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OPTIMAL SAND REMOVAL CAPACITY FOR IN-STREAM MINING IN PERAK RIVER, MALAYSIA

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ABSTRACT

New or alternative source of sands need to be determined due to the increasing demand for sand by construction industry. Floodplain and river bars can be used as new sources of sand mining. This method however is still new in Malaysia. This study was carried out to estimate the sand capacity at floodplain and river island by combining the resistivity method and sediment transport load. By using resistivity survey, the thickness of subsurface can be determined easily and it can also measure large area simultaneously. Hence, this method is able to find new source of sand at floodplain without disturbing any groundwater sources. In Sungai Perak, many river islands and river bars could be new source of sand mining. Nowadays, unpredictable weather can cause high precipitation, flash flood and also drought. The high precipitation can cause high flow in river. This high flow can cause deflected flows by river island which can cause riverbank erosion which leads to instability of river. Therefore, river erosion can probably be reduced by using this technique. Study found that the high replenishment rate of Sungai Perak which is approximately 1245.43 m^3/day can cover back the river bed about six days if 2.0 meter extraction is conducted on this river island A. For river island B, the replenishment period is about 98 days for 2.0 meter extractions.

Key words: Sand Mining; Perak river; Sediment Transport

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1. INTRODUCTION

According to Ladson and Judd (2014), direct sand mining from rivers has been a common source of sand and it is known that it gives significant impact on river morphology. To reduce these impacts, sand mining has been changed from in-stream sand mining operations to other resource of sand such as river island, bars and floodplains. The river islands and bars can decrease the hydraulic performance of the river [2]. This is because river islands can change of the river morphology, which reduces the flooding capacity of the river. Thus, by remove the sand from river islands can increase the hydraulic performance of river and control river erosions. For Malaysia, agriculture is part of key sector of employment. Sediment management is very important to agriculture, both in terms of minimizing erosion from farmland and also in ensuring the efficient operation of irrigation infrastructure (which may be disrupted by excess sediment in waterways) [3].

The unregulated mining activities have resulted in massive damages to the river bed and banks. This study seeks to establish the optimal sand removal capacity to reduce river bed degradation and channel instability. This requires the estimation of sediment transport along the selected rivers and cross-section profiling to estimate safe volume of sand that could be removed with minimal impacts [5].

DID (2009) suggest that floodplain extraction in Malaysia should be set back 100 m from the main channel. It was also recommended the floodplain pits should not be excavated below the elevation of the thalweg in the adjacent channel. This will minimise the impact of potential river capture by limiting the potential for headcutting and the potential of the pit to trap sediment.

Bar scalping or skimming is the method of extraction of sand and gravel, from the top of the bars. Commonly, bar skimming is based on the rate of deposition of sediments. The preferred method of bar skimming as suggested by Padmalal and Maya (2014) is to leave the top one-third of the bar undisturbed to sustain the hydraulic control prevailed upstream by the riffle head. Mining area should limited to two-third portion at the downstream end of the bar. Padmalal and Maya (2014) also found that the river island along some large rivers can be a new source of sand and gravel. This river island can be extracted without severe damage to the river if proper management of sand extraction. Bar excavation can improve the river flow and also avoid the deflected flow of river which can cause river bank erosion.

2. MATERIAL AND METHOD

2.1. Study Area

Sungai Perak which is located in Perak faced major flooding on December 2014 [7]. Sungai Perak is the second largest river in thr Peninsular Malaysia that drains from upstream Titiwangsa and Bintang mountain ranges with a catchment area of about 14,908 km^2.

Sungai Perak not only provides water sources for local people, but this river also is used for recreational, fishery, mining, irrigation to paddy field, and many other human activities. Five cross section have been selected at Sungai Perak, Pendiat, Perak and the coordinates of study area are at 4°22'41"N 100°54'6"E coordinate. Figure 1 shows the study area in Sungai Perak, Perak.

