Pertanika 11(3), 461-468 (1988)

Some Stream Water Quality Characteristics of Two Small Logged Over Watersheds in Selangor

LAI F.S. and NORAJIKI A.J.*
Faculty of Forestry
Universiti Pertanian Malaysia
43400 Serdang, Selangor, Malaysia.

Keywords: Watersheds; water temperature; dissolved oxygen; pH; conductivity; suspended solids; dissolved solids.

ABSTRAK

Satu kajian berkenaan dengan beberapa parameter kualiti air sungai telah dijalankan di dua kawasan legeh hutan yang telah dibalak. Kajian ini mengambil masa selama enam bulan iaitu dari Ogos 1983 hingga Januari 1984 dimana pensampelan air telah dibuat diantara jam 1400 dan 1500. Keputusan yang diperolehi menunjukkan bahawa kesemua parameter yang dikaji itu lebih berbedza untuk kawasan legeh WA yang lebih dibalak berbanding dengan WB. Nilai purata parameter kualiti air sungai untuk WA dan WB adalah berikut: suhu air – 25.3 dan 25.2^{O}C; oksigen terlarut – 6.7 dan 6.7 ppm ; pH – 5.55 dan 5.25; kekonduksian – 16.0 dan 11.3 μmhos/cm; takat pepejal ampaian – 7 dan 22 mg/l; dan takat pepejal terlarut – 31 dan 36 mg/l. Keputusan yang diperolehi mencadangkan bahawa kesan operasi hutan atas kualiti air adalah berbedza. Walau bagaimanapun, kualiti air masih dalam keadaan baik dengan adanya pertimbangan keatas alam sekitar semasa operasi hutan dijalankan.

ABSTRACT

A study of selected stream water quality parameters was carried out in two forested watersheds with varying degrees of disturbance. The study period of six months from August 1983 to January 1984 involved regular sampling at between 1400 and 1500 hours. Results indicate all parameters observed from the relatively more disturbed watershed WA were higher than the less disturbed basin WB. Mean values of stream water quality parameters of WA and WB respectively are as follows : water temperature – 25.3 and 25.2^{O}C; dissolved oxygen – 6.7 and 6.4 ppm; pH – 5.55 and 5.25; conductivity 16.0 and 11.3 μmhos/cm; suspended solids – 22 and 7 mg/l and; total dissolved solids – 36 and 31 mg/l. The findings suggest logging operations had varying influences on the water quality parameters. Although affected, the water quality remains good, aided by environmental considerations during logging operations.

INTRODUCTION

It is often reported that logging of forests adversely affects stream water quality. By physical reasoning it is obvious that this effect is real. Unfortunately, little attention has actually been received to document the physical and chemical stream water quality from affected catchments. More attention has been given, in the country, to quality of receiving waters from heavy polluting industries such as palm oil and rubber processing plants. The need for some comparison between basic data must be stressed in order to better understand not only variations within a particular watershed but also between watersheds. For this

* Present address: Hano Forests Consultants, P.O. Box 169 Limbang, Sarawak.

reason, selected stream water quality parameters pf temperature, dissolved oxygen (DO), pH, conductivity, total suspended solids (TSS) and total dissolved solids (TDS) of two logged over watersheds were measured and reported here.

MATERIALS AND METHODS

General Description of Study Area

A description of the study area is briefly outlined in this section. The geographic setting has been detailed by Lai and Samsuddin (1985).

Two small watersheds demarcated, WA and WB are tributaries of Sungai Rasau, the main river draining the Air Hitam Forest Reserve *(Figure 1).* WA is larger in area covering 7.3 km^2 compared to 4.7 km^2 of WB.

