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# Flow characteristics of the Tasik Chini's feeder rivers, Pahang, Malaysia

Muhammad Barzani Gasim*, Mohd. Ekhwan Hj. Toriman, Zulfahmi Ali Rahman, Mir Sujaul Islam & Tan Choon Chek

School of Environment and Natural Resource Sciences
Faculty Science and Technology, Universiti Kebangsaan Malaysia,
43600 Bangi, Selangor, Malaysia
*e-mail: dr.zani@pkrisc.cc.ukm.my

**Abstract—** The hydrological evaluation of the seven Tasik Chini feeder rivers was carried out between October and December 2004, February, March and April 2005, to assess the total stream flows for maintaining the Tasik Chini to its level. Total of nine sampling stations were established in this study, namely: Datang River, Cenahan River, Hilir Gumum River, Mid Gumum River, Kura-kura River, Melai River, Hilir Kuala Merupuk River, Hulu Kuala Merupuk River, and Jemberau River. The annual rainfall in the study area ranges from 1488 to 3071 mm or 124 to 256 mm/month. Stream flow rate during the sampling days ranged from 0.033 to 0.908 $m^3$/sec during wet season and from 0.004 to 0.245 $m^3$/sec during dry season and an average of 0.167 $m^3$/sec. Estimated water balance from historical data indicates that Tasik Chini experienced six months of water deficit (29-77 mm) and another six months of surplus (30-305 mm). Water quality analysis based on three water quality parameters – turbidity (4.67 – 28.67 NTU), total suspended solids (1.17 – 79.11 mg/L) and total dissolved solids (22.67 – 184 mg/L) indicates that the water bodies in the upstream area were polluted by physical activities. Recent activities such as mining, deforestation, agricultural and residential activities have taken place in the surrounding areas of the lake. These activities are causing environmentally degradation such as changing of hydrological characteristics of the Tasik Chini.

**Keywords:** Tasik Chini, feeder river, stream flow, total suspended solids, environment

**Abstrak—** Pengiraan hidrologi ke atas tujuh buah sungai pembekal ke Tasik Chini telah dijalankan diantara Oktober sehingga Disember 2004, Februari, Mac dan April 2005 untuk menilai jumlah air larian untuk mengekalkan paras Tasik Chini. Sejumlah sembilan stesen persampelan telah dipilih dalam kajian ini, iaitu: Sungai Datang, Sg. Cenahan, hilir Sg. Gumum, tengah Sg. Gumum, Sg. Kura-kura, Sg. Melai, hilir Sg. Kulala Merapuk, hulu Sg. Kula Merapuk dan Sg. Jemberau. Jumlah hujan tahunan dalam kawasan kajian berjulat dari 1488 sehingga 3071 mm atau 124 sehingga 256 mm/bulan. Kadar larian air sepanjang hari pensampelan berjulat dari 0.033 sehingga 0.908 $m^3$/saat semasa musim hujan dan dari 0.004 sehingga 0.245 $m^3$/saat semasa musim kering atau mempunyai nilai purata 0.167 $m^3$/saat. Anggaran imbangan air daripada rekod hidrologi mendapati bahawa Tasik Chini mengalami enam bulan defisit air (29-77mm) dan enam bulan yang lain mengalami lebihan air (30-305 mm). Analisis kualiti air berdasarka tiga parameter kualiti air seperti turbiditi, Jumlah Pepejal Terampai dan Jumlah Pepejal Terlarut telah dapat dibuktikan bahawa jasad air di kawasan hulu telah tercemar oleh beberapa kegiatan fizikal. Hasil kajian menunjukkan, Jumlah Pepejal Terlarut berjulat dari 22.67 sehingga 184 mg/L, Jumlah Pepejal Terampai (1.17 – 79.11 mg/L) dan turbiditi (4.67 – 28.67 NTU). Kegiatan terkini seperti perlombongan, pembalakan, pertanian dan penempatan dikenal pasti berlaku disekeliling kawasan tasik. Aktiviti-aktiviti ini telah menyebabkan berlakunya kemerosotan sekitaran terutama yang melibatkan perubahan ciri dan sifat hidrologi kawasan Tasik Chini.

