Malaysian Journal of Applied Sciences 2016, **Vol 1(2)**: 9-26

eISSN 0127-9246 (Online)

Malaysian Journal of Applied Sciences

ORIGINAL ARTICLE

Environmental Management on Natural Lake Using Sediment and Hydrology Hydraulic Models

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Received: 15/2/2016, Accepted: 29/4/2016

Abstract

The hydrology hydraulic model is established to assess environmental information on hydrology which can be used to investigate causes of various environmental problems at the river and natural lake catchment. This study reports on sediment concentrations at a river using a gravimetric method to investigate the hydrology system at a lake catchment. The measurement was carried out at the upstream, midstream, and downstream stations on the river in normal, rainy and post-rainy seasons. The stations are located along the Chini River, which are connected to a catchment lake (located at latitude 3°26'36.41"E-3°27'03.26"E and longitude 102°54'31.94"N-102°53'35.49"N). From the measurements, it is estimated that on average 787.621 tonne/km^2 of sediment is transferred into the natural lake via Chini River annually. The correlation of statistical analysis between the sediment load and discharge study was very significant (R^2 = 0.980). There is a linear relation between the area of the catchment and sediment load of the connecting river as supported by other studies in Malaysia. The outcome of the study suggests that the high sedimentation is due to land use activity, existence of the dam at the downstream of Chini River that traps the sediment, reverse flow from the Pahang River into Chini River and riverbank erosion factors. From this study, the sediment control steps are suggested such as creating conservation partially at the lake catchment, modifying the dam system, riverbank erosion control, and application of "Monkey Cheek" system. These sediment control steps may help to clean up the high suspended sediment at the whole lake system area, hence solving and mitigating the environmental problems in the natural lake catchment.

Keywords: Sediment management; hydrology hydraulic models; environmental management; river and lake managements; natural lake.

Introduction

River is one of the most important sources of water for all living things in addition to water catchments such as lakes, seas, and underground water. The rivers are very important to humans and other organisms as they are essential resources for living. A number of processes, such as erosion, transportation and deposition, influence the sedimentary content and quality of river water (Zhang & Zang, 2015). These processes mutually interact along the river, from the ridges up to the mouth of the river.

Generally, the characteristics of a river are unidirectional flow (Palma et al., 2014; Fidelis & Peter, 2014; Koiter et al., 2013; Minella et al., 2009). The river will exhibit different water levels, not listed rates of flow and rates of erosion during different seasons such as monsoons and droughts. This situation is influenced by the frequency and intensity of rainfall in the area. Sedimentation is the main determinant of the level of water quality and environmental health of a river and natural lake catchments (Grove et al., 2015; Strauch et al., 2013; Vigiak et al., 2011; Philip et al., 2008). Sediment or sedimentary can be defined as an eroded matter which is carried through the water regime to the deposition location. Suspended sediment usually contains colloidal matter which is microscopic and needs a low-velocity river to carry it from one point to another. Whereas, the sediment-base load is a load with a striped center in between; about 0.2 mm to 2 mm depending on the basic structure of the rocks and soil surrounding the location (Toriman et al., 2012; Kamarudin et al., 2009; Burton, 2002; Owens et al., 2005; Wood & Armitage, 1997). The sediment structure is formed during the settling process or immediately after the sediment matter is deposited. The sediment structure can also be formed before the sediment is compressed. The sediment problem remains for a very long period of time at the cliff area of Chini Lake and it is becoming very serious recently.

Numerous “dipterokap” forest areas surrounding the cliff of Chini Lake has now become secondary forests due to logging (Abdullah et al., 2013). Consequently, soil degradation, interference to the soil physics-chemical characteristics, weathering process, and soil erosion are among many impacts that have contributed to the increase of sedimentation (Manap & Voulvoulis, 2014; Nardi et al., 2012; Alvarez-Guerra et al., 2010; Walling, 2005). Besides that, the serious decrease of the water volume of the lake during the drought season has contributed to the sedimentation and caused the sediment flow rate increase, particularly during the rainy season (Rachel et al., 2015; Padmalal, 2008). All the sediments will enter the lake and flow through Chini River, which is the only outflow from the Chini Lake to the Pahang River (out of the lake catchment). The sediment deposition in the river bed causes the decrease of the Chini River’s depth. Between 1995 and 1996, a dam or weir was built to control the water level in order to facilitate the boat navigation along the Chini River and Chini Lake (Kamarudin et al., 2013; 2009; Toriman et al., 2013). The dam managed to overcome the reduction of water depth problem at the river, hence, Chini Lake has made the movements of the tourist boats, flexible (Jaafar et al., 2010; Mohamad & Toriman, 2006). Nevertheless, the dam does not possess a functional structure to carry the sediment out. Finally, the sediment was trapped and blocked from flowing out of Pahang River. Moreover, the flood phenomenon that happens during every northeast monsoon, has caused a back flow of Chini River. The back flow has resulted in the transportation of the sediment from the Pahang River to Chini River.

In this study, sediment concentrations at Chini River and Chini Lake catchment areas are measured and analysed using a gravimetric method. These data are used to model hydrology hydraulic system in these areas. The system will subsequently be of use to identify and propose the countermeasures to mitigate the environmental problems. This study is important as it will provide observations of the effect of sedimentary content, based on the shape of its river cross section and the river hydrology hydraulic system.

Study Area and Methodology

This study focuses on the Chini River (Sungai Chini) and Chini Lake (Tasik Chini) which located at latitude 3°26’36.41”E-3°27’03.26”E and longitude 102°54’31.94”N-102°53’35.49”N. Chini River, with the length of 4.8km, is the only river that connects the Pahang River through Chini Lake (Tasik Chini). That is the reason why Chini Lake can be visited through water transportation through the river from Kampung Belimbing which is situated at the north of Pahang River (Kamarudin et al., 2013; Toriman et al., 2013). There are three sampling stations that represent the whole Chini River for this study. Station 1 (S1) upstream, Station 2 (S2) midstream and Station 3 (S3) downstream (Table 1 and Fig. 1). Suspended sediment sampling analysis and river discharge value measurement work were conducted three times; in August (normal season), December (rainy season), and April (post-rainy season).