2.2. Data Collections

In this study, the hydraulic data was collected by using Acoustic Doppler Current Profiler (ADCP) which is able to project the river crosses section and profile. The bed load was collected by using Helley-Smith sampler. The study focuses on preliminary assessment based on the geology or geotechnical characteristics of the surrounding area for sand potential. Then, an Acoustic Doppler Current Profiler (ADCP) is utilised to determine discharge capacity and the river profile. The sediment transport rate have been sampled by the Helley-Smith sampler. These sediment samples will be analysed and calculated to determine sediment transport capacity. The utilization of equipment such as:

ADCP is used the Doppler effect to measure the water velocity by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water [8]. ADCP is able to project a detailed profile of water velocity and direction for the river cross section and could help to increases accuracy of flow measurements [9].

Sediment samples were collected using a Helley-Smith sediment sampler for bed load sampling. Suspended load samples were collected manually by bottle. Van Veen sampler was used to obtain bed material. Sampling in wide rivers was carried out by a boat. Sampling method and technique adopted the techniques described in the Guidelines for Field Data Collection and Analysis of River Sediment by Ab. Ghani et al. (2003).

The electrical resistivity is the only geophysical method used to explore sub-surface profile for sand and gravel since 1930 [13]. The new technology of resistivity surveys are expanded the capabilities which are able applied in fluvial geomorphology, mapping of contaminant transport, hydraulic barriers, fracture flow paths, contaminated zone, seepage pathways in embankment dams and hydrocarbon contaminant plume [14]. In summary, the integrated field work will give a better indication of potential, suitability and sustainability of the site for sand mining.

3. RESULTS AND DISCUSSION

3.1. Sungai Perak Profile

Sungai Perak cross section profiles have been produced using ADCP. Five cross sections were selected to obtain the river profile and also sediment collection. Figure 2 shows the locations of river cross sections for sediment transport study at Sungai Perak.

Sungai Perak is wide with its width ranging from 248.18 m to 338.53 m. The sediment collection and cross section measurements were taken on 15 June 2015 and 19 October 2015. The average depth of Sungai Perak is 1.706 m when measured on 15 June 2015 and 1.572 m when measured on 19 October 2015.

The average velocity was between 0.877 m/s to 0.968 m/s. The sediment load of this river is also quite high, ranging from 17.025 kg/s to 80.273 kg/s. The detailed results of average velocity and discharge are shown in Table 1. Further, total sediment loads measured are included in Table 1. Figure 3 shows the typical cross section of Sungai Perak.

Figure 1 The location of study area in Sungai Perak at Pendiat, Perak and cross sections [11], [12].

Table 1 Sungai Perak profile and sediment load.

Data	Depth (m)	Width (m)	Average Velocity (m/s)	Average Discharge (m^3/s)	Total sediment load (kg/s)
SPRK1/07/15	1.589	299.49	0.906	405.731	21.072
SPRK2/07/15	1.433	328.8	0.968	389.107	30.939
SPRK3a/07/15	1.719	142.73	0.956	226.767	20.487
SPRK3b/07/15	1.85	140.42	0.940	230.209	20.487
SPRK4/07/15	1.754	326.58	0.9498	388.962	29.553
SPRK5/07/15	1.895	248.18	0.894	424.065	61.681
SPRK1/10/15	1.894	274.36	0.893	410.907	53.537
SPRK2/10/15	1.328	312.51	0.9	429.364	88.790
SPRK3a/10/15	2.003	156.09	0.946	283.379	22.636
SPRK3b/10/15	1.17	125.78	0.877	130.988	17.025
SPRK4/10/15	1.339	338.53	0.891	435.915	80.273
SPRK5/10/15	1.696	252.06	0.948	398.746	47.912

3.2. Sungai Perak Sub-Surface Profile

The four lines of resistivity surveyed at Sungai Perak are as shown in Figure 4. 32 electrodes were setup on the field with five meter spacing. The Wenner-Schlumberger array was used to project profile for all four lines. The selection of Wenner-Schlumberger array was because of the limited space of the study area. The array has successfully projected the subsurface layer from 25 to 30 meter depth as shown in Figure 5 to 8. The iteration of profile Line 1 is four times with RMS error of 24%. For profile Line 2, the iteration was conducted five times with RMS error of 11%. For profile Line 3 and 4, the iteration was conducted seven times with RMS error of 9% and 18.2% respectively.

