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Integrated Water Resource Management and Pollution Sources in Cameron Highlands, Pahang, Malaysia

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Abstract: The District of Cameron Highlands is a popular tourist resort in Malaysia; it has three main river systems namely the Telom, Bertam and Lemoi rivers which drain the northern, middle and southern parts of the district respectively. The river systems with numerous tributaries (totalling 123) and particularly those within the Telom and Bertam catchment areas play a vital role in Cameron Highlands as sources of water for freshwater supply, irrigation water for agricultural activities and for hydroelectricity generation and recreational activities. Water supply to the District is currently divided into two zones, i.e. the Northern and the Southern Zones. The Northern Zone includes the areas of Kg. Raja, Kuala Terla, Tringkap, Kea Farm, Tanah Rata and Brinchang whilst the Southern Zone includes the areas of Habu and Ringlet. The total water demand in 2002 for the district to fulfill the demand of domestic, commercial and industrial and government institutions was 4.95 ml/day. The commercial sector which comprises mostly of hotels and restaurants, together with the industrial sector are the largest water consumers. It is important to note that, water supply for agricultural use does not come from the District's water supply network. The main sources of water pollution are sewage treatment plants from hotels, rest houses, apartments, markets, stalls, laundries, car repair shops and leachate from garbage dumps. These pollution sources are divided into point and non-point (dispersed) sources and elaboration on the types of sources, identification, their loads and concentrations and their relation to water resources have become important issues in this study. Considering the peculiar characteristics of land use and water flow of Zones 1 to 5, located at the Bertam and Telom Rivers, these two rivers have an existing river classifications of Class III, IV and V during average water flow (AWF). Similarly, for rivers with the same existing river classifications during high water flow (HWF), there are additional non-point sources of pollution, i.e. areas of bare land causing erosion and sedimentation, farmland and construction areas.

Key words: Water resource · Stream flow · Pollution sources · Average water flow · High water flow

INTRODUCTION

Cameron Highlands is a district in the state of Pahang with a total area of 71,218 hectares which constitute three mukims i.e. Mukim Ulu Telom, Mukim Ringlet and Mukim Tanah Rata. It is a popular tourist and recreational area in addition to its being the key agricultural area, for vegetables, flowers and tea. The study area was located in the main mountain range of Banjaran Titiwangsa with elevations ranging from 100 m at the east to 2031 m at the west; the highest peak is Gunung Brinchang (2,031 m). Meteorological records show that the study area received an average rainfall of 2,800 mm, with the western foothill areas receiving higher precipitation compared to that at the higher mountainous areas. Guidelines on Environmentally-Sensitive Areas (ESA), state that any areas of elevation exceeding 1000 m are classified as mountains, areas with elevation of 100 to 1000 m as hills and areas with elevation of 30 to 100 m as developable land. Approximately 25 per cent of the study area was

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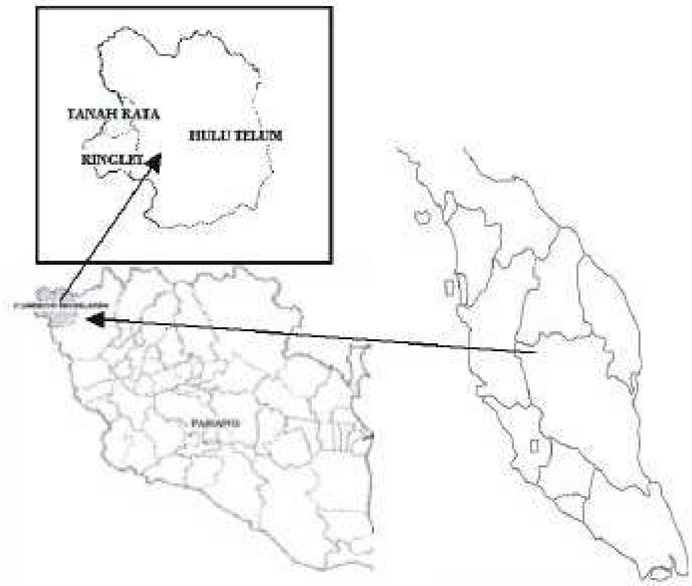

Fig. 1: Maps indicating the location of Cameron Highlands, Pahang

located below the elevation of 1,000 m, whilst two-thirds of the area came within the range of 1,100 to 1,600 m. Figure 1 shows the location of Cameron Highlands with respect to Peninsular Malaysia.