Table 1. Location of sampling stations in Chini River

Station	Latitude	Longitude
(S1) Upstream of Chini River	3°26'36.413" T	102°54'31.946" U
(S2) Midstream of Chini River	3°26'36.400" T	102°54'31.900" U
(S3) Downstream of Chini River	3°27'03.268" T	102°53'35.497" U

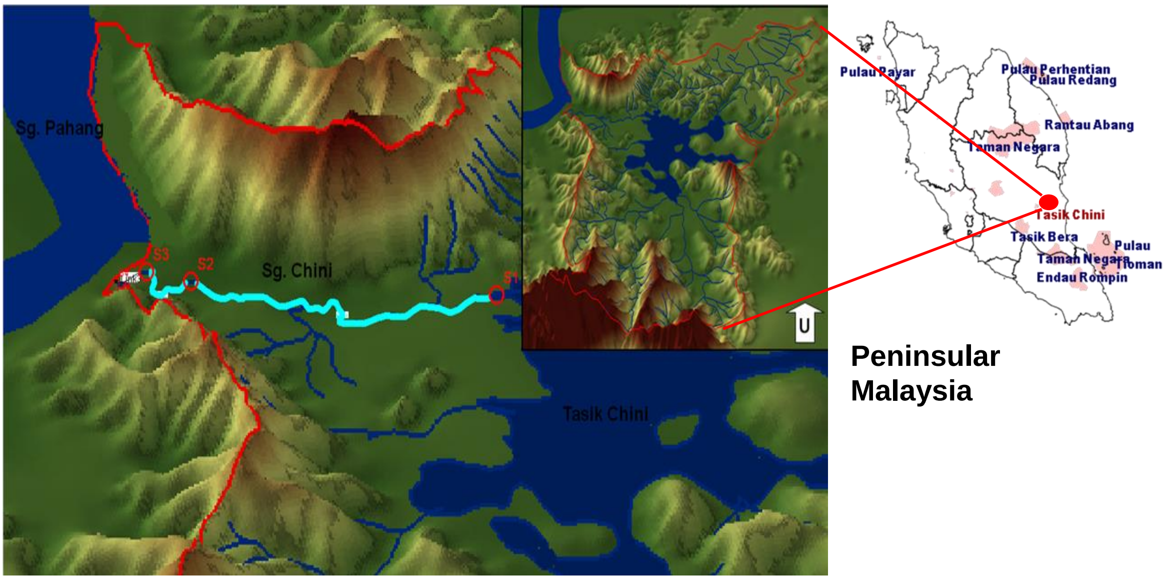


Figure 1. Location of the study areas; Chini Lake and Chini River, which are situated in Pahang, Malaysia

Water samples were collected from every station of Chini River and kept in a specific bottle (500ml) for the Total Suspended Sediment (TSS) analysis. Three sample replications were taken from every station and the results of the study were taken based on the average of the replication. The river cross-section and the water velocity (v) for every station was taken using few instruments such as Current Metre, Depth Measuring Gauge, Measuring Tape, Poles and Theodolite (Kamarudin et al., 2009). The samples were collected for laboratory analysis.

Parameters, such as the flow velocity, width and depth of the river, were determined in situ and used for the purposes of measuring specific discharge values and sediment sampling. Sampling of suspended sediment was carried out using plastic bottles. Before taking a sample, the bottle was rinsed with water from the river. It was then slowly lowered into the water until all the air spaces in the bottle were replaced with water. The Gravimetric method was used to analyse the TSS which is measured in mg/ L^{-1} unit. Water sample of 250ml from every station in the study area plot is required. The suspended solid measurement was performed by weighing the membrane paper of 0.45µm one by one and the reading was taken. Next, the weighed membrane paper is placed on the filtering instrument (Nalgene, U.S.A) which was connected to the vacuum pump. A clamp is used to tidy up.

A water sample was poured slowly into the filtering instrument locust. The membrane paper was taken and dried in the drying locust. Once the membrane paper is dried, it is weighed to get the reading. Varying from the total dissolved solid, its particles were separated from the water body. Precisely, precautionary steps should be taken when water sample is taken. Interference of the river water flow should be minimised to avoid deposition of the measured suspended sediment (Kamarudin et al., 2009; Ruslan & Rahman, 1994). Readings were taken and calculated using the following formula:

$$\begin{aligned} \text{TSS} &= \frac{\{(\text{weight of membrane filter} + \text{dry residue}) - \text{weight of membrane filter}\}(\text{mg}) \times 100}{\text{Volume of filtered water } (\text{mL})} \\ &= \text{mg L}^{-1}/1000/1000/1000 \\ &= \text{tonne L}^{-1} \end{aligned} \tag{1}$$

Discharge value (Q) is the product of average velocity (v) and cross section area (A) or Q = vA. The cross-section area is derived from the product of depth (d) and width (w). Since the cross-section area is trapezium or triangular in shape, its value is half the produce:

$$A = dw\left(m^2\right) \text{ or } A = 1/2\ dw\left(m^2\right) \tag{2}$$

Velocity (v) is calculated by multiplying the distance with the time:

$$v = m\ sec^{-1} \tag{3}$$

Discharge value (Q):

$$\begin{aligned} &Q = vA, \text{ or } Q = ½\ vA \\ &Q = m^3\ sec^{-1} \end{aligned} \tag{4}$$

To derive the unit of L day^{-1}, the following formula is used:

$$\begin{aligned} Q &= m^3\ sec^{-1} \times 86400\ sec\ day^{-1} \times 1000\ L\ m^{-3} \\ &= L\ day^{-1} \end{aligned} \tag{5}$$

The calculation of suspended Sediment Load value (SL) is based on the discharge value, TSS value and area of sampling basin. The analysed data would be used to detect changes in the concentration of suspended matter. Its relationship with hydrological parameters and other variables are given by:

$$\begin{aligned} \text{Sediment yield} &= (Q \times TSS) / \text{River Basin Areas} \\ &= (L\ day^{-1} \times tonne\ L^{-1}) / km^{-2} \\ &= tonne\ km^{-2}\ day^{-1} \times 365\ days \\ &= tonne\ km^{-2}\ year^{-1} \end{aligned} \tag{6}$$

Where Q is discharges, TSS is Total Suspended Sediment, and River Basin Areas are the whole of catchment areas.

The in-situ data obtained at the site were also analysed using the XP-SWMM software. Two modelling models will be used in these simulations which are hydrology and hydraulic models. The main inputs of the model are discharge data, river characteristics, spill crest, datum level, roughness of the river, and topography of the lake catchment. The sediment transportation modelling process consists of three main phases such as hydrology analysis, hydraulic and sediment transportation. Hydrology and hydraulic analyses have to be calibrated earlier before the sediment transportation modelling process is carried out.

Results and Discussion

Based on this study, the annual formation of sediment can be predicted through conducted calculation and simulation modelling. Table 2 shows the estimation of the total suspended sediment load through the overall average of data obtained. The highest value of the sediment formation is obtained during the rainy season, which is about 37.78 mg/L with the highest discharge of 541,123,200 L/day. Next, it is followed by the normal season, which is 31.02 mg/L with a discharge of 138,499,200L/day. The lowest sediment formation occurred during the post-rainy season with the TSS value of 19.18 mg/L and discharge about 181,699,200 L/day.

Estimation of the sediment formation was then tabulated in the value of tonne/km2/year to facilitate the applied estimation volume. The findings show that the highest annual suspended sediment load is during the rainy season which is 1,711.451 tonne/km^2/year, followed by the normal season (359.663 tonne/km^2/year) and post-rainy season (291.748 tonne/km^2/year). Accordingly, the total average that represents the annual formation of sediments in Chini River is about 787.621 tonne/km^2/year (Table 2). The value of the annual suspended sediment load is the highest if the cliff size and the Chini River length were considered.