The most distinct subsurface characteristics extracted from the electrical resistivity survey were the extensive zone of low resistivity at ground level for Line 1 and Line 2 at 5 meter sub-surface depth and at 7 meter subsurface for Line 3 and Line 4. Based on resistivity survey as well, the low resistivity values indicate that the sand is highly saturated with water (0-40 ohm-m) as referred to in Table 2.

Figure 2 The location of the electrical resistivity survey lines at Sungai Perak [11].

Table 2 Typical resistivity values of geologic materials [13], [15], [16].

Material	Resistivity (ohm-m)
Alluvium	10 to 800
Sand and Gravel with silt	About 300
Sand and gravel with silt layer	300 to 2400
Dry sand and gravel	> 200
Saturated sand and gravel	< 50
Sand	60 to1000
Clay	1 to 100
Groundwater (fresh)	10 to 100

It also can indicate the substantial thickness of overburden sand in the resistivity pseudo-section as shown by a low resistivity zone which is between 100-250 ohm-m. From the interpreted data, there is a thin layer of about 5 to 7 meter with high resistivity value as shown in model Line 3 and Line 4 (red to orange colour). This layer probably consists of gravels and coarse sands with silt layers deposited at this area with the range of resistivity value 300 to 2400 ohm-m. This high resistivity value also probably indicates the high noise level of the data set especially in the upper part of the proposed lines.

Furthermore, based on the outcrop observed on the left bank and right bank of the study area, including river islands, there is indication that the electrical resistivity results matches with the materials observed on the outcrop which are sand and gravel with silt materials. River island consists of sand and gravel which are able to be one of new sources of river sand in order to fulfill the demand of sand in construction industry. By extracting from the river island, the study could infer that this method can also improve the hydraulic performance of the river apart from sand mining.

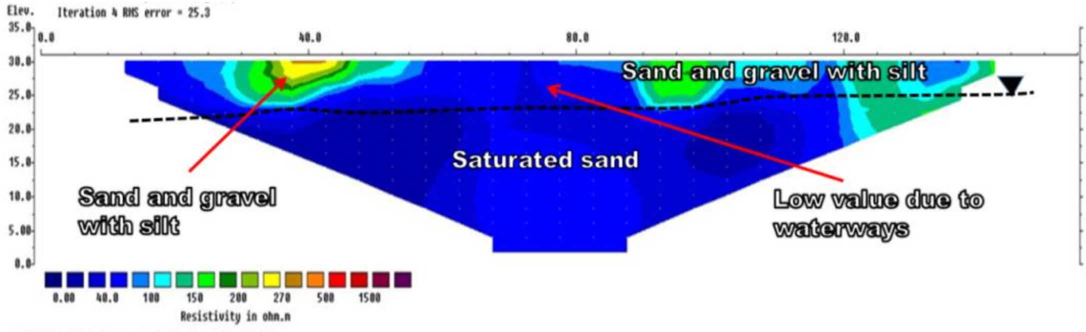

Figure 3 The electrical Resistivity Profile for Line 1 of Sungai Perak.

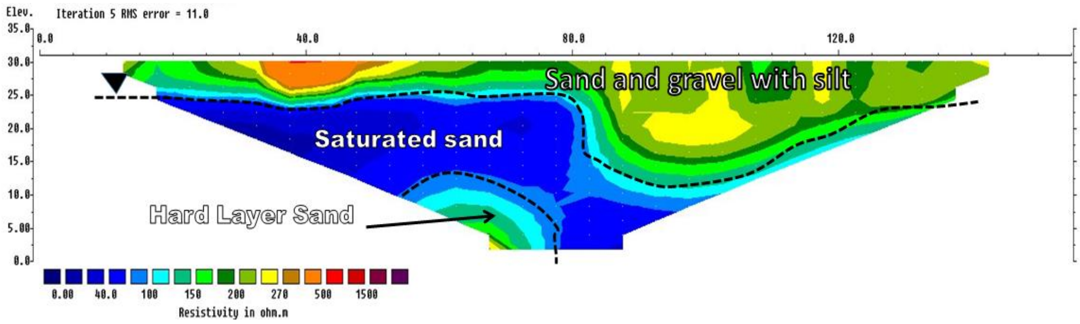

Figure 4 The electrical Resistivity Profile for Line 2 of Sungai Perak.