Previous report, namely those of Norhazni and Pauziah Hanum [1] and UMCB [2] stated that the changes in land use patterns in Cameron Highlands were recognized as the main cause of river water quality deterioration. A technical report by the District Council, Cameron Highlands [3] quoted the DOE's data from 1996 to 1998 and indicated that the overall water quality for the seven rivers namely the Ringlet, Bertam, Habu, Burung and Terla rivers was good, in Class I and Class II. Only the water from the stations at Telom and Tringkap rivers came under Class III. The lowest water quality was recorded for the Ringlet and Khazanah rivers which flowed into the Ringlet Lake. Based on Das and Acharya [4] about one third of the drinking water requirement of the world is obtained from surface sources like rivers, canals and lakes, but these sources seem to be used as the best place for waste discharge from agriculture, domestics and industries [5]. In Cameron Highlands most of the agricultural activity depends on the source of water from the rivers [6]. High soil loss has occurred due to agricultural, residential [7-9] and tourism activities [10]. Suspended solids from various land development activities within the catchment, were found to be the main pollutants of the river system at Cameron Highlands. Urbanization and infrastructural development are usually associated with energy requirement [11], such as the development of hydroelectric power plants in Cameron Highlands. Some chemical pesticides can reach toxic levels in the fatty tissues of fish and other aquatic life. They can also cause deterioration in water quality and this can pose a health threat to humans as the water becomes unsafe for drinking. The pesticide residues detected in the water include endosulfan sulfate, endosulfan I, aldrin, dieldrin and endrin. The presence of pesticide residues in the rivers of Cameron Highlands was also reported by Zuriati *et al*. [12]; in which the presence of most types of organochlorine pesticides as a result of agricultural activities was reported. A water quality study by Cho [13] within the vicinity of the Ringlet Lake including the Ringlet, Khazanah, Jasin and Jasik rivers has shown that the rivers fall under Class I and Class II with the WQI ranging from 80.6 to 100, giving an average of 96.7.

Study Methods: One of the requirements of the study was the determination of the inflow (Q) at the sub-catchments within the study area. In this exercise, the Q for the sub-catchments within the study area was calculated individually whilst for the undeveloped sub-catchments areas it was calculated on a group basis. Data on water use and water management for Cameron Highlands was provided by the District Council Cameron Highlands. The Department of Environment (DOE) has been responsible for water quality monitoring of the rivers since 1987 through a network of ten stations (ASMA-CH01 to ASMA-CH10) initially and later another 64 new

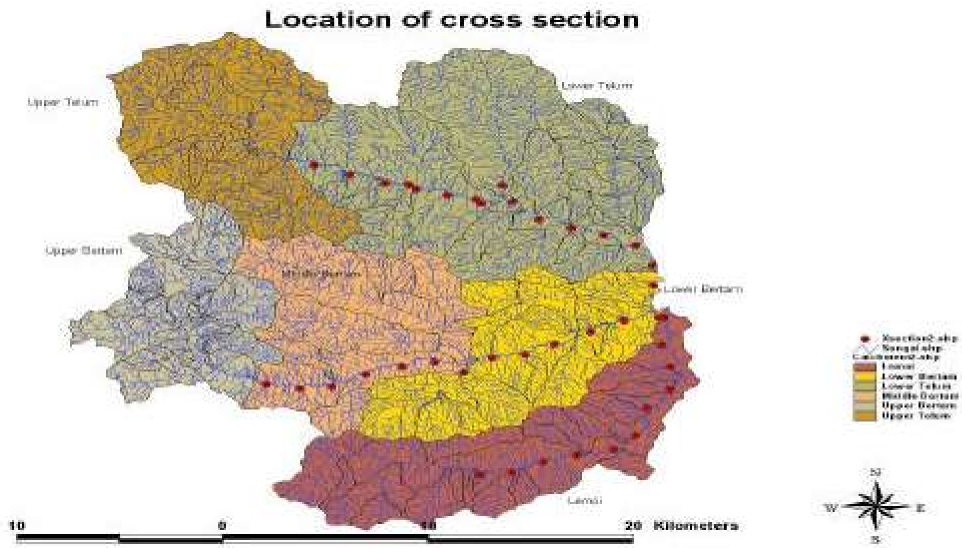

Fig. 2: Map of Cameron Highlands show the location of the three main river basins