Table 2. Estimation of the suspended sediment load at Chini River, Pahang

Suspended Sediment Load	Station (Chini River)			Average
	Normal Season	Rainy Season	Post-Rain Season	
Areas (km^2)	4.36	4.36	4.36	4.36
TSS (mg/l)	31.02	37.78	19.18	29.33
TSS (kg/l)	0.00003102	0.00003778	0.00001918	0.00002933
Estimation Q (m^3/s)	1.603	6.263	2.103	3.323
Estimation Q (L/day)	138,499,200	541,123,200	181,699,200	287,107,200
Sediment yield kg per day (kg/day)	4,296.245	204,443.634	3,484.991	70,741.62
Sediment yield kg km^2 per day (kg/km^2/day)	985	4,688.907	799.310	2,157.739
Sediment yield tonne km^2 per year (tonne/km^2/year)	359.663	1,711.451	291.748	787.621

Based on the outcome of the simulation performed, the pattern of the sediment deposition throughout Chini River was significant whereby the deposition of the sediment increases as it gets closer to the downstream. Fig. 2 shows the changes of the cross section of Chini River based on one year observations during the normal season in August until rainy season in December and to post-rainy season in April. Link 1 is the upstream of Chini River which the Chini River and the Chini Lake meet. The simulation shows that the effect of sediment deposition focuses on the right section of the river, while the erosion takes place in the left section of the river from the normal season to the end of rainy season. The deep and steep left section of the river (± 2.6m rainy season water level) reveals that the high water movement area causes erosion. The high water movement is capable to transport sediment faster compared to the right section of the river. This is because the right section of the river has a slanting slope and is the focus for the sedimentation process (Link 1 in Fig. 2). Nevertheless, during the next season, the occurring erosion changed to a more uniform deposition throughout the cross section at S1. This is due to the decreasing pace of flow movement during the post-rainy season compared to the rainy season.

The simulation also shows that the sediment deposition effect in Link 1 is lesser compared to Link 2. In Link 2, the sediment deposition is fairly high during the rainy season on both sides of the riverbank. This is because the cross section of Link 2 is even, whereby the focus of the water is at the center part of the river. The low water velocity in both sections of the riverbank has caused the sedimentation process and the erosion occur only in the riverbed. At the Link 3, there is a high sediment deposition when only a small portion of the left side of the river did not go through sedimentation process during the rainy season. However, during the next season, the sediment deposition was significant and the thickness of the deposition was managed to be simulated until ± 0.5m (Fig. 2 Link 3/ Fig. 6). This is because Link 3 is a dam area which is situated on the downstream of the Chini River.

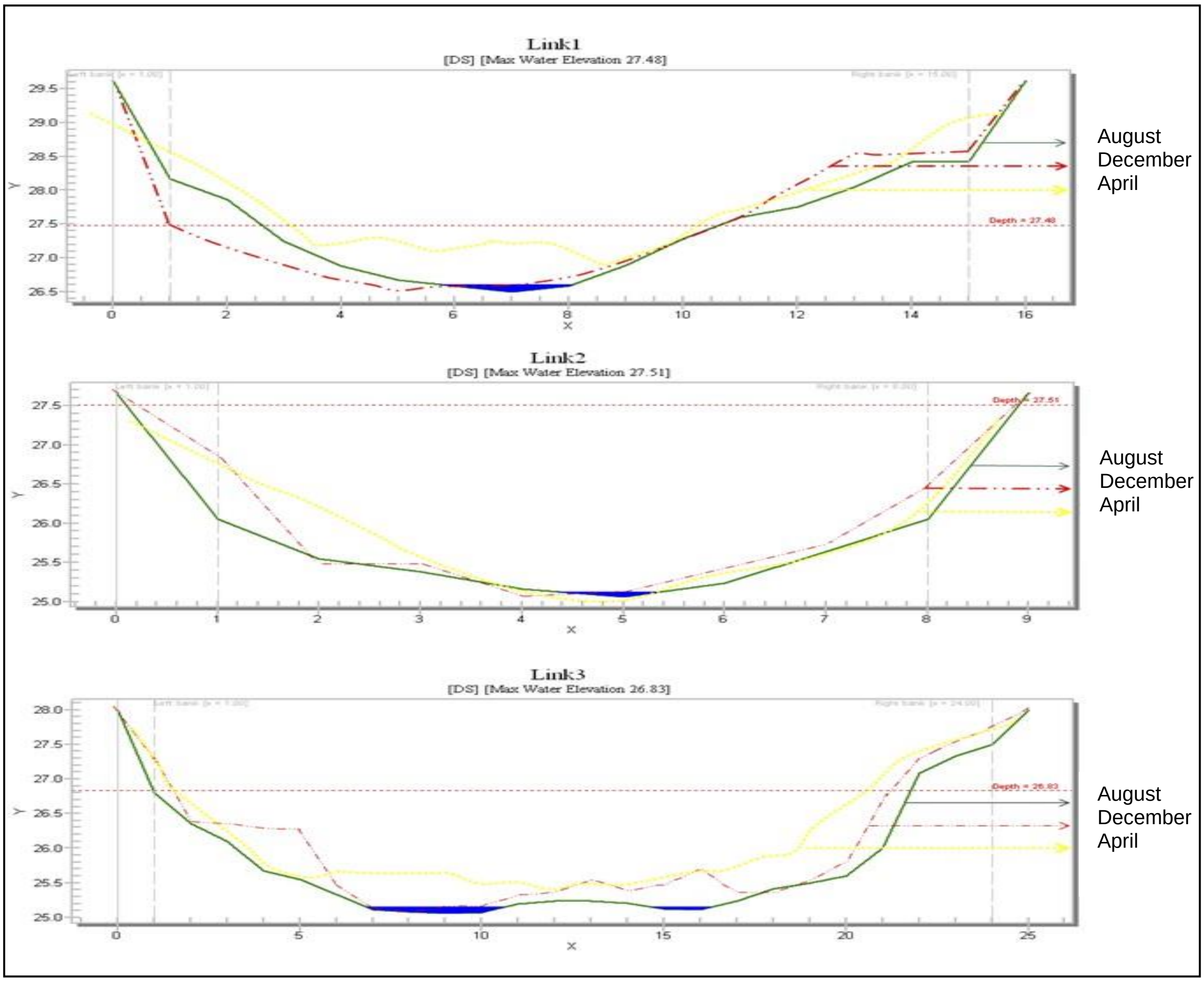


Figure 2. Impact of river cross section changes from hydrology and hydraulic model

Based on Fig. 3, significant correlation between the observed value (Q) L/day with the sediment load value kg/km^2/year is positive with the coefficient value 0.98 or very significantly which is R^2 0.980. This shows that the discharge variable (Q) has a strong positive relationship with the sediment load where the increase of the observed value (Q) will increase the sediment load value in this study. Regression forecasting showed the forecast of sediment production on the discharge increase showed high precision which is 98% where the higher the water discharge the more the sediment load was transported. In hydrology field, the relationship between the sediment value and observation can give a variety of pasteurization towards the environmental impacts that has arisen (Kamarudin et al., 2014; Mohamed Abdallah, 2013; Wang & Feng, 2007). Therefore the cause of the increase of discharge that affecting the sediment yield has to be given attention. The monthly rain rate, land use changes, and creek erosion should be considered in order to identify the problems.

