SEDIMENT LOAD ANALYSIS IN LAKE CHINI

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ABSTRACT

This study is significant to be conducted to reduce the physical impacts of human activities such as water quality deterioration and destabilization of the stream bed and banks. The mining activity near Jemberau River can destabilize channel form, which may result in sedimentation at the downstream area. The rate of sediment discharge and the rate of water quality deterioration are expected to increase near the mining area close to Jemberau River. Bedload and suspended load sampling were carried out in the dry and wet months from September to December 2016. High suspended solid concentrations (SSC) were recorded in Chini and Jemberau Rivers especially during the wet months. Total Maximum Daily Load (TMDL) estimation for 5, 10, 15 and 20 years are also given.

Keywords: Sediment load analysis, Suspended sediment concentration, Total Maximum Daily Load (TMDL)

Introduction

Uncontrolled development activities have significantly affected the ecological, biological and hydrological characteristics of the Lake Chini catchment area. It could be categorized as a sensitive ecosystem due to the responses to the changes from its surrounding environment. According to Sujaul, (2012), the hydrology and the mechanism of sediment loading at the Lake Chini was dependent on the hydrometeorological conditions.

The activities related to the contribution to the economic development have severely affected the Lake Chini catchment for over 20 years. There are several activities which contributed to the tremendous change of Lake Chini such as mining, oil palm planting, deforestation, agricultural and unsustainable development. For instance, the agriculture, logging and mining activities have resulted in significant land use change within the catchment area of the lake and have affected the nearby ecosystems of the lake. According to Fernandez, (2012), conversion of secondary forest to mono-crop plantations, mainly oil palm and rubber has rapidly led to the deterioration of the lake ecosystem. Moreover, an abandoned mine was also reactivated to start iron-mining activities in early 2005. With the increased demand for iron ore, more mines have recently been opened close to the lake, further adding to the deterioration of the water quality (Fernandez, 2012). As a result, the impact of these activities may cause some environmental problem to the

Lake Chini and adjacent areas by changing the area's hydrological characteristics, which in the long terms may lead to deterioration.

The mining activity is located near Jemberau River, one of the feeder rivers for Lake Chini. Activities such as land clearing, sand mining, reservoir construction and land use change may have some influence on the lake water quality. The objectives of this paper are to determine the physical properties of soil for the riverbed of Jemberau River due to the mining activity and to measure the sediment load concentrations of Jemberau River and Chini River.

Characteristics of Lake Chini and Related Arising Issues

Lake Chini is the second largest freshwater lake in Malaysia located in the east of Peninsular Malaysia in the State of Pahang. It comprises of 12 adjoining water bodies giving it the characteristic finger-like projections. These open water bodies are recognized as laut ('seas') by the local community. The 12 'seas' are Gumum, Pulau Balai, Cenahan, Tanjung Jerangking, Genting Teratai, Mempitih, Kenawar, Serodong, Melai, Batu Busuk, Labuh and Jemberau (Sujaul et al., 2013; Jamil et al. , 2012; and Toriman et al. , 2012). Lake Chini is drained by Chini River which meanders for 4.8 km before flowing into Pahang River, the longest river in Peninsular Malaysia. Pahang River forms the largest river basin with a total catchment area of 27,000 km2.

The area has a humid, tropical climate with two monsoon periods, which characterized by a bimodal pattern and received annual rainfall between 1488 mm to 3071 mm. The highest rainfall of 3071.4 mm was recorded in 1994. The mean annual rainfall is 2500 mm with the temperature range is within 21°C to 32°C. Potential evapotranspiration is between 500 mm and 1000 mm. Since 1994, the open water area has expanded due to the increment of water retention after the construction of a barrage at the downstream of Chini River. The lake drains northwest into the Pahang River via the Chini River which meanders for 4.8 km before flow into the Pahang River (Sujaul et al., 2015).