stations (designated as WR5 to WR74) were added, covering all the three catchments of the Telom, Bertam and Lemoi Rivers. The monitoring of water quantity and quality along these three rivers was carried out twice a year. Three sampling cycles were carried out at the 64 new stations. The first two cycles were carried out effectively during average water flow (AWF) and represented the status of the rivers during the average or dry water flow periods. The third sampling cycle was undertaken during high water flow (HWF) in order to show any changes in water quality during the high water flow period as experienced during the rainy season. Due to accessibility problems during heavy rain, some stations could not be sampled during HWF. At each sampling, *in situ* measurements of temperature, dissolved oxygen, pH, conductivity, turbidity and stream flow of each river were taken using relevant field equipment [14]. The field meters used were calibrated in the laboratory before sampling and again in the field in between stations. Laboratory analysis was also carried out on the water samples for other physico-chemical parameters.

Water Uses: The study area is drained by three main river systems i.e. the Telom, Bertam and Lemoi Rivers which drain to the northern, middle and southern areas of the district. These rivers flow eastwardly and join up with the Telom River and finally form the Pahang River. The river systems have numerous tributaries (totalling 123) particularly those located within the Telom and Bertam River catchment areas. These three rivers play a vital role in supplying Cameron Highlands with sources of freshwater and irrigation water besides being used for hydroelectricity generation and recreational activities. Figure 2 shows the water catchment areas and zones of the three main rivers and their tributaries.

Land Cover: The entire area of Cameron Highlands is divided into 6 zones with Zones 1 and 2 located at the upper and lower catchments of the Telom River respectively and consisting of 37 catchments. Zones 3, 4 and 5 are located at the upper, middle and lower catchments of the Bertam River and consist of 63 catchments. Zone 6 is the catchment area of the Lemoi River with 20 catchments. The entire river systems in Cameron Highlands consist of 123 catchments. The catchment within the Telom and Bertam areas, play a vital role to the Cameron Highlands District as freshwater supply sources for human consumption, agricultural activities, hydroelectricity generation and recreational activities.

For the purpose of differentiating land cover, each zone is divided into 3 categories namely Forested areas, Agricultural land and Urban areas. During 2002, the forested area for Zone 1 and 2 occupied 29498.3 ha or 48.12%; for Zone 3, 4 and 5 forests occupied an area of 20710.12 ha or 33.78% and for Zone 6 it covered 11092.55 ha or 18.10%. Agricultural activities in zone 1 and 2 covered 3272.18 ha or 38.28% and for Zone 3 and 4 covered 5279.12 ha. There was no agricultural activity in Zone 5 and Zone 6. Urban activities only occurred at

Table 1: Area and percentage land cover in the Water Catchment Areas (2002)

Zone	Forest Ha.	Forest %	Agriculture Ha.	Agriculture %	Urban land Ha.	Urban land %
Zone 1 (Upper Telom)	11809.95	19.27	3144.45	36.78	289.18	21.17
Zone 2 (Lower Telom)	17688.4	28.85	127.73	1.50	-	-
Zone 3 (Upper Bertam)	8366.3	13.65	2755.52	32.22	1076.52	78.83
Zone 4 (Middle Bertam)	3992.25	6.51	2523.6	29.5	-	-
Zone 5 (Lower Bertam)	8351.57	13.62	-	-	-	-
Zone 6 (Lemoi)	11092.55	18.10	-	-	-	-
Total	61301.02		8551.3		1365.70	

Table 2: Average annual flow of the Telom River

Flow Condition	Average annual Flow (m^3/s)
Q(min)	44.86 m^3/s
Q(mean)	66.86 m^3/s
Q(max)	93.05 m^3/s

Table 3: Average annual flow per hectare for the Telom River

Flow Condition	Average Annual Flow (m^3/s)	Average Annual Flow per Hectare (m^3/s per hectare)
Q(min)	44.86 m^3/s	5.1386×10^{-4}
Q(mean)	66.86 m^3/s	7.6586×10^{-4}
Q(max)	93.05 m^3/s	1.0658×10^{-3}

Table 4: Average annual flow of the Bertam River

Flow Condition	Annual Average Flow (m^3/s)
Q(min)	9.72 m^3/s
Q(mean)	14.04 m^3/s
Q(max)	18.18 m^3/s

Table 5: Average annual flow per hectare for the Bertam River

Flow Condition	Average Annual Flow (m^3/s)	Average Annual Flow per Hectare (m^3/s per hectare)
Q(min)	9.72 m^3/s	4.585×10^{-4}
Q(mean)	14.04 m^3/s	6.6226×10^{-4}
Q(max)	18.18 m^3/s	8.5755×10^{-4}

the upper Telom and upper Bertam zone (Zone 1 and Zone 3). The Lemoi catchment in Zone 6 is still considered a forested area, as it has only a small colony of indigenous people living there. Table 1 shows the land cover of the 6 zones.