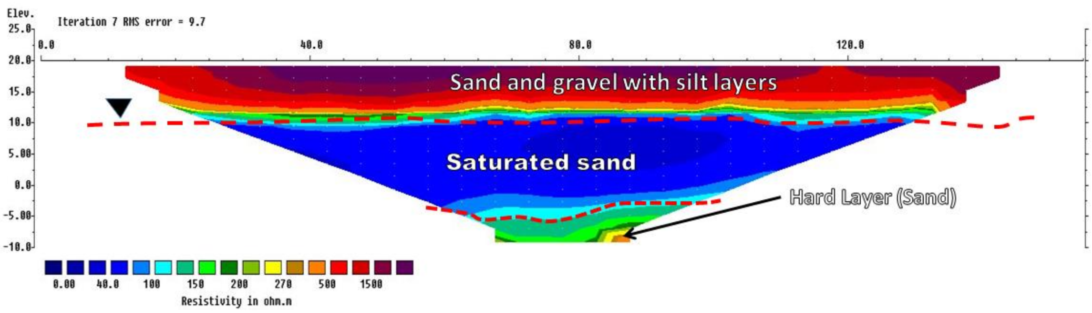

Figure 5 The electrical Resistivity Profile for Line 3 of Sungai Perak.

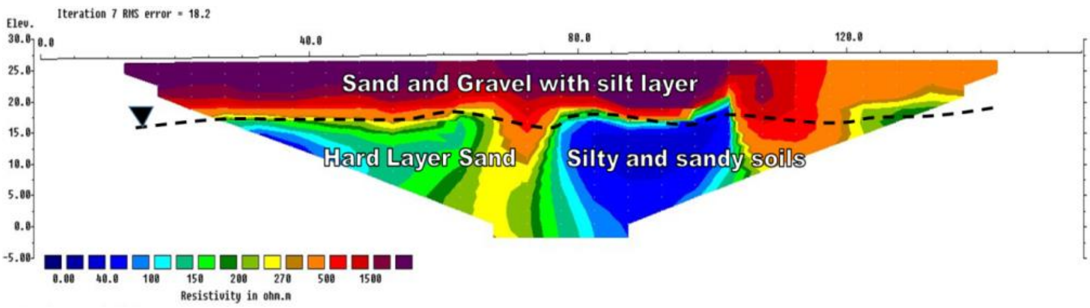

Figure 6 The electrical Resistivity Profile for Line 4 of Sungai Perak.

3.3. Resource Estimation of Sand of River Island

To reduce the significant impact of sand mining, Padmalal and Maya (2014) suggested a practical assessment of sand resource. This is essential to estimate the mineable limits of sand in each stretch of river environment [17]. The following steps are suggested for the purpose:

First, mapping the river channel, associated natural (in-stream and riparian vegetation, sand bars, pools, and riffles) and hydraulic structures such as bridges, water intake structures, and side protection structures. Then, estimation of sand resource in the river channel using suitable methods (shallow seismic surveys in river stretches with sufficient depth and width to run the instrument, resistivity surveys in dry river beds, spiking and coring using specially fabricated coring devices, etc.). Lastly, estimate the mineable quantity of sand in the river channel. Mineable quantity of sand is the volume of sand resource up to a specific depth (fixed by an expert group) in river reaches.

3.4. Estimation Sand Source at Sungai Perak

From resistivity survey, the study infers, that the river bar in Sungai Perak is able to be the new source of sand. The resistivity survey found that the river bar or island have a good type of sand with more than 98% of sand. The calculations of potential sand river extraction from river island are as shown in Table 3.

