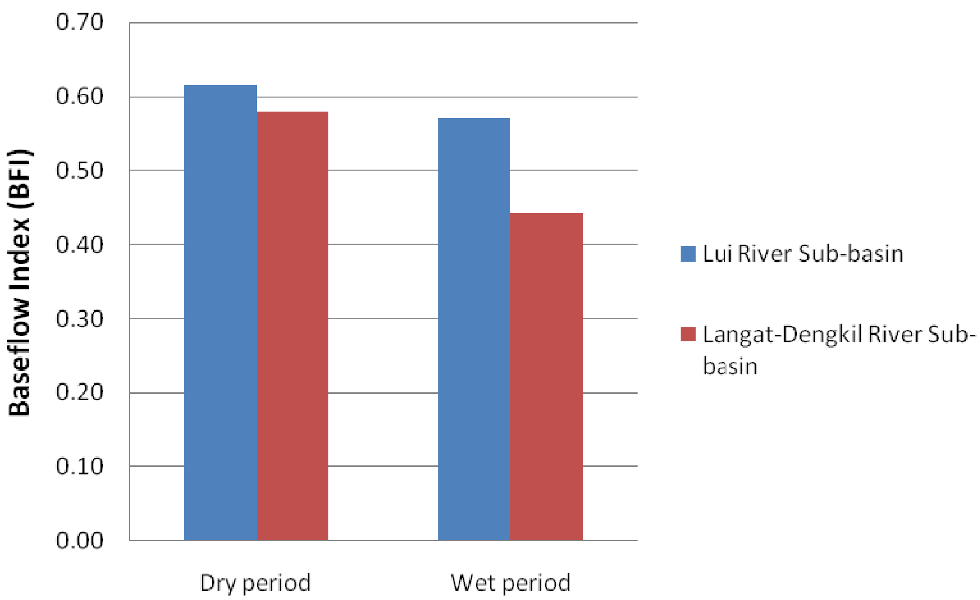

Figure 9. Comparison of average BFI in Lui and Langat-Dengkil River Sub-basin for dry and wet period.

of the 7Q1 is used because the graph of 7 day low-flow against time (year) for both Lui and Langat-Dengkil sub-basin can be plotted as in Figure 10 and Figure 11.

Based on the Figure 10, 7 day low-flow for Lui sub-basin shows the upwards trend through time. The trend line is moderately steep with of merely 0.0047. The result of simple regression shows that the coefficient of determination (R^2) is 0.0267, coefficient of correlation (R) is 0.1634 (little if any correlation), the analysis is not significant at 0.05 level of significance. The increasing trend of the 7Q1 indicates that the increasing in amount of actual flows in a river occurring during the dry season of the year which is extremely important for water supply particularly in drought.

Also, 7 day low-flow for Langat-Dengkil sub-basin from year 1965 to 2009 is down in Figure 11. From observation, it is an increasing type of trend through time. In facts, the trend line is more steep than the Lui River sub-basin (0.0295 > 0.0047). This is because the flow-rate amount of low-flow in the Langat-Dengkil sub-basin is larger, a small changes in trend lines causing a large changes in low-flow flow-rate. The result of simple regression shows that the coefficient of determination (R^2) is 0.0133, coefficient of correlation (R) is 0.1153 (little if any correlation), the analysis is not significant at 0.05 level of significance.

As noted in Figure 6, the rapid development and urbanization has occurred in the downstream area of Langat-Dengkil River Sub-basin. To make matter worst, this urbanization has greatly affects the hydrology of an area where the decreasing trend of BFI is identified. The reduction in the base-flow volume has greatly connected to the discharge can sustain flows in stream channel over extended periods between rainfall (base-flow) or minimum flow in river during dry periods of year (low-flow). Throughout the year of study on 7 day 1 years (7Q1) low flow for Lui River sub-basin and Langat-Dengkil Sub-basin, the upwards trend is displayed although BFI trend in Langat-Dengkil sub-basin is a downward trend. This is clearly, obviously and apparently indicated that even though the rapid urbanization and decreasing in BFI value has occurred, the 7Q1 for both sub-basins is in positive sign and trend. Hence, the availability water supply particularly in drought is ample as the whole system is robust.