Distribution Plan of Water Resources: Water resource is determined based on total flow from each catchment within the study area. In this study, the Q for the sub-catchments was calculated on individual basis whilst in the undeveloped sub-catchments the total Q was calculated on group basis.

The purpose of a plan is to ensure that a balance can be achieved for the following major activities:

- Water supply for domestic consumption
- Water supply for irrigation
- Water supply for hydro electricity generation
- Water supply for water based tourism activities

Annual Water Flow: Calculation of Average Annual water Flow (m^3/s) was carried out at the Telom and Bertam Catchments to estimate the total annual flow. For the Telom catchment, the average annual flow (m^3/s) of the Telom River or Bt. 49 was taken and used as the reference Station, with readings as follows (Table 2).

The Average Annual Flow per hectare for the Telom River with a total catchment area of 87.3 km^2 (8730 hectare) is presented in Table 3.

For the Bertam catchment, the average annual flow (m^3/s) was calculated with the Bertam River or Robinson Falls used as the reference Station. The base data was taken from 1949 to 1997. The Average Annual Flow was as follows (Table 4).

The Average Annual Flow per hectare for the Bertam River with a total catchment area of 21.2 km^3 (2120 ha) is presented in Table 5.

Water Supply: The Cameron Highlands Local Plan (CHLP) showed that the water supply to the district is currently divided into two zones, i.e. the Northern and the Southern Zones. The Northern Zone included the areas of Kg. Raja, Kuala Terla, Tringkap, Kea Farm, Tanah Rata and Brinchang whilst the Southern Zone included the areas of Habu and Ringlet.

In addition, as detailed in the CHLP study, the areas of Tanah Rata, Brinchang and Kea Farm in the Northern Zone received fully-treated water from the Water Treatment Plants of Sg. Burung and Brinchang. On the

Table 6: Cameron Highlands-water supply for the year 2002

Supply Plant	Present Supply (ml/day)	Supply Capacity (ml/day)
1.Sg Burung Water Supply Plant	1.86	2.18
2. Brinchang Water Supply Plant	1.68	1.82
3. Tringkap Dam	0.32	0.41
4. Kuala Terla Dam	0.32	0.41
5. Kg. Raja Dam	0.55	0.64
6. Habu Dam	0.18	0.27
7. Lubuk Tamang Dam	0.09	0.18
8. Lembah Bertam Dam	0.32	0.32
9. Ringlet Dam	0.27	0.41
10. Kuala Terla Dam	0.32	0.41
TOTAL	5.91	7.05

Source: CH District Local Plan 2003-2015(JBA Pahang)

Table 7: Cameron Highlands-Water Demands by the various sectors (2002)

Sector	Present Demand (ml/day)
Domestic	1.21
Commercial and Industrial	3.40
Government Institutions	0.29
Others	0.05
TOTAL	4.95

Source: CH District Local Plan 2003-2015 (JBA Pahang)

other hand, other areas in the Northern Zone i.e. Tringkap, Kuala Terla and Kg. Raja as well as all the areas in the Southern Zone received partially-treated water. Details of the water supply in 2002 for the District are presented in Table 6.

The total water demand for the year 2002 for the District as presented in the CHLP Study was 4.95 ml/day and the breakdown according to the supply to the various sectors is shown in Table 7. The commercial sector which comprises mostly of hotels and restaurants, along with the industrial sector are the largest water consumers. It is important to note that, water supply for agricultural use does not come from the District's water supply network [3].

The total water demands for the various sectors in 2002 was 4.95 ml/day, this amount was supported by the 2002 water supply of 5.91 ml/day excluding the demand from the agricultural sector.