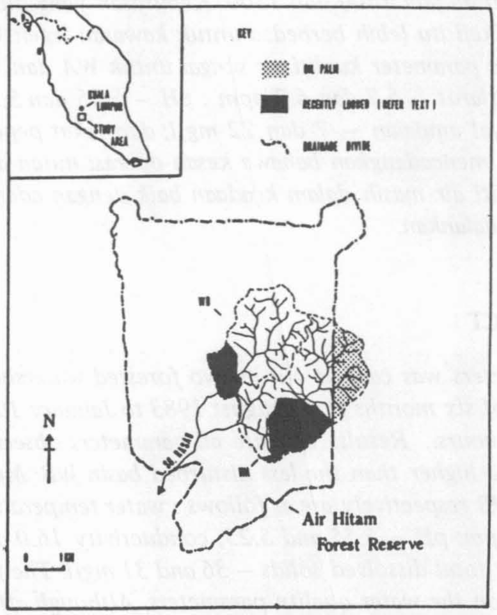

Figure 1. Location of study area.

Soil type for both watersheds are similar comprising the soil series of Serdang-Kedah and Durian association (Zainuddin, 1976). The Serdang series occurs along places downslope while that of Kedah and Durian are found on the ridges and upper slope regions. The local Alluvium Colluvium association occurs in the valley and foothill regions.

Prior to logging, the reserve was a lowland dipterocarp forest; with logging it was gradually replaced by secondary disturbed forest (Ali Riza, 1977). From past records, logging has been the main activity in the study area. Log extraction from the forest reserve began as early as 1930 and thereafter continued on commercial and subsistence basis up to 1983. In the harvesting, prior to this study, a crawler tractor-San Tai Wong system in which a Komatsu 16 was used. On record, WA is relatively more disturbed compared to WB: logging operations (including salvage logging) ceased in July 1983 in WA, a year after operations stopped in WB-about 35% and 13% of basin areas of WA and WB were logged respectively.

Data Collection

Over the study period, the stream water quality parameters were regularly sampled at between 1400 and 1500 hours at both stations. In addition, hourly sampling was also carried out for both stations on a 5-consecutive day basis to obtain any indication of diurnal fluctuations. A brief outline of methods used to record the selected water quality parameters in the study is given below.

Dissolved oxygen readings were made on site using a YSI 54 oxygen meter and YSI 5739 DO probe with an accuracy of ± 0.1 ppm.

Water temperature and conductivity readings were recorded on site using a YSI 33 S–C–T meter. The YSI 3000 Series probe for the instrument was submerged halfway from the water surface at the mid-stream section. Water temperature was checked and calibrated against a submerged laboratory thermometer. Sufficient time was allowed for stable readings before recordings were made. For comparison purpose, air temperature of the surroundings was measured using a laboratory thermometer well-placed in shaded areas - readings were noted at about the same time water temperature was recorded.

Measurement of pH was also carried out on site using a Mini-Mite pH meter (PA-11). The electrode was placed in the same section of the stream, as the temperature/conductivity and DO probe described earlier.

A one-litre plastic bottle sampler was used to collect stream water samples for suspended and dissolved solids analyses. The container was fixed with two copper tubes, one as intake and the other as air exhaust constructed following the sampling mechanism of a point integrating sampler. The water sample collected was later analysed in the laboratory using 4 replicates of individual samples. Concentrations of total suspended and dissolved solids were determined following the procedures outlined by Wang and Ong (1978).

RESULTS

Water Temperature

Analysis of variance for instantaneous water temperature data showed no significant difference ($P < 0.05$) between stations WA ($\bar{x} = 25.3^oC$) and WB ($\bar{x} = 25.2^oC$). Similarly, the range noted throughout the study period does not indicate obvious variation (Table 1) although the lowest values recorded were in the order of 25.0°C and 24.2°C for WA and WB respectively. In addition, a fair number of recordings taken during time of sampling were higher in WA than in WB. This can be attributed to the relatively exposed condition in certain stream reaches in WA mainly resulting from logging; direct sunlight provides the major energy source for heating the exposed streams. In small shaded streams, temperature changes induced by logging is directly proportional to the amount of exposure given the stream surface (Brown, 1974).

It was not possible to ascertain, however, if the temperature has an indirect relationship with discharge and by how much from the two basins since most of the recordings were done during low flow conditions.