Although the depth of sand is 10 meter, as found by resistivity survey, the sand extraction cannot be done up to ten meter depth. This is due to the risk of creating nick point in river. The nick point can lower the river profile and increase the river flow at downstream and when over-mining occurs, it can jeopardizes the health of the river and the environment [18]. Based on calculation in Table 3, Sungai Perak is able to cover sand capacity and as alternative sand source.

Table 3 Estimation of sand extraction from river island.

Island No	Depth of extraction (m)	Total extraction
A	0.5	1759.97 m^3 4663907.25 kg
	1.0	3519.93 m^3 9327814.50 kg
	1.5	5279.90 m^3 13991721.75 kg
	2.0	7039.86 m^3 18655629 kg
B	0.5	30204.55 m^3 80042057.50 kg
	1.0	60409.10 m^3 160084115 kg
	1.5	90613.65 m^3 240126172.5 kg
	2.0	120818.20 m^3 320168230 kg

The high replenishment rate of Sungai Perak which is approximately 1245.43 m^3/day can cover back the river bed about six days if 2.0 meter extraction is conducted on this river island A. For river island B, the replenishment period is about 98 days for 2.0 meter extractions. The proper management to control excessive sand mining is needed to ensure the safety of worker and machine. Before starting the extraction, the sand mining operator needs to determine the suitable machine to be used to extract the sand on river island. River island can have a great impact to the river performance.

Ali et al. (2014) have found that the negative impacts of river islands or obstacles which include instability of river cross sections hence reducing the hydraulic performance of the river. It can also cause problem at the intakes of water pumping stations. The river island can cause deflected flow which causes riverbank erosion and instability as illustrated in Figure 9.

Ali et al. (2014) also found that the impact of river island can cause increasing the turbidity, growing of reeds, as well as the effect the aesthetic view over the river and its banks.

4. CONCLUSIONS

Based on resistivity, the river bars and floodplain at Sungai Perak consists of sand and gravel which can be alternative source of sand for construction industry. The resistivity survey was used to obtain the subsurface profile of river island and floodplain. This method is able to project large area of subsurface rapidly at a low cost. Sediment transport is a complex phenomenon [20], due to this factor the sediment load was determined to get the actual sediment load in Sungai Perak to get average and accurate data.

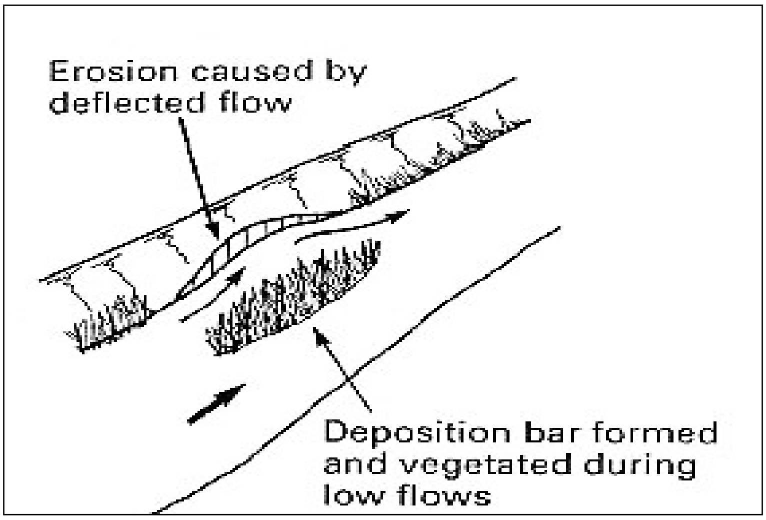

Figure 7 Erosion due to deflected flow by river island [21].

By using this sediment data, it can estimate the replenishment rate of the sand mining area. By using resistivity survey method, the thickness of sand at river bar can be determined which is very useful to determine sand capacity at river bar. The extraction limit at river island has been set to 2 meter to avoid the headcutting. Sediment rating curve can be used to estimate the replenish time to recover the exraction point to ensure that sand extraction is carried out in a sustainable method.

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