Chini River has experienced the deterioration of water quality due to the sedimentation process and unbalanced development at the surrounding of the catchment area. It is imperative to measure the streamflow and sedimentation rate for the Chini River because it is the only river that flows out of Lake Chini to Pahang River. Idris and Kutty, (2004), reported that the condition of Lake Chini has worsened when a small dam was built in 1995 to retain the lake's water level for tourism purposes. According to the study conducted by Sujaul et al. (2012) and Sujaul et al. (2015) at Chini River; there was a significant correlation between sediment load and discharge. The studies found that the major contributions of sediments had originated from i) land use activities, ii) existence of weir at the downstream site which blocked the sediments motion, iii) back water flow from Pahang River especially during the wet season and iv) river bank erosion.

Based on the report from Action Committee of Lake Chini 2012, the strong river current from Pahang River which surges into the lake through Chini River during the high monsoon season also brings in a high loading of suspended solids and other contaminants such as ammonia-N. All of the above mentioned scenarios are the main causes of the continuous deterioration of Lake Chini ecosystem.

Description of Study Area

The feeder river at Lake Chini that was affected by mining activity is the Jemberau River. On the other hand, Chini River has faced continuous impacts from other feeder rivers, especially from Jemberau River. The mining activity is located at the upstream of Jemberau River and the operation was discontinued in 2015. The location of the Jemberau River and the area of mining activity at upstream of Jemberau River is shown in the map of Figure 1. Figure 2 and 3 shows the photos of Jemberau River andthe mining locations taken during the site observation, respectively. It is noted that the sediment and water samples were taken at locations as shown in Figure 2 and 3.

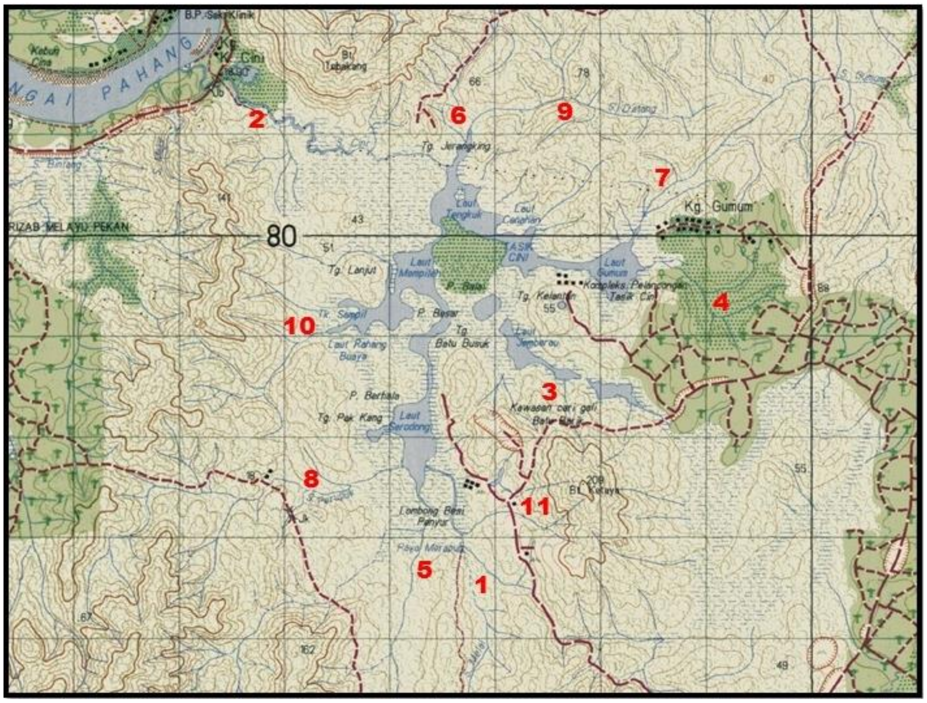

Figure 1. Illustration of all river networks in Tasik Chini with locations of the different landuse activities. (with modifications)
Note: 1 Sg. Melai; 2 Sg Chini; 3 Sg Jemberau; 4 Sg Kura-kura; 5 Sg Serodong; 6 Sg Jerangking; 7 Sg Gumum; 8 Sg Perupuk; 9 Sg Datang; 10 Sg Kenawar; 11 Sg Chok