Although monitored separately, the diurnal variation of the water temperature for both WA and WB showed similar patterns *(Figures 2a and 2b)*. The maximum water temperature occurred in the late afternoon (approx. 1600 and 1800 hours) while minimum readings were recorded during early parts of the day (approx. 700 to 1000 hours) after the highest and lowest air temperatures had been attained respectively. The pattern is characteristic of tropical streams (Edinger *et al.*, 1968) because of shortwave solar radiation influence which causes the maximum equilibrium temperature to occur near noon in the diurnal cycle while bottom heating gives a higher value at the end of the day (Geijskes, 1942).

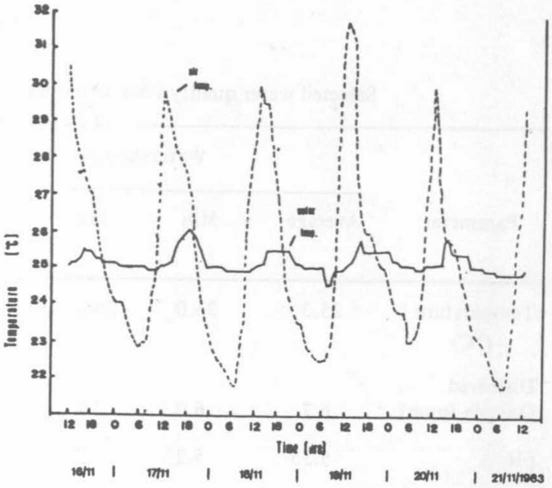

Figure 2a: 5 consecutive day air and water temperature – WA

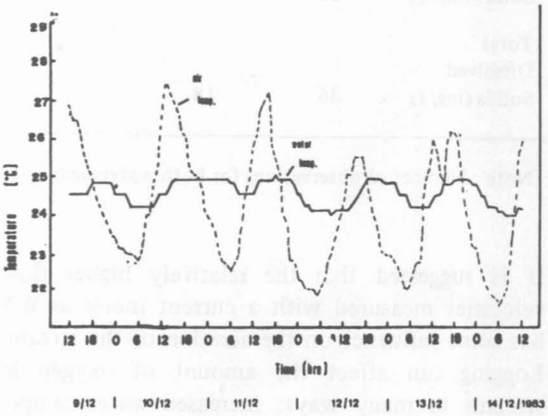

Figure 2b. 5 consecutive day air and water temperature – WB.

Throughout the diurnal water temperature observation, minor variations between hourly readings for both watersheds were noted. That small temperature variations do occur is because the amplitude of the actual water is only a small portion of the diurnal amplitude of the water equilibrium temperature (Edinger *et al.*, 1968).

Dissolved Oxygen

Dissolved oxygen range for the two watersheds are summarized in Table 1. The results for WA are significantly higher ($P < 0.01$) than WB although the mean values are 6.7 and 6.4 ppm respectively.

TABLE 1

Selected water quality characteristics for WA and WB (August 1983 to January 1984)

Parameter	Watershed A				Watershed B			
	Average	Min	Max	Standard Deviation	Average	Min	Max	Standard Deviation
Temperature (°C)	25.3	25.0	26.2	0.4	25.2	24.2	26.2	0.58
Dissolved Oxygen (ppm)	6.7	6.0	7.1	0.4	6.4	5.9	6.9	0.31
pH	5.55	5.25	5.70	0.09	5.25	5.06	5.48	0.11
Conductivity (μmhos/cm)	16	9	30	5.5	11.3	5	28	5.22
Total Suspended Solids (mg/1)	22	4	56	10.7	7	0	23	5.26
Total Dissolved Solids (mg/1)	36	18	77	13.4	31	18	42	6.30

Note : Number of observations for both watersheds – 44

It is suggested that the relatively higher flow velocities measured with a current meter at WA has some influence on the aeration of the stream. Logging can affect the amount of oxygen in streams in many ways: increased water temperature (thereby decreasing DO) as a result of clear cutting along streams – this is not clear in the study since the water temperature range data appear similar and are not statistically significant; and increase in BOD because of higher microorganism activity due to accumulation of debris. Recent logging in WA has not resulted in a substantial decrease in DO which can also be attributed to low logging intensity and the fact that no clearcutting along river banks was permitted.