Irrigation Water for Agriculture: The water for irrigation of agricultural areas in the Cameron Highlands is obtained by channeling the river water in the proximity of the areas from upstream for the agricultural plots via self constructed piping using high density polyethylene tubes. This is the unusual type of irrigation used in agricultural areas in the District and is approved by the local authority with a minimal annual fee of RM10 payable to the District Land Office. For the relatively larger agricultural plots a temporary pond would be made upstream and the collected water be channeled to a temporary distribution pond in the agricultural plot from which water will be distributed for agricultural activities. Several farmers in Cameron Highlands use modern drip-irrigation system inclusive of fertigation (fertilizer + irrigation) and overhead sprinkler irrigation systems in the open field. Irrigation is important after sowing until the seedlings emerge and during fruit development. For most vegetables, there are periods in the growth cycle where lack of water can significantly affect yield and quality.

Hydroelectricity Generation: Hydroelectricity generation takes place along the network of the Telom and Bertam Rivers with the use of three retention ponds and two stretches of tunnels. When sufficient amount of water is collected in the retention ponds, the water is used to move the turbines in the hydroelectric generator stations for energy production. The two stretches of tunnels namely, the Telom Tunnel which is linked to the Telom River and the Ringlet Lake and the Bertam Tunnel which is linked to the Ringlet Lake and the Sultan Yusuf Generator Station were built to contain and divert sufficient volume of water for hydroelectricity generation.

Soil Erosion Threats: Rapid developments such as agriculture, urbanization, infrastructure development and deforestation in Cameron Highlands have contributed to severe upland soil erosion. For years, during heavy rainfall, the rivers in Cameron Highlands have had to accommodate high amounts of eroded sediments coming from these sources. Poor sediment control has resulted in the filling up of the Ringlet Reservoir after just 30 years of it's commissioning in the 1960's. Out of the three main rivers in Cameron Highlands, only the Telom and Bertam Rivers are under the threat of erosion and sedimentation problems. Another diversion channel has also been constructed to divert water from the Telom to the Bertam River. This tunnel is the main source of sediment flow into the Ringlet Reservoir which was designed with a targeted life-span of 80 years. Based on Malaysian soil loss tolerance rate, soil loss in Cameron Highlands ranges from very low to very high (Table 8).

Table 8: Potential rate of soil loss in the Cameron Highlands area

Land use	Rainfall erosivity index (J/ha)	Vegetation/cover factor	Computed soil loss (ton/ha/yr)	Soil loss classification
Forest area	1672	0.001	0.0005	Very low
Farm area	1672	0.015	0.28949	Very low
Settlement	1672	0.300	11.47212	Low
Township	1672	0.800	77.90346	High
Agriculture	1672	0.800	480.07025	Very high

Table 9: Classification of river water quality at the 74 monitoring stations during Average Water Flow (AWF)

A) Telom River		
Station		WQI
ASMA	CH07-CH 10	I
RW	6, 8, 10, 11	I
RW	5, 7, 9, 12-23	II
B) Bertam River		
Station		WQI
ASMA CH07-CH10	CH01-CH06	II
RW	36, 43, 73	I
RW	26-31, 37-42, 44-66, 70-72, 74	II
RW	67-69	III

Water Quality Degradation: Nutrients in fertilizers and manure that are carried by surface water will over stimulate the rivers and lakes, causing eutrophication. The water quality deterioration appears to be widely distributed and prominent in the Cameron Highlands District. In the upper region of the Telom and Bertam catchments, high level of agricultural activities and settlements close to the river banks are known to be one of the main contributors of the increase in suspended solids, nutrients, sewage and possibly, pesticides in the area. Based on regular monitoring, it was found that the water quality in both catchments were generally clean except for the high levels of suspended solids (TSS) in some of the stations at Telom and slight pollution at the Bertam River during average water flow.

Water quality during Average Water Flow (AWF): During AWF, as shown in Table 9, the water quality of the rivers in the three catchments are generally clean, predominantly in Class I and Class II, based on the value of the water quality indices (WQI).

Only at three stations upstream of the Bertam River (RW67, RW68 and RW69) the quality of water was recorded to be in Class III. Upstream of the rivers in the stations of Telom (RW6 and RW10), Terla (RW8), Kedal (RW11), Bertam (RW6), Jasik (RW43) and Lemoi (at RW73), the water was very clean and categorized under Class I. These are only seven stations where the quality of the water can be categorized under Class I. This means that during AWF, following the National Water Quality Standards (NWQS), the water from the above rivers can be used as drinking water, using the conventional treatment methods.