**Kata kekunci:** Tasik Chini, sungai pembekal, luahan, jumlah pepejal terampai, sekitaran

## INTRODUCTION

Surface water resources have played an important role throughout the history in the development of human civilization. About one third of the drinking water requirement of the world is obtained from surface sources like rivers, canals, and lakes (Das & Acharya, 2003). Hydrological aspect is the most important factor for maintaining the stability of the lake ecosystem. Water level of the Tasik Chini is definitely depending on the feeder rivers discharge that comes from the surrounding area. Tasik Chini recently has undergone devastating situation as a lake environment since 1984 or earlier due to development activities in the surrounding areas such as oil palm plantations and residential developments. Tasik Chini was once well known to be rich in biological resources. The condition of Tasik Chini became worse when a small dam was built in 1995 to retain water in the lake for tourism purposes (Mushrifah Idris & Ahmad Abas, 2005). In general view, a dam is a visible tool for managing freshwater resources, contributing to electricity power, drinking water supply, recreation, flood control, fisheries, aesthetics and transportation (Hammer & Mac Kichan, 1981; UNEP, 2003). Despite of their benefits, many negative impacts have

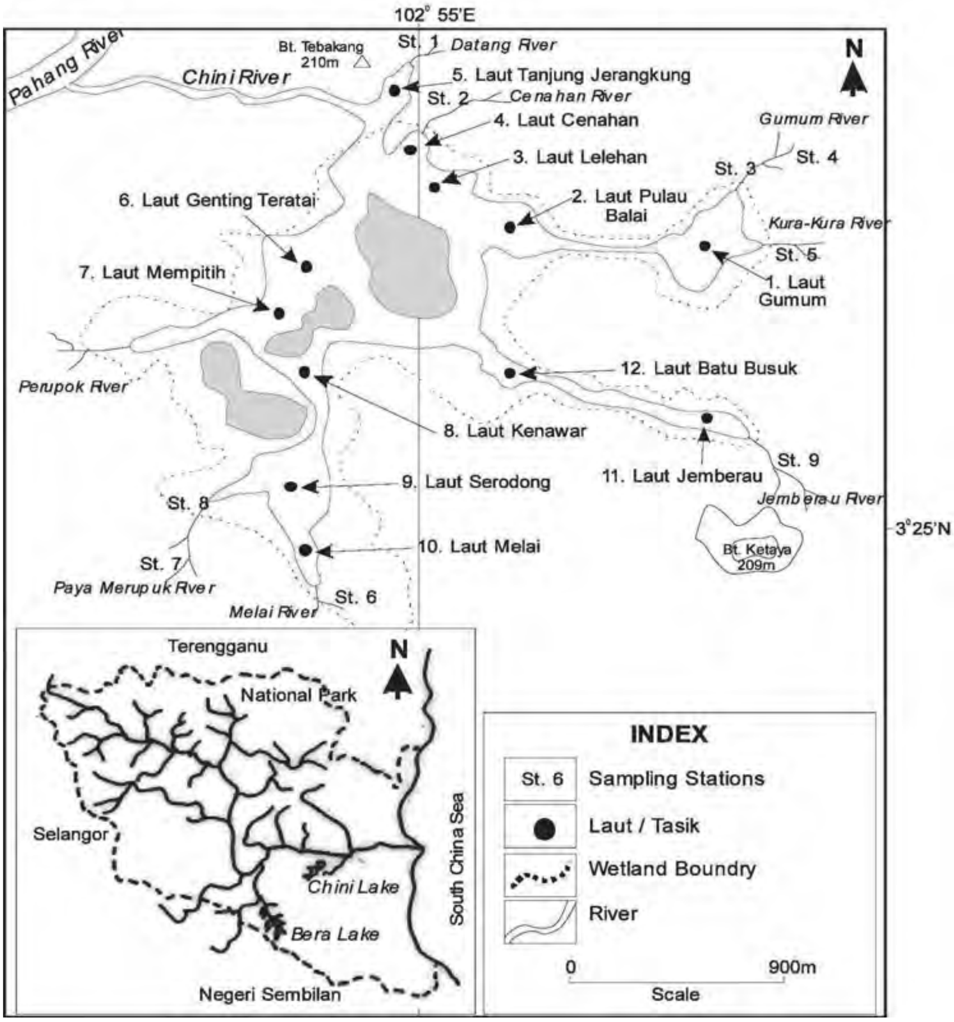


**Figure 1:** Location of Tasik Chini and their feeder rivers.

been attributed to dams. Dams often disrupted the existing structure, and had caused water movement became less dynamic by modifying flow regimes, disrupting sediment transport, altering water quality and severing their biological continuity (David and Leroy, 2002). The surrounding environment of the lake being disturbed due to water level increase and water overflow to the land, causing thousands of plants became suffocated and died. Negative impacts have been identified on the dam such as changes in downstream water flows, degradation of water quality, increased in-lake sedimentation and river bank scouring (Muhd. Barzani *et al.,* 2004). Lake water was defined only safe for recreation purpose (Ahmad Abas *et al.,* 2005). Since 1998, after the barrage was cut down, another problem arose, which causes low water level, loss of aquatic biodiversity, and the worst impact is the decrease in number of local and international tourists. A better understanding of the hydrological properties of water bodies will be beneficial to Tasik Chini and will make it possible to develop and manage the lake in more sustainable way. A research on the hydrologic and water quality of Tasik Chini was carried out in order to examine the existing physical environment during the study period from October 2004 to April 2005. The main objectives of the research are to identify the stream flow and discharge pattern of the Tasik Chini's feeder rivers between dry and wet seasons, as well as to identify pollution sources.