Table 3 shows the comparison between the areas of the shed location with the sediment load for certain selected rivers in Malaysia starting from 1990 until 2014. The comparison between the sediment load values for Chini River basin areas with other rivers with a slight difference in the basin area is very high. For an example the sediment load value for Bangi Anak River, Selangor which has a basin area of 3.7 km^2 recorded as much as 10.186 tonne/km^2/year for sediment load concentration. Whereas Chini River marks a sediment load value of ±77 times higher this is 787.621tonne/km2/year with area of 4.36km^2. This shows that the total sediment formation in this basin is higher compared to the selected rivers in Malaysia.

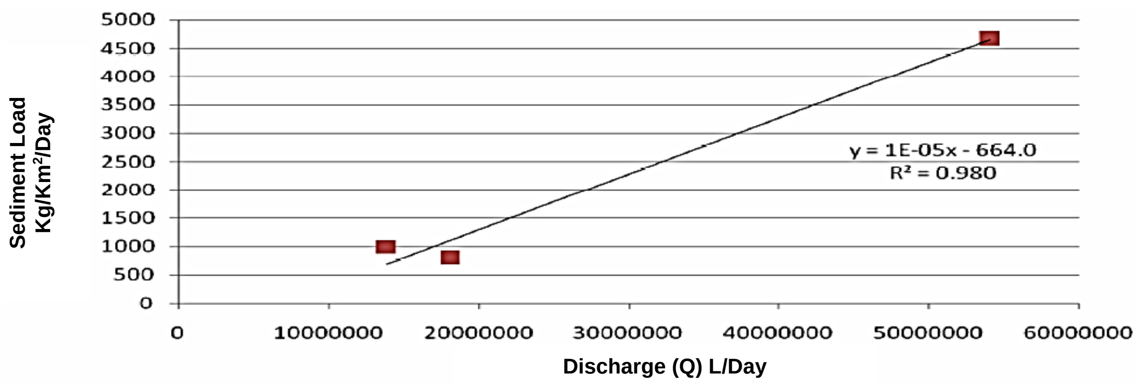


Figure 3. Relationship between sediment load value and discharge (Q) in Chini River

Table 3. Areas of shed and sediment load for selected river study in Malaysia

Study Area	Area of Location (km²)	Average Sediment Load (tonne/km²/year)	Source
Sipitang River, Sabah	0.15	54.431	Malmer & Grip, 1990
Relau River, Pulau Pinang	8.9	2,450.305	Ruslan & Rahman, 1994
Anak Bangi River, Selangor	3.7	10.186	Toriman *et al.,* 2006
Chini River, Pahang	4.36	787.621	Study outcome

The relationship between the area of the catchment location and the sediment load for the selected rivers studies in Malaysia was significant, where R^2 0.824 with regression prediction strength of 82.4% (Fig. 4). This indicates a clear relationship that, as the basin area increase, the sediment load production also will increase. In other words, the changes of the overall activities in the catchment of a river or lake will give an impact to the sedimentation process in the river. Therefore, the uses of land changes, existence of open area will directly affect to the sedimentation process in the lake and will flow directly into the Chini River.

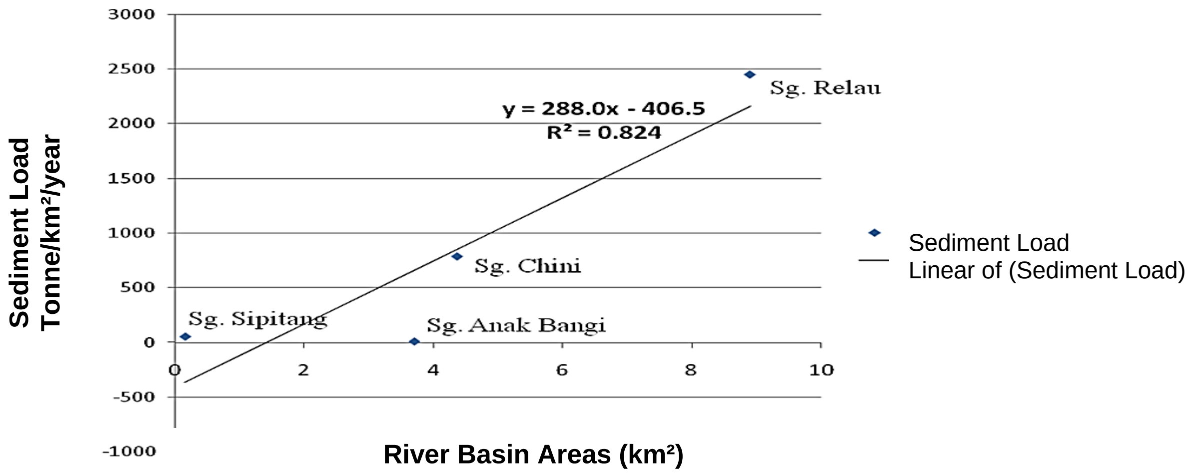


Figure 4. The relationship between the area of the basin and the sediment load in the selected study in Malaysia

Factors of Sedimentation Problem

Land Use Changes

Fig. 5 shows the changes in land use in the surroundings of Chini Lake basin from early 1994 to 2004 (Gasim et al., 2006). Within the ten years duration a very significant land use change took place. A total of 4.3% of reserve forest was missing (from 54.2% in 1999 to 49.9% in 2004) and replaced with an agricultural land, such as rubber and palm oil, tourism development, residential area and so on. The rapid forest exploration has resulted in the existence of open areas which are vulnerable to erosion process (Manap & Voulvoulis, 2014; Vigiak et al. 2011). The high average of the annual rain in Chini River with the value of 5,314.6 mm makes the erosion process more prone to happen.

In order to control the erosion that contributes to sedimentation, the forest canopy density method is very suitable because it reduces the surface erosion. The function of the several layers on the canopy layer was good filtration through bypass process and to reduce at once the erosion spark effect due to rains drops (Toriman *et al.,* 2013; Haslinur *et al.,* 2012; Yusri *et al.,* 2009; Walling, 2005). Precisely, all types of activities which have the potential to produce open areas in the basin have to be controlled and monitored.