Diurnal DO decline towards the evening hours was observed especially in WA *(Figure 3a)*. It is not clear, however, why this trend is such.

The 5–day diurnal DO range is slightly higher for WB (0.9 ppm) than WA (0.5 ppm) which can be attributed to a number of factors. With weather fluctuations – since photosynthetic oxygen production by aquatic plants is proportionl to light intensity (Krenkel and Ruane 1979), DO can be reduced compared with normal 'bright' days. Additionally, storm flows can also affect DO concentrations due largely to dilution and transportation of large amounts of suspended matter – a drop in DO level from 6.8 to 6.0 ppm occurred just before the storm hydrograph peaked and increased steadily after that to assume the "normal" diurnal fluctuation (*Fig. 3b*).

pH

pH recorded for WB is significantly lower than WA ($P < 0.01$) (Table 1). The difference can be explained by the higher organic matter concentration from WB reported by Shamsuddin (1984) in a separate study. Organic matter has an important influence on the pH concentration; higher organic matter content usually leads to a higher occurrence of decomposition, thus affecting pH.

The 5–day diurnal pH for WA and WB shows higher levels of occurrence during the day and lower levels during the night *(Figures 3a and*

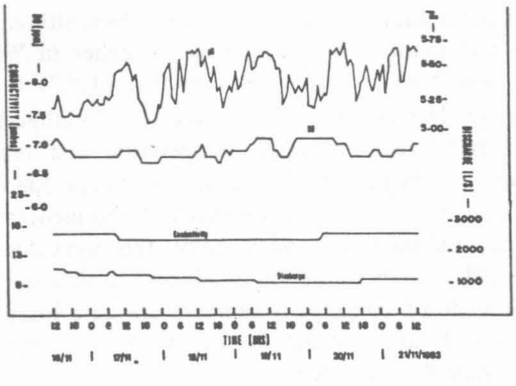

Figure 2a. 5 consecutive day water quality survey - WA.

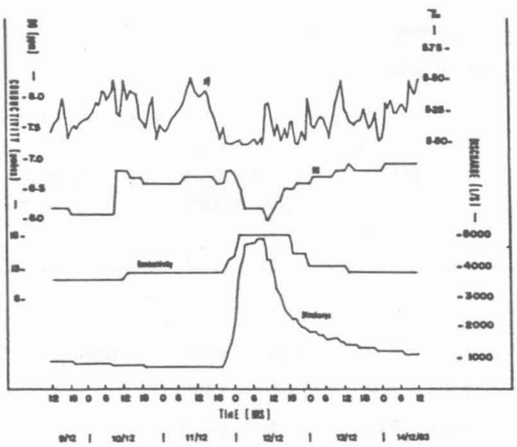

Figure 3b. 5 consecutive day water quality survey–WB.

3b) that pH remains almost consistent in terms of daily variation for both watersheds until the occurrence of stormflow This suggests that the dependence on the hydrologic response is more dominant.

Conductivity

Relatively higher conductivity levels were observed in WA and significantly different ($P < 0.01$) compared with WB (Table 1). Because of recent exposure and disturbance resulting from logging roads and skid trails, the role of surface wash becomes dominant. This can lead to an increase in dissolved solids load in the stream. Consequent to which, the increase in dissolved solids improves the ionic strength of the water, thereby raising the conductivity level. The findings of this study are in agreement with those reported by Hatch and Shea (1977), Thanasilungkoon and Ruangpanit (1981) where higher conductivity levels were obtained from disturbed forested watersheds compared with undisturbed ones.

Conductivity levels remained consistent over the 5–day diurnal recordings for WA. For WB however, an increase from 12 to 18 μmhos/cm at $25^{o}C$ was recorded during the occurrence of a storm of which higher readings were gradually registered initially with a rise in water level. For 18 hours, even after peak discharge had occurred and the stormflow had begun to recede, conductivity readings remained stable.