## GEOMORPHOLOGY AND DRAINAGE

Tasik Chini is located in the southeastern region of Pahang, Malaysia. The lake system lies between 3°22´30″ to 3°28´00″ N and 102° 52´40″ to 102° 58´10″E. The area has a humid tropical climate with two monsoonal periods, characterized by bimodal patterns: southwest and northeast monsoons bring annual rainfall from 1488 to 3071 mm. The open water area has expanded greatly since 1995, due to increased retention of water after the construction of a barrage at Chini River. Tasik Chini is surrounded by various vegetated low hills and undulating lands which constitute the watershed of the region. There are three hilly areas surrounding the lake: (1) Ketaya Hill (209 m) located at the southeast; (2) Tebakang Hill (210 m) at the north and (3) Chini Hill (641 m) at the southeast. Seven river systems were identified as feeder rivers for the Tasik Chini namely (1) Datang River, (2) Cenahan River, (3) Gumum River, (4) Kura-Kura River, (5) Melai River, (6) Kuala Merupuk River and (7) Jemberau River. The lake consists of 12 water bodies which are known by local people as laut, they are: 1. L. Gumum, 2. L. Pulau Balai, 3. L. Lelehan, 4. L. Cenahan, 5. L. Tanjung Jerangkung, 6. L. Genting Teratai, 7. L. Mempitih, 8. L. Kenawar, 9. L. Serodong, 10. L. Melai, 11. L. Jemberau and 12. L. Batu Busuk. The lake drains northeasterly into Pahang River via Chini River, which flows for 4.8 km before it reaches Pahang River (Figure 1).

## MATERIALS AND METHODS

### a. Sampling and Preservation

Global Positioning System (GPS) was used to determine the coordinate of sampling stations and to re-confirm the location of stations during the subsequent sampling periods. Nine sampling stations were selected during the first trip to Tasik Chini. These 9 stations were established as the main feeder rivers of the lake: Datang River (Station 1), Cenahan River (Station 2), downstream of Gumum River (Station 3), middle of Gumum River (Station 4), Kura-kura River (Station 5), Melai River (Station 6), upstream of Kuala Merupuk River (Station 7), downstream of Kuala Merupuk River (Station 8) and Jemberau River (Station 9). Current flow was measured using flow meter (model FP101) and a rangefinder (model Bushnell 20-0001) was used to measure the river width. One liter sample of surface water was collected about 10 cm below the surface using HDPE bottle (500 ml) for measuring their concentration using standard laboratory methods (APHA, 1998). The samples were labeled, preserved using acid nitric and stored in an icebox and transported to the laboratory for analysis within 48 hours.

### b. Water Balance Procedure

Detail hydrological balance conditions are discussed below. Note that most of the climatological data were obtained from Muazam Shah Climatological Station with permission from Malaysian Meteorological Department. The station is located about 65 km from the field area and is the nearest climatological station from the study area. In this study, daily and monthly rainfall data from 1990-1999 were abstracted directly from the climatological records whiles the potential evapotranspiration (PE) and runoff (r) were calculated using the equations below:

$PE = 1.63N\ [10\ T/I]^a$ ……..………...............…..........[1]

Where N = a factor to correct for unequal day length, T = monthly mean air temperature, and I = summation of monthly heat index.