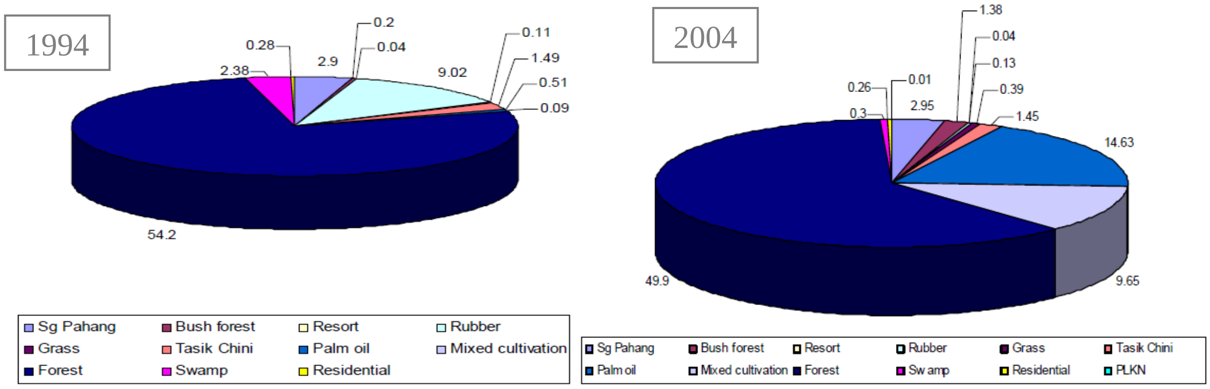


Figure 5. Land use changes in the Lake Chini Basin from year 1994-2004
Source: Gasim et al., 2006

Dam in Chini River Downstream

The dam on the downstream of Chini River is built to control the water level for the navigation movement of the tourism boat. Nevertheless, the absence of sediment flow-out facility has caused the sediment to be trapped easily at the front part of the dam. Fig. 6 shows the modelling outcome of the sedimentation impact on river cross section in the downstream of the Chini River.

The findings indicate that there is a significant deposition due to the trapped sediment as much as ± 0.5 meter in the dam. During rainy season, the deposition is lesser compared to the post-rain season. This is because during the rainy season and normal season, the dam is still functional where the river flow that transports the sediments can still flow in and out from the dam. During the post-rain season, the water volume has reduced. So the water cannot flow out and this enables the deposited suspended sediment to end up as bed sediment.

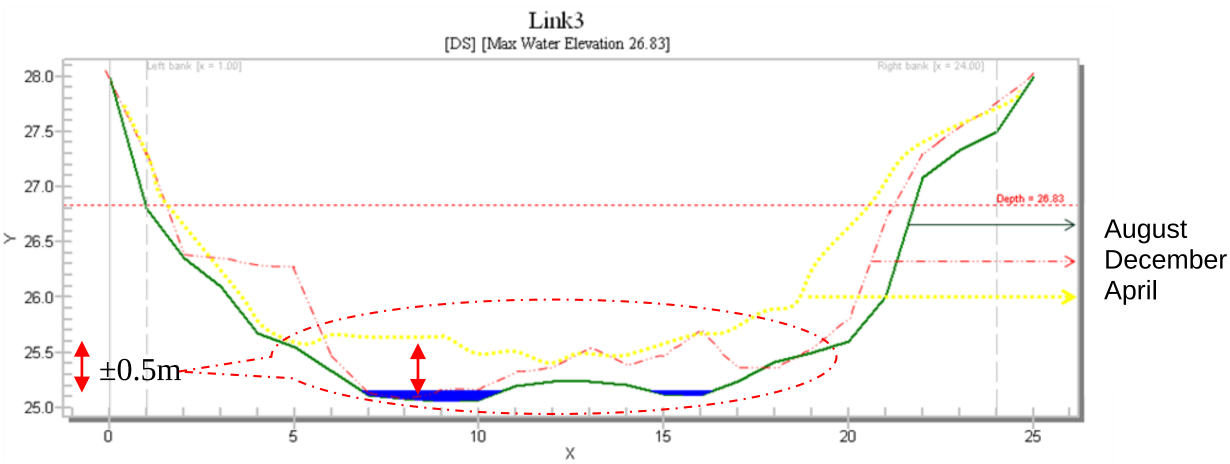
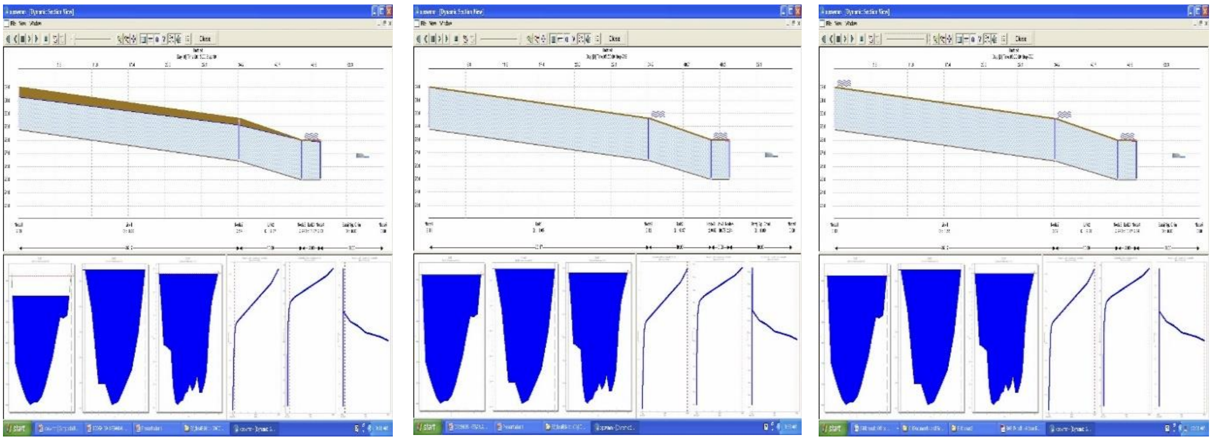


Figure 6. Impact of sedimentation on river cross section in the downstream of Chini River

Backflow (Natural Phenomenon)

Backflow is an abnormal flow during floods because of the ingression of water from Pahang River flow in to the Chini River and Chini Lake. The simulation modelling results managed to prove the presence of this flow (Fig. 7). At the 3rd minute, the simulation carried out found nod in station 3. The downstream of the river flow is the first nod that will be submerged by water during the floods. The analysis result finds that the discharge rate (Q) is 13.67 m^3/s with a velocity of 1.34 m/s.

The next nod submerged with water is nod 2 in the period of 5 hours and 56 minutes with a discharge of 9.37 m^3/s with a velocity of 0.89 m/s. Whereas until the 6 hour simulation ends, nod 1 also was submerged with water with a lower discharge rate compared to nod 1 and nod 2, which is 1.66 m^3/s with the velocity of 0.05 m/s. The ratio between the high discharge value with low water velocity and long-time duration for nod 2 and nod 1 to submerge is caused by the backflow phenomenon. This flow will bring along the sediment from Pahang River and deposited along the Chini River.