Total Suspended and Dissolved Solids

Table 1 shows the data range obtained for both watersheds. Statistically, TSS concentrations are significantly different ($P < 0.01$) between WA and WB. This is expected because of the more recent disturbance in WA due to logging operations in terms of soil exposure and erosion. Although the difference is significant however, a maximum of 77 mg/l and 58 mg/l recorded for WA and WB respectively, is not indicative of the whole TSS rating range.

Most samples were, unfortunately, taken during lowflows or when stormflows had receded. As commonly reported, (e.g. Heidel, 1956; McPherson, 1971; Walling, 1977; Finlayson and Wong, 1982; Carling, 1983; Lai and Samsuddin, 1985) most of the organic and inorganic material supply would have already been "flushed" out of the system during the first and earlier storms. As a result, TSS concentration is reduced after this or even after a rapid succession of storm events. Once the available material supply is reduced, concentrations decline even though discharge may continue to rise due chiefly to dilution. It also follows that the concentration of suspended solids will vary within a particular storm depending on the water stage, that is, rising, peak or falling. This is evident as Samsuddin (1984) reported maximum concentration of 362.2 mg/1 for the same basin during stormflows. Nevertheless, the results provide some indication of forest disturbance on TSS concentrations during receding and low flows.

The variation of TDS concentration is not definite and was not significantly different between watersheds. Because sampling was not intensively carried out during stormflows, it is not possible to suggest any probable TDS concentration range for the two watersheds. Much also depends on the influence of geomorphology and geology of the study area (Kunkle and Meiman 1967; Finlayson and Wong, 1982).

DISCUSSION AND CONCLUSION

Although the six month study on the water quality was largely confined to low flow samples, it is clear from the general variation patterns that logging in the watersheds has resulted in varying changes insofar as the selected water quality parameters are concerned (Table 2).

The study showed no significant difference in water temperature between watersheds although a fair number of readings were higher in WB. It has been indicated by Crowther (1982) that forest clearance would lead directly and indirectly to an increase in water temperature and temperature fluctuation. This could be mainly due to greater exposure of the streams in WB to incoming solar radiation at which point this hypothesis would have been better established with a good network of continuous temperature data loggers installed at strategic locations along streams draining the watershed.

Although water temperature has a direct relationship with DO, the small effect logging

TABLE 2

Summary of selected parameter concentration range of present and previous studies in Selangor

Description / Study Area	Area (Km^2)	Temp (^oC)	D.O. (ppm)	pH	Conductivity (μmhos/cm)	Source
Sg. Gombak*						
Station I	123.3	22.5 – 25.0	7.04 – 7.88	6.65 – 7.35	31.92 – 48.00	Bishop (1971)
Station II	(total	22.2 – 24.5	7.34 – 8.00	6.70 – 7.39	26.40 – 33.60	
Station III	catch-	23.8 – 28.5	7.25 – 7.92	6.70 – 7.64	26.40 – 34.71	
Station IV	ment)	24.4 – 29.0	6.86 – 7.52	6.30 – 7.10	25.20 – 36.54	
Station V		24.8 – 30.5	4.78 – 6.67	6.23 – 6.95	35.40 – 50.40	
Sg. Renggam**						
Station V	20.0 (total catch-ment)	–	4.80 – 7.45	5.50 – 6.50	9.20 – 27.0	Ho (1973)
Sg. Rasau						
WA	7.3	25.0 – 26.2	6.0 – 7.1	5.25 – 5.70	9.0 – 30.0	Present study
WB	4.7	24.2 – 26.2	5.9 – 6.9	5.06 – 5.48	5.0 – 28.0	

Notes :

*Landuse of total catchment area : forest – 56.7%; rubber – 23.7%; rice and irrigated land – 2.5%; urban and paved roads – 11.9%; tin mining – 4.9%; quarrying – 0.3%