Using this equation, it is assummed that PE in open water areas and wetlands is equal to reference PE during the calculation period. The r was then calculated using the equation (Mohd Ekhwan, 2005):

r = Precipitation (P)–Potential Evapotranspiration (PE) ....[2]

Data obtained from the historical records and compute data were then used to estimate the average water balance of the lake. By presuming that inflow waters were derived from direct and indirect rainfalls to the lake and outflow waters through evaporation and runoff to the Chini River, a simple water balance equation can be expressed as below,

(Inflow) $P_{direct} + P_{indirect}$ = (Ourflow) PE + r …..............…[3]

where P = precipitation; PE = Evapotranspiration and r = runoff.

The monthly water balance of Tasik Chini is tabulated in Table 1. The result indicates a deficit on water balance for six months, namely January, February, March, June and July while the other months show surplus water between 30 mm (May) to 305 mm (December). The fluctuation of water balance scenario reflects the volume of lake as discussed below.

### c. Analytical Methods

Water samples were analyzed in the laboratory to determine three water quality parameters. Total suspended solid (TSS) was measured using filtration methods with membrane filter 45 µm and vacuum pump (gravimetric method), total dissolved solid (TDS) was measured using sample water after filtration for TSS; turbidity was measured using a spectrophotometer.

## RESULTS AND DISCUSSIONS

### a. Hydrology

Hydrological analyses were carried out to evaluate rainfall pattern as a water resource, drainage systems and their discharge and fluctuation of water body (Gray, 1970; Ceballas & Schnabel, 1998 & Muhd. Barzani Gasim *et al.* 2005a). Annual total rainfall (1990 to 2004) for the Chini area range from 1488 mm to 3071 mm, the highest rainfall was 3071 mm in 1994 and the lowest was 1488 mm in 1997 and the average was 2235 mm (Figure 2). The total annual rain days (1990 to 2004) range from 154 to 197 or an average of 178 days. The highest total rain days were identified in 1993 and 1994 (197 and 190 days respectively), while in 1997, there was only 154 days (Figure 3). The total annual rainfall was 2192 mm in 2004, the highest rainfall was recorded as 553.5 mm in October 2004 and the lowest was recorded as 16.2 mm in February 2004 (Figure 4). The highest number of rain days (21 days) was obtained during the wet season, especially during October to December,

**Table 1:** Monthly water balance for Tasik Chini catchment.

| Month | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P, mm | 85 | 51 | 115 | 164 | 146 | 88 | 98 | 108 | 186 | 285 | 296 | 466 |
| PE, mm | 127 | 87 | 106 | 108 | 97 | 147 | 152 | 161 | 124 | 118 | 100 | 89 |
| r, mm | 35 | 25 | 38 | 23 | 19 | 12 | 18 | 22 | 27 | 50 | 51 | 72 |
| WB, % | -77 | -61 | -29 | +33 | +30 | -61 | -72 | -75 | +35 | +117 | +145 | +305 |

Note: - deficit; + surplus

while February recorded the lowest number of rain day (5 days) in 2004 (Figure 5). During the half year of 2005, total rainfall ranged from 5.3 mm (February) to 182.9 mm (May) or an average of 98 mm/month (Figure 6). Total rain days for 2005 ranged from 1 day (February) to 11 days (June) or an average of 7 days/month (Figure 7).

**b. Stream Flow**

Stream flow from each feeder river of Tasik Chini is relatively low; it ranges from 0.0042 to 0.9083 $m^3$/sec or an average of 0.1674 $m^3$/sec. Flow of Kuala Merupuk River was the highest, it was 0.9083 $m^3$/sec and Melai River was the lowest (0.0042 $m^3$/sec). Datang River is considered as a dead river, because there is no flowing water. Similar inferences have been made on earlier observations in different feeder rivers of Tasik Chini (Muhd. Barzani *et al.*, 2005b; Tan *et al.,* 2005; Norlida *et al.,* 2005). Stream flow of the following rivers mainly depends on rainfall events; highest steam flows were obtained during wet season, for example: 0.033 to 0.6166 $m^3$/sec in October 2004, 0.172 to 0.9083 $m^3$/sec in December 2004. While during dry season, especially February to April 2005 lower steam flow was recorded; 0.0118 to 0.207 $m^3$/sec in February 2005, 0.0042 to 0.2448 $m^3$/sec in March 2005 and 0.0029 to 0.0718 $m^3$/sec in April 2005 (Figure 8). Average stream flows for 9 feeder rivers of the Tasik Chini are: 0.2162 $m^3$/sec on October 2004, 0.5308 $m^3$/sec in December 2004, 0.0624 $m^3$/sec in February 2005, 0.0655 $m^3$/sec in March 2005 and 0.0157 $m^3$/sec. in April 2005.