(Simulation at 00.03) (Simulation at 05.56) (6th hour simulation)

Figure 7. Backflow simulation in Chini River

From one aspect the backflow phenomenon is vital where the Chini Lake plays a role as a natural water reservoir especially during the floods season. This could be explained during the heavy rain and when the Pahang River could not control the overflow of water from the upstream, then Chini Lake will retain the water naturally which will then reduce the magnitude of greater floods in the downstream of Pahang River. However, water from the Pahang River carries with height numerous and very small suspended sediments in to Chini River and Chini Lake. The situation becomes worse when the water recedes and flows out back into Pahang River and the dam at downstream of Chini River will block and trap this sediment.

Riverbank Erosion (Natural and Boat Navigation)

Riverbank erosion or cliff erosion occurs naturally where the water flow is moved by the gravity force and this force increase pressure the land eroded the riverbank (Liang *et al.,* 2015; Bariteaua et al., 2013; Toriman et al., 2013; Julian & Torres, 2006). In Chini River, the riverbank erosion is quite critical and worse until causing the big trees along the riverbanks collapse. Generally the high velocity rate and large volume of water has a strong erosion rate compared to slow speed rate and low water velocity. The eroded soil particulates will enter the river as sediments. In Fig. 3, the significant relationship between the discharge and sediment load is R^2 0.980 portrays a positive relationship towards the erosion where, as the discharge increase, the erosion and sediment load increases.

According to Strahler (1978), the water flow is influenced by turbulence. Turbulence is a whirlpool system that is always formed and disappears. That is the reason why a water molecule moves in an irregular and swirling way when flowing downstream. Water molecule probably moves up, down, and up again. Besides that, the water speed in the middle region of the river is faster compared to the side region of the river groove. According to Sahibin et al., (2009), the Chini Riverbanks are dominated by the argillaceous texture. The argillaceous texture can cause the erosion of riverbank when there is an extraordinary flow or wave.

Furthermore, the usage of boats for tourists and locals use has created a high turbulence in the Chini River especially for those boats which using a high-powered boat engines. The boat fast current cleavage has resulted in big waves and struck the riverbanks until the erosion becomes more active and worst (Marden et al., 2014; Toriman et al., 2013; Kessler et al., 2013; De Rose & Basher, 2011). Finally, the riverbank erosion has contributed to the sedimentation process in Chini River.

Environmental Management Suggestion

Based on the study carried out, the cause of high sedimentation in Chini River was identified. Thus, several management, control, mitigation, and conservation methods were suggested to reduce this problem.

Solution to Land Use Changes

The significant change of land use such as agriculture and mining that create an open area (clear land), is the cause of sedimentation in the lake and along the Chini River. However, this study suggests the enforcement of laws is vital to control the unplanned land use activity in this basin. The suggestion to create a zoning border of the lakes and rivers in the basin area of Chini Lake including the main river is a smart way to overcome this problem (Fig. 8). The existence of the conserved zones not only reduces the sediment entry from the direct flow of the main river, but it will also create and sustain the natural habitat of the flora and fauna in the surrounding area.

The Chini Lake is the country's tourist attraction. Thus, the land use of this area will certainly change in order to provide the tourist infrastructure and facilities Therefore, despite sedimentation problem caused by open area, the study also suggests that establishing development and land use can still be performed in this basin area. The bio-ecology drainage system or urban storm water management (MASMA) is considered as a suitable system to be applied in this location to solve the expected open area problems (Abdullah et al., 2004). This system will ensure the cleanliness of the runoff water from the developed areas and follows the standards.

Solution for the Dam in Chini River Downstream

For the dam complications at the Chini River downstream, this study suggests modifications to the structure of the dam for natural escape for the trapped sediment. Fig. 9 shows the suggested cross section of the dam. Mechanical A was added and modified from the existing dam at Chini River downstream. Once the key has been unlocked, a part of the bottom of the dam will be unlocked too. The bed sediment will be removed automatically by gravity and pressure energy in the water. With this concept, the deposited of bed sediment problem could be solved easily. Nonetheless, this manual method requires a systematic and periodic monitoring, as the mechanical structure needs scheduled locking system (based on the deposition of bed sediment pattern).