**Land use of total catchment area: undisturbed forest – 1%; logged over forest – 21% cleared land, urban development – 68%; industrial – 8%; oil palm – 2%

operations had on the former suggests that there are other factors that could in combination, result in the higher DO levels recorded for one of the two watersheds. One such factor is the higher occurrence of algae and aquatic plants observed in the stream draining WA compared to WB. As pointed out by Krenkel and Novotny (1979) the most important factor which constitutes the effect of aquatic plants and DO within a particular time of day is plant density. As suggested earlier, the relatively higher flow velocity at the sampling site WA could also have contributed to the high DO concentrations.

pH levels recorded during the study period suggest an increase after disturbance in the watersheds. WA recorded significantly higher pH values than WB although both drainage basins have similar geology and soil types. The reasons are not clear although it is probable that photosynthesis from the fairly abundant aquatic plants in WA using CO_2 can raise the pH level (Thanasilungkoon and Ruangpanit, 1981). It is also likely that pH is largely influenced by hydrological conditions. Ramberg (1981) observed a significant increase in pH after improved drainage in coniferous forest due to lesser acidification of groundwater – although this observation was made in temperate conditions, it is interesting to note whether the presence of a small well-drained oil palm stand in the upper catchment of WA could also have affected pH in the same way.

The dominant role of surface wash after logging can affect the water chemistry in some ways. In this study, for instance, conductivity, TSS, and TDS were found to have been affected in varying degrees. Significantly higher conductivity levels sampled at disturbed basins compared with undisturbed ones have been reported by Hatch and Shea (1977), Thanasilungkoon and Ruangpanit (1981). Although statistical tests did not show any significant difference in dissolved solids between watersheds, there were indications that TDS can be higher in concentrations for WA. This is also evident from readings obtained for a stormflow on 12/12/1983 during the 5–day survey *(Fig. 3b)* – conductivity increased from 12 to 18 μmhos/cm. It was unfortunate, however, that only a small discharge range was sampled during the entire study preventing an otherwise detail data analysis and interpretation. Nevertheless, data variation for the parameters reflect much dependence on hydrological conditions.

The stream water quality of WA and WB has remained good after logging. As a comparison, studies on water quality conducted by Bishop (1971) and Ho (1973) in Selangor also showed variations for selected parameters (Table 2). Land use in their studies were more diverse, thereby explaining the wide range recorded. For example, temperature varied from 22.5 to 25.0°C in the upper catchment which is 99% forest and 24.8 to 30.5°C in the lower catchment of Sg. Gombak – the results suggest marked temperature changes compared to the present study. Additionally, DO range also appears wide from 4.78 to 6.6 ppm for Sg. Gombak, 4.80 to 7.45 ppm for Sg. Renggam compared with 6.0 to 7.1 and 5.9 to 6.9 ppm for WA and WB respectively.

The comparison largely indicates the important influence of land use on the selected water quality parameters. Land development including urbanisation and industrialisation are frequently considered to have drastic environmental consequences. Essentially, the concentration variation reflects a change to the previous ecosystem which almost always results in inadvertent deterioration of water quality provided adequate measures are undetaken to minimise environmental damage.

Logging can affect water quality as suggested by the results in the study. In contrast, for undisturbed watersheds, the constancy and systematic variations in the water chemistry is influenced by various geological and biological processes. It must be noted, however, that environmental considerations were observed during logging such as the use of previous logging roads, avoidance of stream crossings and cutting along stream banks. Coupled with low timber production, i.e. 14–17 m^3/ha, the impact on the selected water quality parameters can be considered minimal. However, it is not known if the impact can be more serious during logging operations. Finally, despite the short period of study, the results provide some indication of stream recovery since logging in both watersheds were carried out at different times.

ACKNOWLEDGEMENTS

The authors wish to thank the Dean of the Faculty of Forestry, Universiti Pertanian Malaysia for facilities, Saad Nyan for technical assistance, Tuan Hj. Wan Mamat Saufi Wan Yusuf, Encik Abdul Kadir Jaafar and Encik Bashri Razali for their kind cooperation. The authors are also grateful for the financial assistance granted by Universiti Pertanian Malaysia.