Average stream flow for December 2004 was chosen as a model for wet season while April 2005 for dry season to show how important the influence of season to support water level of the lake. Average stream flow for December 2004 is 0.5308 $m^3$/sec and 0.0157 $m^3$/sec for April 2005. Total flow from other scattered small sub basins (other than 7 sub basins) based on the stream flow calculation is 0.271 $m^3$/sec.

The average depth of the Tasik Chini is 1.5 m (range from 0.5 to 2.2 m), the area of the lake is 2.02 $km^2$, so the volume of the lake can be calculated as 2.02 $km^2$ or $2.02\times10^6$ $m^2$ x 1.5 m = $3.03\times10^6$ $m^3$ or 3,030,000 $m^3$. The difference between the high and low water levels of the Tasik Chini can be determined in the barrage wall, usually it fluctuates from being 0 to 25 cm lower. During wet seasons, water overflow from the barrage and during the dry seasons, water level lower down to 30 cm. Based on the calculation: $2.02\times10^6$ $m^2$ x 0.30 m = 606,000 $m^3$ of water in the lake decreased during the dry season, due to the low flow of the feeder rivers or water lost due to evaporation, leakage from the barrage or breakthrough seepages.

Daily stream flow measurements using automatic sampler from March to April 2004 (inter monsoon period), which were obtained from the Gumum River monitoring gauge, show that the results are within the threshold of 0.0026 $m^3$/sec. to 1.248 $m^3$/sec. (Mohd Ekhwan & Sulong Mohamad, 2004). Stream flow based on field measurement from October and December 2004, February, March and April 2005 on Gumum River ranges from 0.0132 to 0.5126 $m^3$/sec. Fluctuation of stream flow can be seen from the Artificial Neural Network (ANN) result (Figure 9). Data obtained from the historical records and computed data were then used to estimate the average lake's water balance. By presuming that inflow of water was derived from direct and indirect rainfalls to the lake and outflow of water through evaporation and runoff to the Chini River, a simple water balance equation can be expressed as below:

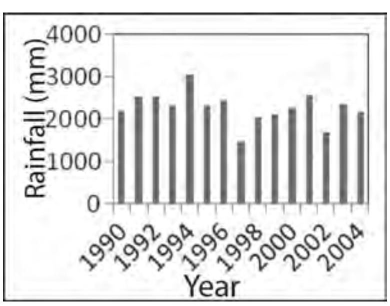


**Figure 2:** Distribution of rainfall from 1990 to 2004.

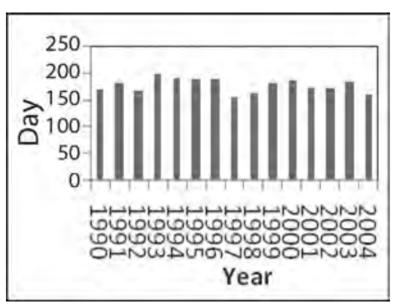


**Figure 3:** Distribution of rain days from 1990 to 2004.

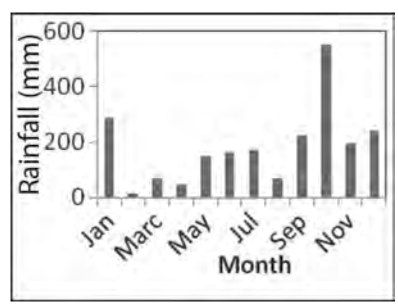


**Figure 4:** Distribution of rainfall from January to December 2004.

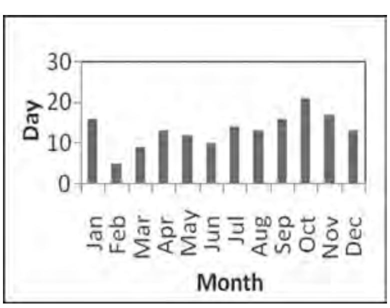


**Figure 5:** Distribution of rain days from January to December 2004.

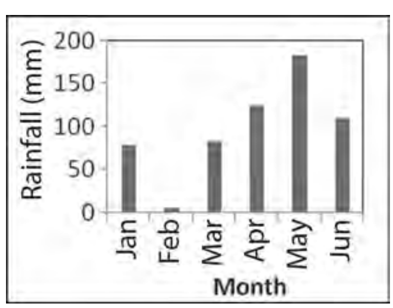


**Figure 6:** Distribution of rainfall from January to June 2005.

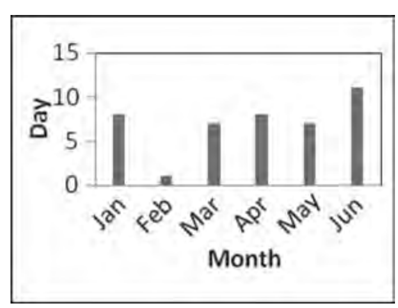


**Figure 7:** Distribution of rain days from January to June 2005.

$P_{direct} + P_{indirect} = E + r$, where
P = precipitation (2235 mm)
E = Evaporation (606 000 m$^3$)
r = runoff (3030, 000 mm$^3$)

## c. Water Quality Status

In general, the water quality of the sampling sites could provide useful information on landuse activities within the lake's catchment. Turbidity, TDS and TSS were chosen to show their relation to human activities as well to discharge.

### Turbidity

The turbidity of 9 sampling stations varies from 4.67 to 28.67 NTU, or an average of 16.41 NTU; the highest (28.67 NTU) at Cenahan River (Station 2) during the wet season and the lowest (4.67 NTU) at Melai River (Station 6) during the dry season. The ranges of turbidity in the different sampling times were: 11.0 to 28.67 NTU in October; 16.0 to 27.33 NTU in December 2004; 5.33 to 22.67 NTU in February; 10.67 to 18.33 NTU on March and 4.67 to 21.67 NTU in April 2005 (Figure 10). Overall, turbidity is higher during the wet season. Comparatively the highest turbidity value was recorded at Kura-Kura River during both seasons. According to International Standards, the acceptable turbidity of water for domestic use ranges from 5-25 NTU (Hammer & Mac Kichan, 1981). INWQS does not propose any threshold level for turbidity of fresh waters for the support of aquatic life. The Ministry of Health has set a threshold level of raw water turbidity at 1000 NTU.

### Total Dissolved Solid (TDS)

The range of TDS values in this study are: 73.33 to 112.76 mg/L in October; 75.33 to 100.67 mg/L in December 2004; 22.67 to 78.33 mg/L in February; 50 to 8.67 mg/L on March and 35.33 to 66.67 mg/L in April 2005 (Figure 10). The range of TDS in different seasons varies from 22.67 to 112.76 mg /L and within the permissible limit of World Health Organization (WHO, 1984). The highest concentration (112.76 mg/L) was measured at Kuala Merupuk River (Station 8) during wet season and the lowest value (22.67 mg/L) was recorded at Datang River during dry season (February 2005). TDS values at 9 feeder rivers are within Class I (INQWS). In general, TDS increases from dry to wet season. During the dry season (February to April 2005) TDS ranges from 22.67 to 80.67 mg/L and it ranges from 73.33 to 112.67 mg/L during the wet season (November to December 2004). The range of TDS values were higher (45.33 to 108 mg/L) at Jemberau River (Station 9) in both seasons.

### Total Suspended Solids (TSS)

The TSS values range from 1.17 to 34.0 mg/L or an average of 12.27 mg/L; the highest (34.0 mg/L) was recorded at Kura-kura River (Station 5) during the dry season and the lowest (1.17 mg/L) at Kuala Merupuk River (Station 7) during the wet season. The ranges of TSS in the different seasons are: 1.17 to 19 mg/L in October, 4.25 to 27.83 mg/L in December 2004, 4.0 to 34.0 mg/L in February, 4.5 to 26.67 mg/L in March and 4.17 to 22.5 mg/L in April 2005 (Figure 11). Comparatively the TSS values were higher at Gumum River during the both seasons. There was a sudden rise of TSS values between February 2005 and March 2005 at Gumum River (Stations 3 & 4) and Kura-kura River (Station 5). Overall, the TSS concentration was considered low. Acceptable range of TSS value is from 25 to 50 mg/L for Malaysian rivers. The INQWS threshold level of TSS for supporting aquatic life in fresh water ecosystems is 150 mg/L (DOE, 1994).