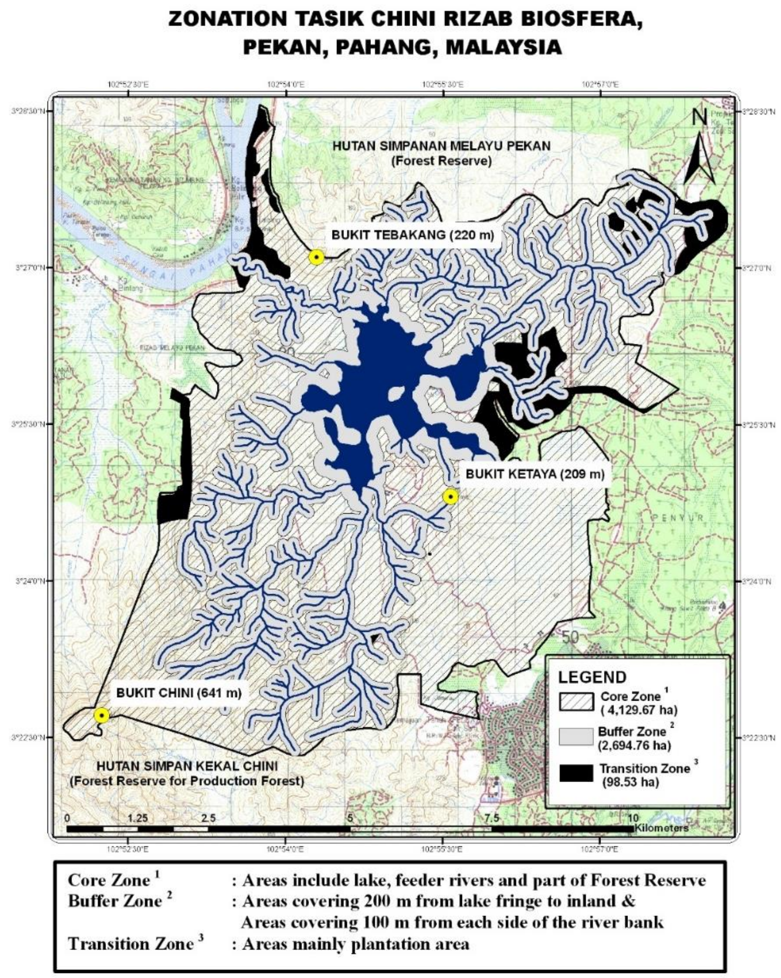


Figure 8. The proposed map of zone management in Chini Lake

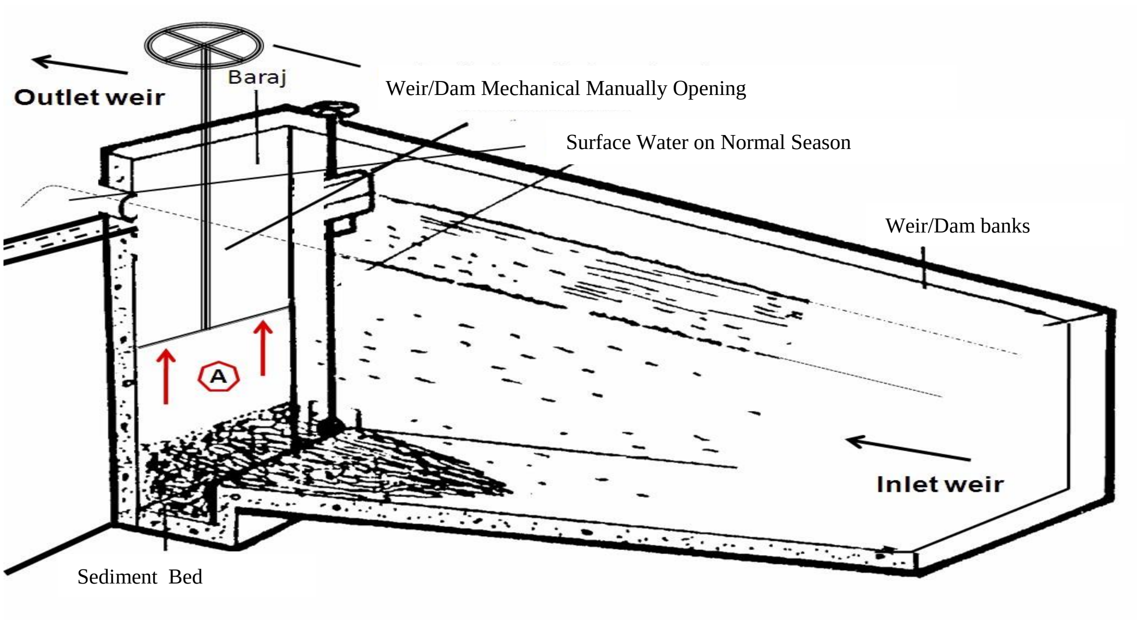


Figure 9. Example of the proposed manual bad sediment discharge system (manually)

The automatic sediment discharge control was also suggested through the water pressure energy technique application (Fig. 10). The sediment control mechanical was built using the floating material according to the water level of the river. During the normal season, the sediment control mechanical will not function because its closes the tunnel or the bed sediment discharge hole at once. This position of the mechanical can control the water level for the boat movement in the Chini River. Towards the rainy season, the water level will rise and the research findings reveal that the sediment formation is the highest during this season. At this time, the sediment control mechanical functions automatically whereby this mechanical (B in Fig. 10) will float according to the water level of the river. Then, it will release the deposited of sediment bed through water pressure and gravitational forces (Fig. 10). Initially, this tunnel forces the sediment to flow into the sediment trapping pond. This trapping pond will help to control the sediment from flowing into the Pahang River. The collected sediment can also be used for various activities such as for agricultural use.

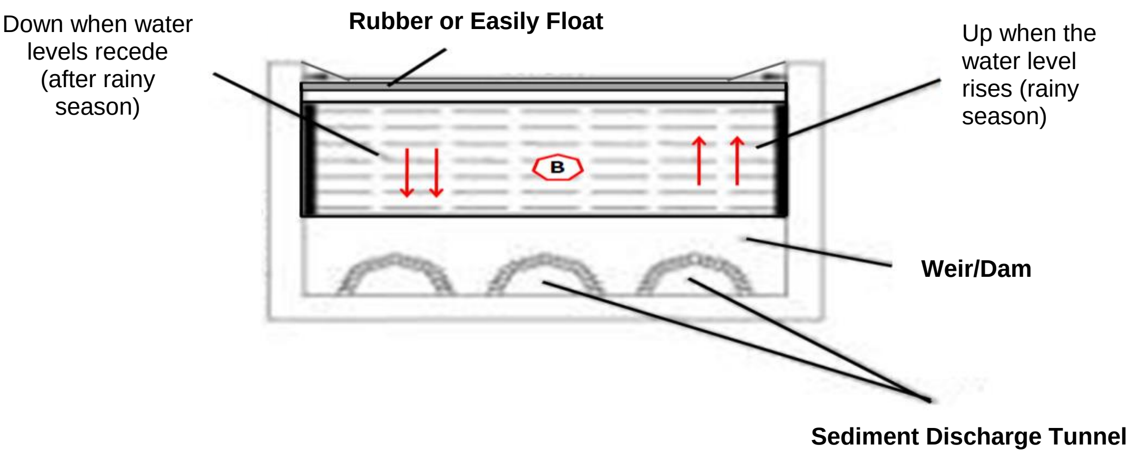


Figure 10. Example of the proposed manual bad sediment discharge system (automatically)

Backflow Solution (Natural Phenomenon)

Backflow is an important phenomenon in reducing the flood magnitude in a part of the Pahang River downstream (Kamarudin et al., 2014). During post-rainy season, sediments will be transported to Pahang River. Despite of this, the sediments will be deposited in the front area of the dam. Therefore, this study recommends a new application system called "*Monkey Cheek*" which has been developed in Bangkok, Thailand (Web to Monkey Cheek, 2014). This system uses a natural system by collecting and restraining the water flow at the tributary and then releases it when that water is needed (in dry season). The released water flow pressure can help to transport the sediment out from Chini River and Chini Lake especially during the dry season (See Fig. 11).

In the surveyed area, this system was suggested by restraining the water from the tributary during the rainy season. This is because the water level of the Chini Lake can increase from two to six metres from the normal season water level. This water will be released when the Chini River flow is back to normal. It is called back flow phenomenon. With condition of high velocity and high water discharge released at once, the sediments that were brought by the Pahang River will be cleaned immediately from the water released by this system (*Monkey Cheek*).