Source: Drainage and Irrigation Department (DID) Pekan, Pahang

Figure 2.View of Jemberau River

Figure 3. View of Mining Activity at Upstream of Jemberau

Figure 4. Chini River (Upstream)

Figure 5. Chini River

Materials and Method

Field Sampling Program

Field sampling was conducted from September to December 2016 within the Jemberau River and Chini River. Suspended load sampling was carried out in accordance to DOE (2006). A method for measuring bed load was carried out according to the Manual on Operational Methods for the Measurement of Sediment Transport and World Meteorological Organization, Operational Hydrology Report No. 29 (Yuqian, 1989). The Hydro-Bios Van-Veen Grab Sampler was used to grab bed materials by lowering the grab in an open position by a line.

Laboratory Analysis

*Suspended Sediment Concentration***.** A known volume of raw water is filtered through a pre-weighed 0.45 µm pore diameter filter paper. The suspended sediment concentration is then calculated where the dry weight (in grams) of the filter paper plus retained sediment, minus the original weight of the filter paper, all divided by the volume (ml) of the sample, as given in Equation 1 below:

Total suspended sediment concentration (mg/L) = $[W_{\text{sand + silt + clay}}/V_{\text{sample}}] \times 10^6$ Equation 1

Sediment Grain Size. Sieve analysis and hydrometer test can be used to determine the particle size distribution of the sediment size. Sieve analysis is for sediment size greater than 0.063mm and hydrometer test is for sediment size less than 0.063mm. Reference was made to the British Standard, BS 5930:1981 consisting of test for the classification of soil and for the determination of basic physical properties.

Data Analysis. Sediment load can be estimated from the total of bed load and suspended load. Equation 2 and Equation 3 are equations for the calculation of suspended load discharge and bed load discharge (Blanchard *et al.*, 2011)

$$Q_s = Q_w \text{ x SSC x K} \quad \text{Equation 2}$$

where Q_s is the suspended load discharge in tons per day, Q_w is the instantaneous water discharge (ft^3/s), SSC is the Suspended Sediment Concentration (mg/L) and K is a coefficient (0.0027) to convert the units of water discharge and SSC into tons/day and assumption of specific gravity is 2.65 was made.

$$Q_b = \text{K x} \left(\frac{W_t}{T_t}\right) \text{x} M_t \quad \text{Equation 3}$$

where Q_b is the bed load discharge in tons per day, K is the conversion factor (0.381), W_T is the total width of the stream which the sample was collected, T_t is the total time the sampler was on the streambed and M_t is the total mass of sample collected, in grams.

Result and Discussion

Composition of the Bed Materials at Jemberau River and Chini River. Details of particle size distribution for Jemberau River and Chini River are shown in Table 1. The uniformity coefficient, C_u gives an indication of how well sorted or poorly sorted a sample is. Some commonly used measures are the uniformity coefficient. The analysis specifies that the C_u values for Jemberau River are well-graded soil as compared to Chini River. The value of D_{50} in the Jemberau River also signifies that the type of sediments could be categorized as uniform sediment and lightweight materials based on the range of particle size proposed by Yalin (1963) in Haddachi et al. (2013).

Table 1.Composition of the bed material samples (8 – 14 September 2016)

Date	Sampling Location	Composition	C_u/C_c
8/9/2016	Sg. Chini (Downstream at navigation lock)	1% gravel 84% sand 15% fine silt and clay	1.67/0.94
14/9/2016	Sg. Chini (Upstream at navigation lock)	1% gravel 84% sand 15% fine silt and clay	2.00/1.00
14/9/2016	Sg. Chini (Downstream at navigation lock)	64% sand 36% fine silt and clay	2.64/0.95
8/9/2016	Sg. Jemberau (at mining area)	15% gravel 81% sand 4% fine silt and clay	9.29/1.34
14/9/2016	Sg. Jemberau (at mining area)	15% gravel 81% sand 4% fine silt and clay	8.59/0.82

Analysis of Sediment Load for Jemberau River and Chini River. The suspended load was high during the wet weather condition with heavy rain and high tide. The highest total sediment load during the sampling measurement was found during the high tide condition which was estimated to be 1732.5 kg total load/day. Table 2 shows the results of sediment load estimation for Jemberau River.