## d. Correlation Analysis

Statistical analysis between hydrology and physical water quality parameters shows that there are correlations between stream flow and turbidity (r=0.60) and TDS (r=0.40) during wet season and no significant correlation during dry season. Most of the correlations were indicated as between very weak and weak with r value ranging from 0.20 and below (Figure 12).

From the correlation analysis, it shows that the pollutant loads came from dilution and not from erosion. Raining during the wet season had diluted the soil into the river and it increases the concentration of TDS and turbidity. Stream flows were recorded during the wet and dry seasons and rainfall data of the earlier five days of sampling days were collected. The relationship between discharge and rainfall showed a significant correlation ($r = 0.822$, $p= 0.001$) and shown as positive slope (Figure 13).

## e. Sources of Pollution

The environment of Tasik Chini is strongly influenced by total discharge and quality of the feeder rivers. Discharge

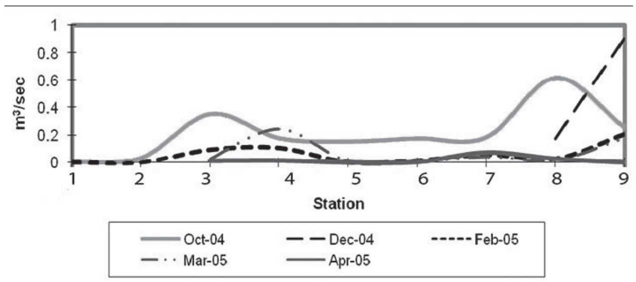


**Figure 8:** Stream flow distribution in 9 sampling stations.

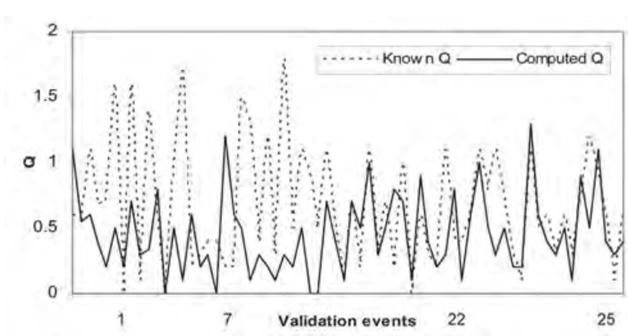


**Figure 9:** Validation output of ANN model for Gumum River, Tasik Chini.

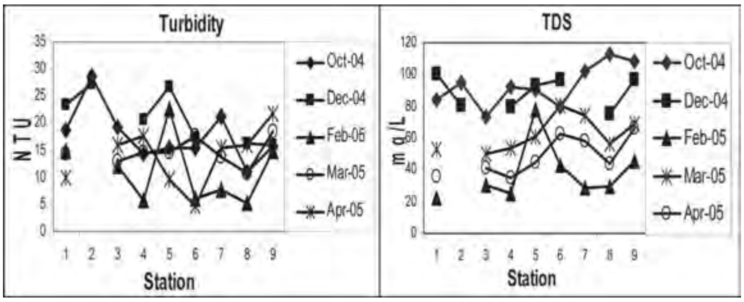


Figure 10: Distribution of turbidity and TDS values at 9 sampling stations.