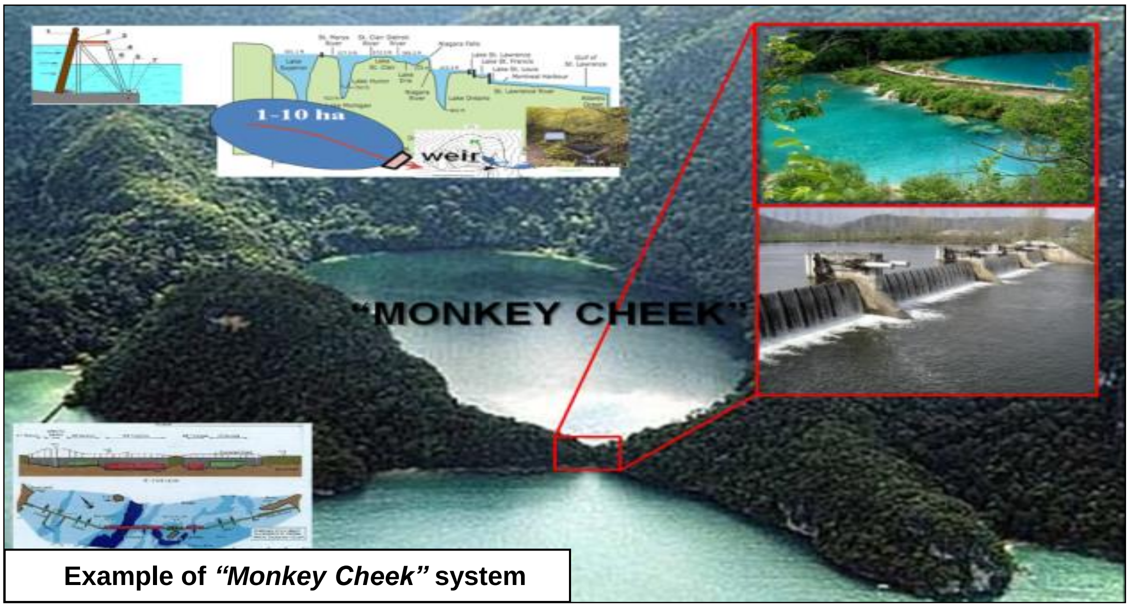


Figure 11. Example of the proposed "*Monkey Cheek"* system

Solution to Riverbank Erosion (Natural and Boat Navigation)

The riverbank erosion is one of the contributors to the formation of suspended sediment and bed sediments in the Chini River. The control structure for the riverbank erosion is usually done by building an erosion wall. The wall is commonly used as barriers for the erosion. It is known as "*gabion*" structure or stone nest.

The study suggests the construction of riverbank erosion control in the Chini River by using a more natural substance such as "*fibre roll*" (See Fig. 12). Besides that, the planting of erosion barriers trees such as "*Rasau*", "*Ban Air*" and "*Menerong*" was also suggested to overcome the riverbank erosion problem. Concurrently, the planted trees can function as a natural sediment filter for the river. Referring to the research findings, the speed and the power capacity of the boat's engine used in the Chini River should also be under control.

Based on this study, characteristic of the riverbank erosion shows that the erosion happens through the dredging process from the bottom, namely Cantilever erosion (Toriman et al., 2013). This phenomenon occurs due to the strong and fast wave strokes towards the riverbank resulted from the boat movements. The awareness on the boat movement impacts on the riverbank erosion should therefore be inculcated among the boatmen in the Chini River. Speed warning sign boards could be one of the ways to provide awareness to the fellow boatmen.

Conclusion

Based on the complications identified, a few suggestions were proposed to overcome the sedimentation process in Chini River. Nevertheless, these suggestions are only based on the scientific study performed by a group of researchers. Therefore, for implementation, a more thorough and detailed study need to be conducted. This is to avoid various problems that may arise due to the suggested construction solutions.

Overall, the active sediment deposition during the rainy season, especially in Chini River downstream (S3) is rather serious. If this phenomenon progresses, it will destroy the aesthetic value and the role of the Chini Lake, which connects the Chini and Pahang Rivers. Thus initiative, mitigation and preservation steps as discussed above, need to be considered for immediate actions. The execution of these actions should be expedited in order to minimise the sedimentation problem in Chini River and Chini Lake, Malaysia.

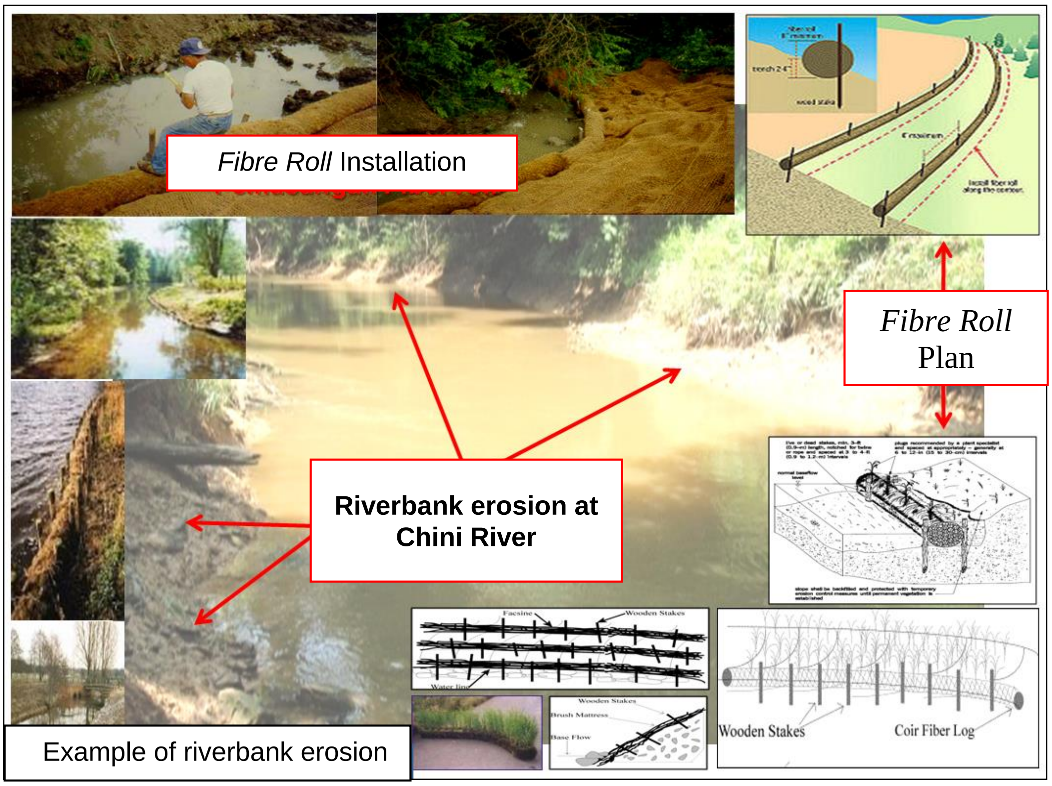


Figure 12. Example of the proposed riverbank erosion control using *"fibre roll"*

Acknowledgments

The researcher are grateful to the Ministry of Education Malaysia through the Research Acculturation Grant Scheme (RAGS): (RAGS/1/2015/WAB05/UNISZA/02/1) and university research grant: (UniSZA/2015/GOT/03). Special thanks to East Coast Environmental Research Institute (ESERI), University Sultan Zainal Abidin, National University of Malaysia and Chini Lake Research Centre (PPTC-UKM) for the guidance and contributions.

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How to cite this paper:
Kamarudin, M.K.A., Toriman, M.E. & Idris, M., Juahir, H., Azid, A., Gasim, M.B., Umar, R., Endut, A., Mohktar, M., Khalit, S.I., Ismail, A., Mat Yaakob, N.H. & Rwoo, M.A. (2016). Environmental management on natural lake using sediment and hydrology hydraulic models. *Malaysian Journal of Applied Sciences, 1*(2), 9-26.