Table 2.Result of sediment load estimation for Jemberau River

Date of Sampling	Weather Condition during Sampling	Suspended Load (kg/day)	Bed Load (kg/day)	Total Load (kg/day)
24-Nov-16	Heavy Rain	1180.6	NA	-
1 Dec 2016	After Rain	564.44	NA	-

8 Dec 2016	Sunny	266.56	10.62	277.18
15 Dec 2016	Sunny (Tide)	60.43	6.13	66.56
22 Dec 2016	Sunny (High Tide)	1715.6	16.92	1732.5
29 Dec 2016	Sunny (High Tide)	282.8	NA	-

Comparative analysis of suspended solid concentration (SSC) at Jemberau River and Chini River is shown in Figure 6. The graph illustrated that the concentration of suspended solids was high in Chini River as compared to Jemberau River. This may be attributed to sediments from Jemberau River that was transported to the downstream of Chini River. However, there is no recorded data for SSC at the upstream of Chini River during the wet months.

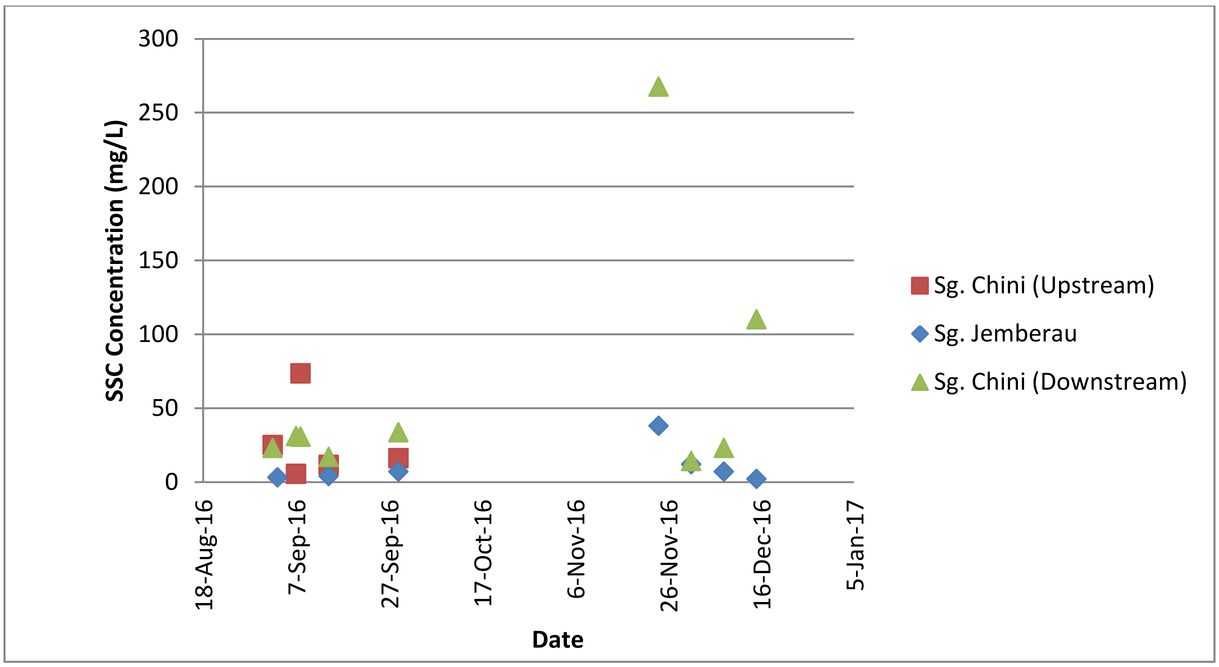

Figure 6.Comparison of SSC at Jemberau River and Chini River

Total Maximum Daily Load. Total Maximum Daily Load (TMDL) for suspended sediment concentration can be calculated using Equation 4 below. TMDL estimations are divided into three (3) events: before 2011 to 2011, 2011 to 2012, and 2012 to present. Estimation of TMDL requires sufficient value of Margin of Safety (MOS) due to the uncertainty of data analysis for allowing a safety buffer in between the calculated TMDL and the actual load of pollutants. The larger water body size will give a greater amount of contaminants that can be presented while still maintaining the MOS.