Conclusion

Without doubt, land-use change has greatly impacted the hydrological regimes particularly base-flow for the upstream area and downstream area as the result of analysis on of Base-flow Index (BFI) as well as 7-day 1 year low-flow analysis. The yearly BFI time analysis of Lui River sub-basin almost no changes or exhibit constant through time while Langat-Dengkil sub-basin exhibit a downward trend. According to the analysis, Lui River sub-basin has higher high groundwater contribution to stream-flow compared to Langat-Dengkil River sub-basin with average BFI for Lui and Langat-Dengkil River Sub-basin's is 0.5616 and 0.5005 respectively. This implies that 56.16% and 50.05 of water in the river is contributed by groundwater storage and/or shallow subsurface storages while the other 43.84% and 49.95 of river flow is made of quick-flow or storm-flow from rainfall events. In term of stability of the catchment in base-flow

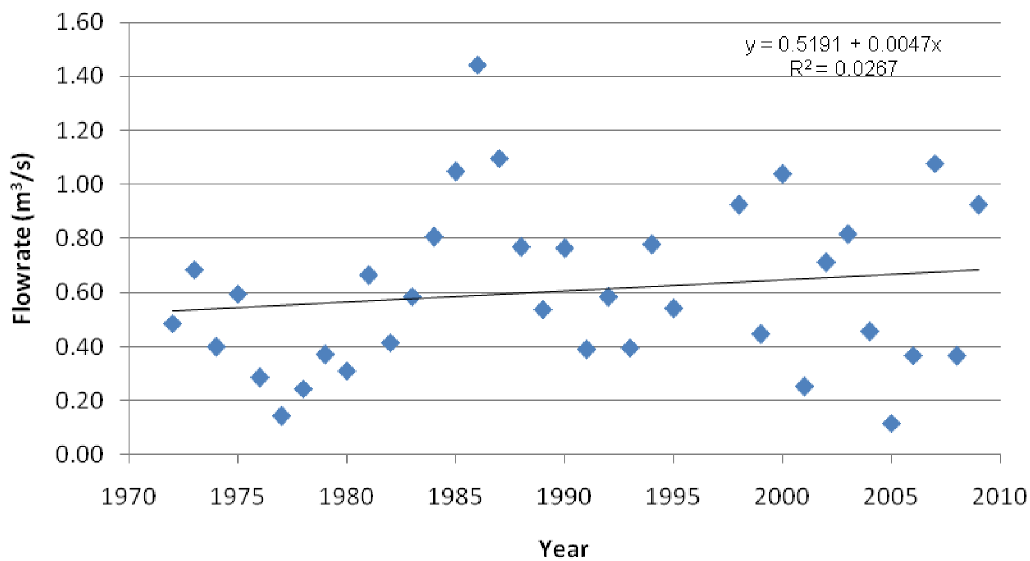

Figure 10. 7-day 1-year (7Q1) low-flow for Lui River Sub-basin.

