TECHNICAL REPORT FOR THE ESTIMATION OF SEDIMENT YIELD

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LIST OF ABBREVIATION

BS	British Standard
DID	Department of Irrigation and Drainage
Sg	Sungai
SS	Suspended Solid
TMDL	Total Maximum Daily Load

1.0 INTRODUCTION

This Technical Report suggests appropriate methods of sampling and measurements to estimate sediment yield that include the monitoring strategies for rivers. Methods suggest are in accordance to the DID Hydrological Procedure No. 15 (1976), and the Manual on Operational Methods for the Measurement of Sediment Transport and World Meteorological Organization, Operational Hydrology Report No. 29 (Yuqian, 1989).

2.0 ENVIRONMENTAL ISSUES

Landuse activities that are human-induced have significant impacts on the river water profile and sediment concentration. These disturbances if uncontrolled can bring about ecological, biological and hydrological changes in the river environment which could lead to further environmental degradation.

Environmental issues as in the case study for sediment discharge in the outflowing river Sg Chini and Sg. Jemberau in Tasik Chini consist of land clearing for plantation and mining activities which impaired water quality of the rivers and lake (Tasik Chini) with sediment release. Land clearing for agriculture/plantation/logging and mining activities has resulted in significant land use change within the catchment area of the lake. Sediment runoff is expected to increase in concentration level during wet weather flow which may cause sedimentation problems and instability to the river channel.

3.0 EROSION AND SEDIMENTATION

Erosion and sedimentation are natural fluvial processes. Erosion involves the removal/detachment of sediment from the parent material anywhere within the watershed. Detached sediments get transported to lower elevation by wind and water as transporting agents. There exist 2 mode of transportation of detached sediments; bedload and suspended load. Bed loads are non-cohesive sediments that enter motion when the critical shear stress is exceeded. They are generally sand and gravel (coarser fractions) that slide, roll and bounce along the river bed partly supported by turbulence in the flow and partly by the bed. Suspended sediment load is the grain that moves in suspension and they are mainly silt and sand. Wash load is part of the suspended-sediment load but the only difference is it does not rely on the force of mechanical turbulence to keep it in suspension. Deposition of sediments takes place along the boundary and is governed by the shear stress of water, density of sediment, viscosity of the flowing water, grain size, surface roughness of the boundary and critical shear stress functions. The above is an excerpt from Fluvial Geomorphology – Anthropogenic Agents of Change and Their Implications (Ariffin, J, 2016).

4.0 EQUIPMENTS AND METHODS OF MEASUREMENTS

This section describes the equipments to be used in sampling sediments and methods of measurements to be adopted. All methods adopt both national and international standards namely DID Hydrological Procedure No. 15 (1976), and the Manual on Operational Methods for the Measurement of Sediment Transport and World Meteorological Organization, Operational Hydrology Report No. 29 (Yuqian, 1989).

4.1 SEDIMENT SAMPLING EQUIPMENTS

4.1.1 Bed Load Sampler

Method for measuring bed load will be in accordance to the Manual On Operational Methods for the Measurement of Sediment Transport and World Meteorological Organization, Operational Hydrology Report No. 29 (Yuqian, 1989). Wading technique will be employed for rivers with less than one meter flow depth as suggested by Yuqian (1989).

There are two types of bed load samplers and their applications depend on the type of sediment and water depth. They are the suspended Helley-Smith bed load sampler (Emmett, 1980) and wading type Helley-Smith bed load sampler (Emmett, 1980). The nozzle areas for the suspended bed load sampler and the wading-type bed load samplers 82 mm (Width of opening) × 74 mm

(Height of opening) and 89 mm (Width of opening) × 90 mm (Height of opening) respectively. Both samplers are attached to a collecting bag of 460 mm length. The two types of samplers are shown in **Figure 1** and **Figure 2**. These samplers are suitable for sampling bed load sediments with sizes ranging from 1 mm up to 64 mm size.

Bed load samples will be brought to the laboratory for measurement of their weight. The average bed load for each cross-section can be obtained by averaging all bed load samples for the cross-section. Bedload discharge per unit width is kg/ms and the total bedload for the whole cross-section is kg/s. Dry sieving method will be adopted for sand and gravel and hydrometer test will be carried on sediments consists of clay and silt. All tests will be carried out in accordance to the British Standard Methods of Test for Soils for Civil Engineering Purposes BS1377: Part 2:1990.