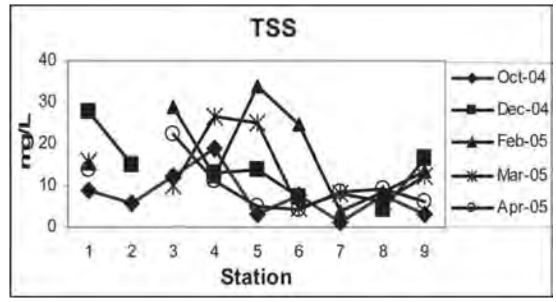


**Figure 11:** Distribution of TSS values at 9 sampling stations.

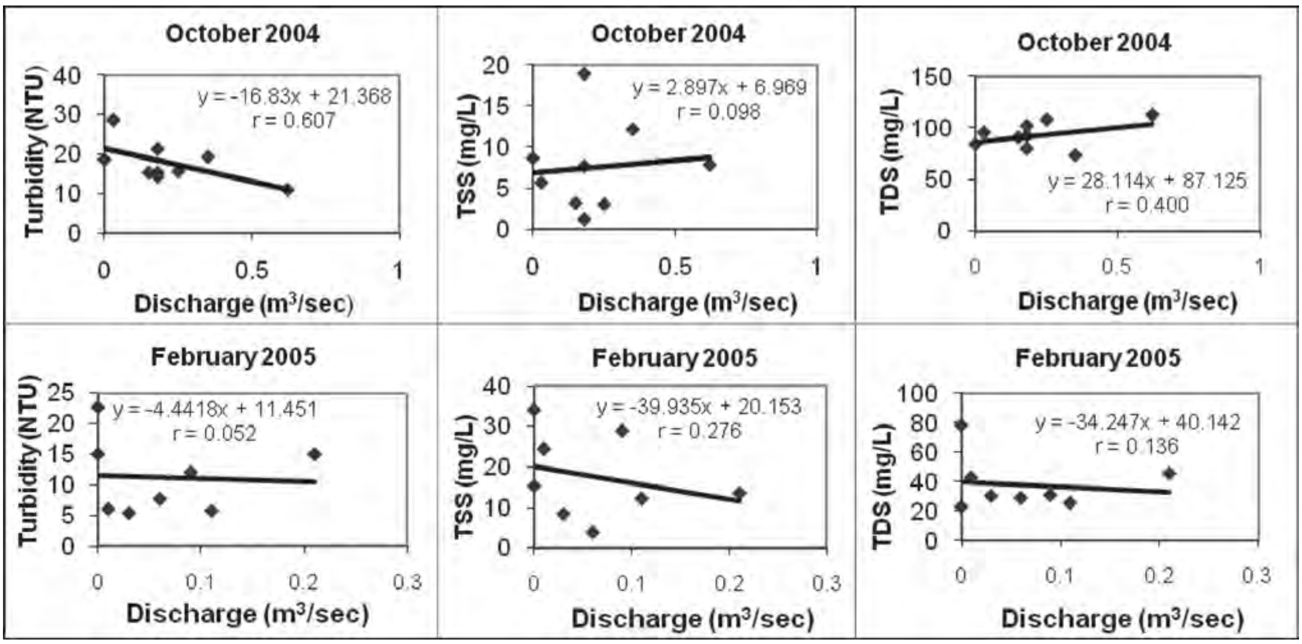


**Figure 12:** Relationship between discharge and TDS, TSS, Turbidity, during wet (October 2004)and dry (February 2005) seasons.

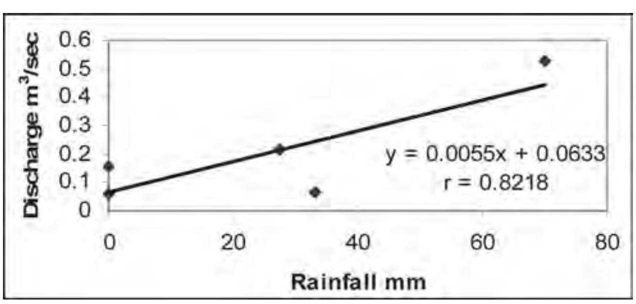


**Figure 13:** The relationships between rainfall and discharge.

from each sub basin is strongly depending on weather condition and total runoff. The quality of the inflowing water from each feeder river to the lake is a function of the pollutant sources. The above criteria show that pollution sources were carried during rainfall through water runoff along the different land use from the upstream into the Tasik Chini. Sources of pollution include direct runoff from land clearing activities, i.e. deforestation, agriculture and cultivation, and siltation due to reversible flows from Pahang River entering the Tasik Chini through Chini River during wet season.

## CONCLUSIONS

Stream flow discharge from each feeder river to Tasik Chini is directly correlated with rainfall. In the dry season rainfall was low and the discharge from each feeder river was low compared to the wet season. The feeder rivers' water quality status in the catchment is mainly influenced by the stability of the catchment area. A basin protection strategy in the form of development of the monitoring system, assessment of pollution, pollution control and basin conservation should be proposed in order to minimize the impact. If proper alternative arrangements like sustainable management of water resources, protection from logging, and increase in the awareness of local people are not taken into action, the environment of the Tasik Chini may deteriorate at an alarming rate.

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