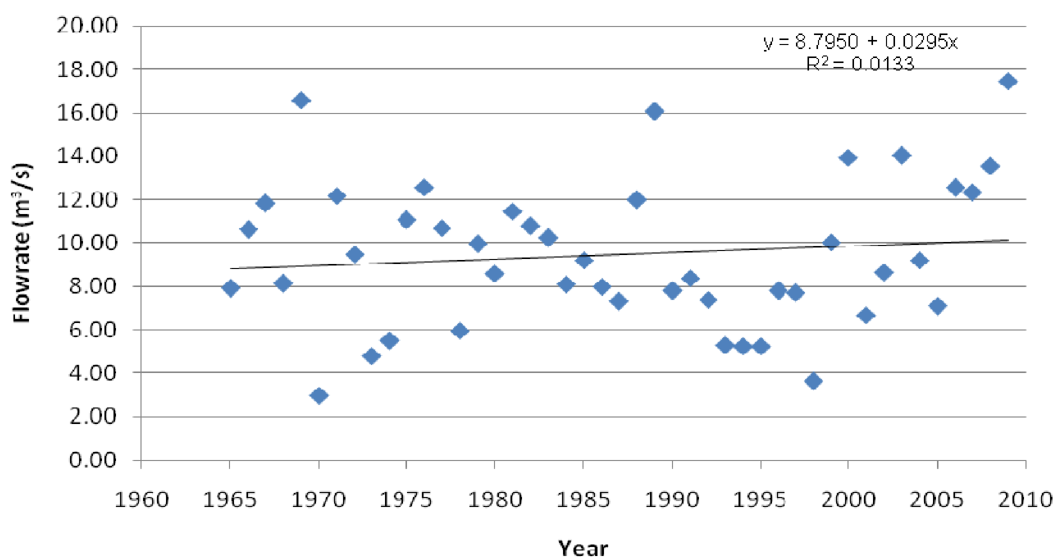

Figure 11. 7-day 1-year (7Q1) low flow for Langat-Dengkil River Sub-basin.

regime, Lui River is relatively approximate to the stable range of BFI (0.04) recommended by UKIH (1980) in compared to Langat-Dengkil Sub-basin.

In the analysis of dry and wet period, estimated average amount of base-flow volume in the Langat-Dengkil River sub-basin is reported as larger if compared to Lui River sub-basin as the latter is the part of the Langat-Dengkil River sub-basin (dry period: 27,707,479 m^3> 2,292,015 m^3;wet period: 115,462,286 m^3> 5,726,246 m^3).The average BFI in Langat-Dengkil River sub-basin for both dry and wet period is always smaller than the Lui River sub-basin where 0.5790 < 0.6149 for BFI in dry period and 0.4432 < 0.5702 for BFI in wet period. Throughout the year of study on 7 day 1 years (7Q1), the upwards trend is displayed for Lui River sub-basin and Langat-Dengkil sub-basin although BFI trend in Langat-Dengkil Sub-basin. This is apparently shows that even though the rapid urbanization and decreasing in BFI value has occurred; the 7Q1 for both sub-basins is in positive sign and trend. This shows that the increasing in amount of actual flows in a river occurring during the dry season of the year. Therefore, the availability water supply particularly in drought is ample and likely no water shortage may occur.

RECOMMENDATION FOR FUTURE RESEARCH

On the whole, UKIH is an empirical formula that performed based on a real data which could support the mathematical estimation of BFI. However, usually, such procedure could be applied in certain pilot area that experienced similar environmental conditions but could be not valid in other pilot areas with different environmental conditions. In this context, further research could be done to find out different empirical coefficients that could provide better estimation for BFI under different conditions.

In general, the application of UKIH to estimate the BFI is promising to be applied in several study areas. However, better performance for estimating BFI could be improved with certain modification UKIH method. In addition, pre-processing for the data is essential step for time series estimation model and required more survey and analysis that could lead to better accuracy in our application. Furthermore, recently the Artificial Neural Network (ANN) proved high performance in estimating and forecasting several hydrological components process. In this context, a recommendation for utilizing ANN model would be another alternative to estimate the BFI and attraction to be investigated.

ACKNOWLEDGEMENTS

This study is based on the M. Eng "Thesis of the first author". Author would like to express my deep and sincere gratitude to the funding received by the second and the third author (UKM-KK-02-FRGS0125-2009) received from ministry of High Education, Malaysia and (UKM-DLP-2011-002. In addition, Author would extend appreciation and gratefulness to the staff members from Earth Observation Centre (EOC), UKM for their participation in completion of the project.

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