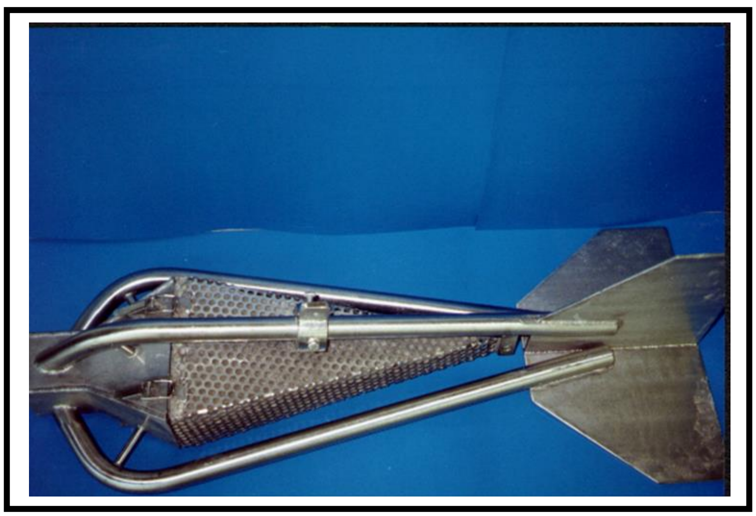


Figure 1 Suspended Helley-Smith bed load sampler

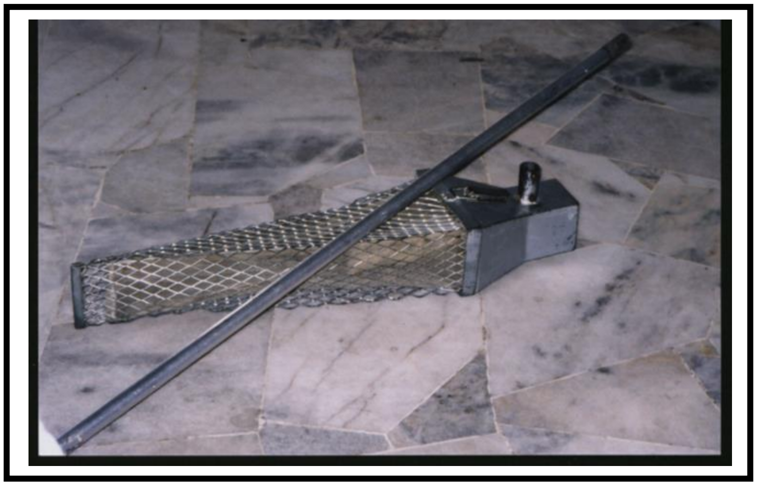


Figure 2 Wading type Helley-Smith bed load sampler

4.1.2 Suspended Load Sampler

Method for measuring suspended load will be in accordance to the DID Hydrological Procedure No.19. (1994). Two types of instruments namely DH-48 and DH-59 (Drainage And Irrigation Department Hydrological Procedure No.19, 1994) are commonly used. DH-48 (**Figure 3**) is suitable for flow depths less than one meter and DH-59 (**Figure 4**) for flow depths exceeding one meter. The DH-48 Suspended Sediment sampler (**Figure3**) is a light-weight sampler with wading rod attached. It consists of a streamline aluminium cast, 33 centimeters in length that partially encloses a 0.47 liter sample container. A standard 1.27 cm wading rod is threaded into the top of the sampler body.

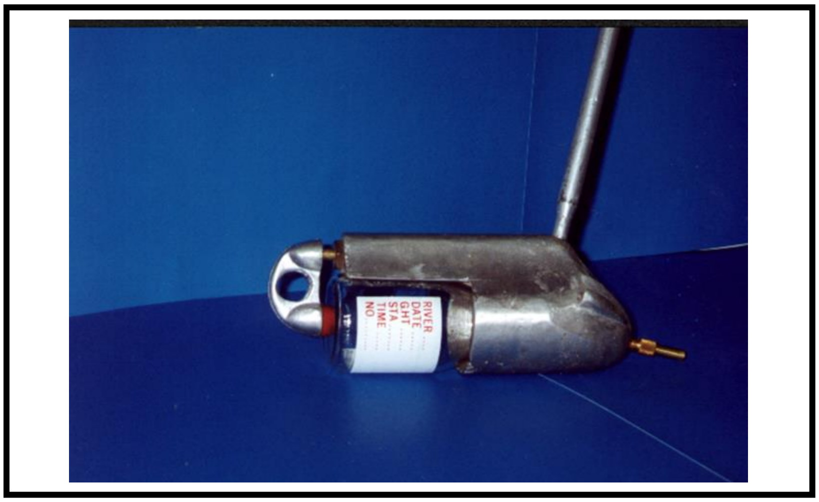


Figure 3 DH-48 type depth integrating sampler

The DH-59 Suspended Sediment sampler (Drainage And Irrigation Department Hydrological Procedure No.19, 1994) as shown **Figure 4** comprises a streamlined bronze casting, 38 centimeters long that partially encloses a pint-size 0.47 liter sample container. The sampler has weight of about 10 kg equipped with a tail vane assembly to facilitate orientation of the intake nozzle to the direction of flow.