Table 3 shows the soil loss proposed by Sujaul et al. (2013). Assuming a MOS of 25% with the expansion details of the mining area (based on satellite images of 2011 to 2014) the TMDL values are given in Table 4.

TMDL = Load Allocations + Margin of safety + Future Growth Equation 4

Table 3. Drainage area and estimated soil loss from selected sub-catchments in Lake Chini (Sujaul et al., 2012)

Feeder River	**Drainage Area (km^2)**	**Soil Loss (tonnes/km^2/year)**
Melai	3.96	9.10
Paya Merapuk	12.7	7.58
Chenahan	0.69	14.91
Jemberau	**4.55**	**5.77**
Kura kura	2.92	6.53
Gumum	13.06	16.45
Datang	4.81	17.74

Table 4. Bukit Ketaya mining area (ha) of subcatchments in Chini Lake catchment area (Sujaul et al., 2013)

Landuse-Mining captured from Satellite Images	**Mining Area (ha)**	**% Increase**	**TMDL (kg/day)**
Before2011	34.15	-	
2011	90.46	62.25	**27**
2012	202.97	55.43	**57.50**
2014	202.97	0.0	Mining activities are still active

The estimated Total Maximum Daily Load (TMDL) for suspended sediment concentration from soil loss upstream of Jemberau River was found to be 57.50 kg/day. The cumulative TMDL estimated for 2011, 2016 (5 years), 10 years, 15 years and 20 years assuming 111 days of rainfall in one year has demonstrated a linear increase as shown in Figure 7.

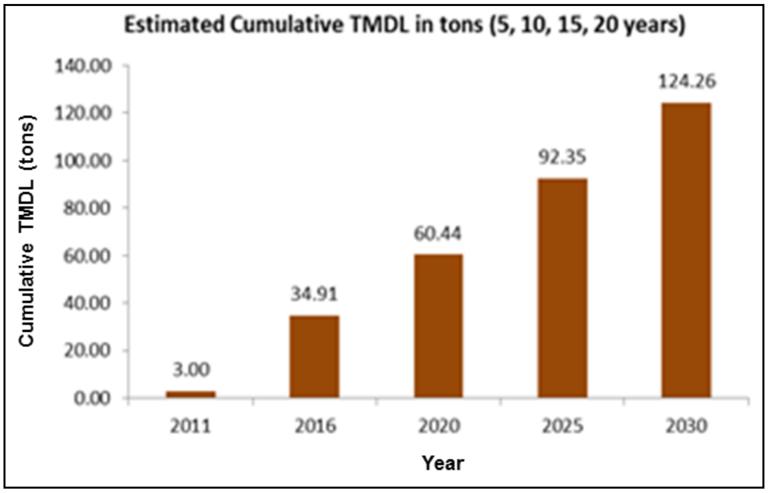

Figure 7. Estimated cumulative TMDL in tons (5, 10, 15, 20 years)

TMDL for suspended sediment concentration estimated approximately 35 tons of increment for every 5 years. The calculation was based on 111 days of the rainfall event. Deposition at several parts of the lake is anticipated based on the Particle Size Distribution results. Further investigation is required to confirm on the above.

Conclusion

Water quality in rivers and lake area has deteriorated as a result of mining activities at Jemberau river banks. The TMDL of soil loss was estimated to be approximately 35 tons every 5 years under the present conditions. Calculation was based on 111 days of rainfall event. Constant loading of sediment poses risk of sediment deposition in the river and lake areas. Management of sediment and stormwater discharge into rivers and lake area can significantly affect the lake functions and their ecosystem. Effective and sustainable control measures must be implemented to restore the river and lake environment.

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