The overall clean water quality of the rivers in Cameron Highlands recorded during AWF, as found in present study, are in line with several recent reports. Assessment of the data monitored at the ten ASMA stations from 2002 to 2003 showed that the water quality at all the ten stations were clean and of Class II according to NWQS. This is to be expected since the sampling for the above monitoring work (done twice a year) was carried out during average water flow. As seen in Table 10, four rivers within the Bertam catchment, have been degraded to Class IV. These are the Sik (RW47), Kelui (RW 49) and Ringlet (RW51) rivers which were originally in Class II (during the AWF) and the Bertam (RW 67) river which was originally in Class III (during the AWF).

Water quality during High Water Flow (HWF): In contrast to water quality recording during AWF, measurements performed during HWF clearly indicated deterioration of water quality at almost all stations, due to sudden increase in the level of total suspended solids (Table 9). The high TSS values caused degradation in the water quality of the rivers to affect a shift from Class I or II to Class III and IV. The most significant effect of TSS was recorded for the Telom (RW6) and Bertam (RW36) Rivers where the water quality degraded from Class I to Class III. For most of the other stations the degradation was from Class II to Class III.

Data for stations ASMA-CH01 to ASMA-CH10 were generally taken during AWF only. When there are no entries for the class in the HWF column, it means that no measurements were performed at the station during HWF. However, out of the 64 stations monitored in this study

Table 10: Classification of river water quality of the 74 monitoring stations during High Water Flow (HWF)

Station		WQI
A) Telom River		
Station		WQI
RW	8	I
RW	5, 7, 10, 12, 16, 18-21, 23	II
RW	6, 11, 13-15, 17, 22	III
B) Bertam River		
Station		WQI
RW	73	I
RW	26-28, 30-31, 38, 42-43, 45, 53-56, 63-64, 72, 74	II
RW	29, 36-37, 39-41, 44, 46, 48, 50, 52, 57-58, 65-66, 68-71	III
RW	47, 49, 51, 67	IV

Table 11: List of rivers not affected by water flow and remains at Class II during average and high water flow

Telom Catchment		Bertam Catchment	
Station I.D.	Name of river	Station I.D.	Name of river
RW5	Sg. Tajam	RW26	Sg. Rotan
RW7	Sg. Ikan	RW27	Sg. Bertam
RW12	Sg. Kial	RW28	Sg. Ruil
RW16	Sg. Getun	RW30	Sg. Pauh
RW18	Sg. Teringkap	RW31	Sg. Bertam
RW19	Sg. Palas	RW38	Sg. Bisik
RW20	Sg. Pertang	RW42	Sg. Ayer Kecil
RW21	Sg. Telom	RW43	Sg. Jasik
RW23	Sg. Terisu	RW45	Sg. Khazanah
RW53	Sg. Sengut		
RW54	Sg. Lucut		
RW55	Sg. Ibu Remas		
RW56	Sg. Anak Remas		
RW63	Sg. Bertam		
RW64	Sg. Tehi		
RW72	Sg. Mensun		

(excluding the ten DOE stations), 25 stations (as listed in the Table 11) maintained the same quality that is Class II, during both AWF and HWF indicating that they did not receive overly high levels of TSS during HWF. This clearly indicates that the water from these rivers can be used for domestic drinking water supply and for other special uses in Cameron Highlands both during the dry and rainy periods. Table 10, summarizes the classification of the rivers based on the WQI at all the stations during AWF and HWF.

The results clearly indicate that the water quality of most rivers change with the speed of water flow. Most of the rivers seem to degrade significantly in quality after heavy rainfall.

CONCLUSIONS

A water resource study involving two main rivers in Cameron Highlands for the period 2001 to 2002 showed that the water consumers were satisfied with the supply. There was plentiful supply of water recorded from both rivers with the quality ranging from Class I to Class II. During average water flow (AWF), the quality varied from Class I to Class III with the majority of the rivers falling in Class II. Four rivers namely the Sik, Kelui, Ringlet and the central portion of the Bertam (RW67) River recorded significant degradation from Class II to Class IV during HWF, other rivers mostly degraded from Class II to Class III. Water quality pollutants of significance are identified as TSS, COD, phosphate (P), ammoniacal nitrogen ($N\text{-}NH_3$) and *E. coli.* The sources of the pollution are expected to increase because of human activities in the steeper areas involving agriculture, urbanisation, tourism, etc.

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