REFERENCES

ALI RIZA (1977): A long range development plan for main access road of Air Hitam Forest. Unpublished B. Sc. (Forestry) Project. Univ. Pertanian Malaysia, Serdang.

BISHOP, J.E. (1971): Limnology of a small Malayan river: Sg. Gombak. Unpublished Ph.D thesis. Univ. Malaya. Kuala Lumpur.

BROWN, G.W. (1974): The impact of timber harvest on soil and water resources. School of Forestry, Oregon St. Univ. Oregon.

CARLING, P.A. (1983). Particulate dynamics, dissolved and total load, in two small basins, northern Pennines, UK. *Journ. Hydrol. Sc.*, 28(3): 355-375.

CROWTHER, J. (1982): The thermal characteristics of some West Malaysian rivers. *Mal. Nat. Journ. Vol.* 35: 99-108.

EDINGER, J.E., D.W. DUTTWEILER and J.C. GEYER. (1968): The response of water temperatures to meteorologic conditions. *Wat. Resour. Res.* 4(5): 1137-1144.

EDINGTON, J.M. (1965): Some observations on stream temperature. *Oikos* 15: 263-273.

FINLAYSON, B.L. and N.R. WONG. (1982): Storm runoff and water quality in an undisturbed forested catchment in Victoria. *Aust. For. Res.* 12: 303-315.

GEIJSKES, D.C. (1942): Observations on temperature in a tropical river.*Ecology*. 23(1): 106-110.

HATCH, A.B. and S.R. SHEA. (1977): Water quality in allan road Catchment, Western Australia. Res. Pap. No. 30. For Dept. West. Aust.

HEIDEL, S.G. (1956): The progressive lag of sediment concentration with flood waves. *Trans. Am. Geophy. Union.* 37(1): 56-65.

HO, S.C. (1973): The ecology of a lowland stream: Sg. Renggam with special references to water pollution. Unpublished M. Sc. thesis. Univ. Malaya. Kuala Lumpur.

KRENKEL, P.A. and V. NOVOTNY. (1979): River water quality model construction: 17/1-17/22 in Modelling of rivers (Shen, H.W., Ed.) John Wiley & Sons. N. York.

KRENKEL, P.A. and RUANE R.J. (1979): Basic approach to water quality modelling: 18/1-18/40 in Modelling of Rivers (Shen, H.W., Ed.) John Wiley & Sons. N. York.

KUNKLE S.H. and J.R. MEIMEN. (1967): Water quality of mountain in watersheds. Hydro. Pap. No. 21. Colorado St. Univ. U.S.A.

LAI, F.S. and M. SAMSUDDIN. (1985): Suspended and dissolved sediment concentrations of two disturbed lowland forested watersheds in Air Hitam Forest Reserve, Selangor. *Pertanika* 8(1): 115-122.

McPHERSON, H.J. (1971): Dissolved, suspended and bed load movement patterns *Jour Hydrol.* 12: 221-233.

RAMBERG, L. (1981): Increase in stream pH after a forest drainage, *Ambio.* 10(1): 34-35.

SAMSUDDIN, M. (1984): Suspended and dissolved sediment concentration of two disturbed forested watersheds in Air Hitam Forest Reserve, Selangor. Unpublished B. Sc. (Forestry) Project. Univ. Pertanian Malaysia, Serdang.

THANASILUNGKOON, C. and N. RUANGPANIT. (1981): Some physical and chemical aspects of water quality under various land use of Sakaerat Environmental Research Station. For. Res. Bull. No. 81. Kasetsart Univ. Thailand.

WALLING, D.E. (1977): Assessing the accuracy of suspended sediment rating curves for a small basin. *Wat. Resour. Res.* 13(3): 531-538.

WANG, C.W. and K.C. ONG. (1978): Standard manual of chemical and biological examinations for the wastewater project network. Wastewater Reclamation Project (Mal.).

ZAINUDDIN, M.A. (1976): Long range development plan for road network and a detailed plan for the main access road of Air Hitam Forest. Unpublished B. Sc. (Forestry) Project. Univ. Pertanian Malaysia. Serdang.

(Received 3 December 1987)