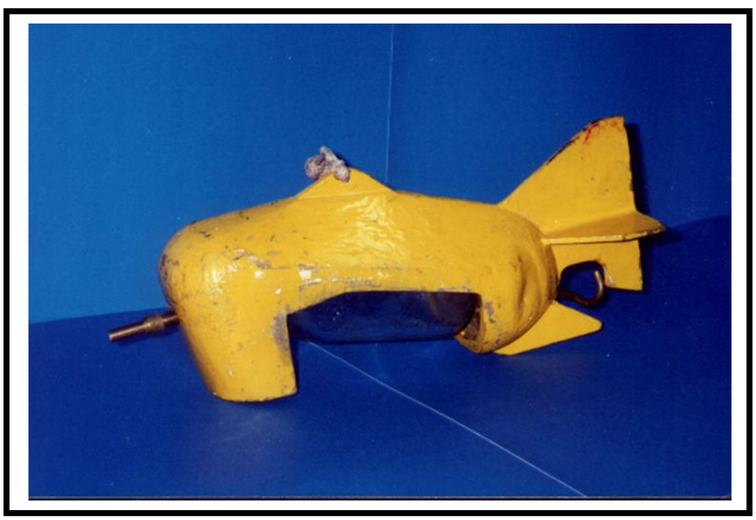


Figure 4 DH-59 type depth integrating sampler

4.1.3 Van Veen Grab Sampler for Bed Material Sampling

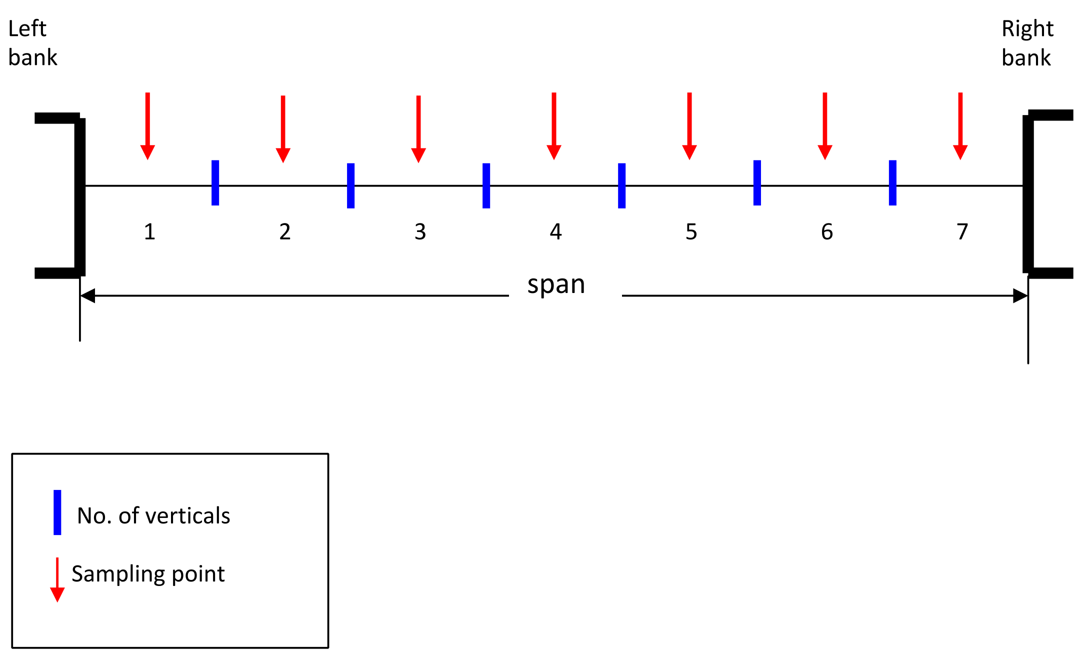
The Hydro-Bios Van-Veen Grab Sampler (**Figure 5**) will be used to grab bed materials. It consists of a grab that can be lowered in an open position by a line. When contacting the bed, the lever that keeps the grab in an open position disconnects and while hoisting, the grab is closed and holds the bottom sample. The depth of sample measured is one foot and the volume of samples that it may capture is about 1 kg by weight. This instrument is simple, of sturdy construction and can be easily maintained in the field, thus does not require a skilled worker to operate the equipment. Materials collected to be emptied into labeled plastic bags and tested in the laboratory for size distribution.

Figure 5 Hydro-Bios Van –Veen Grab sampler

4.2 FIELD MEASUREMENTS

4.2.1 Bedload measurements in the field and sampling strategy

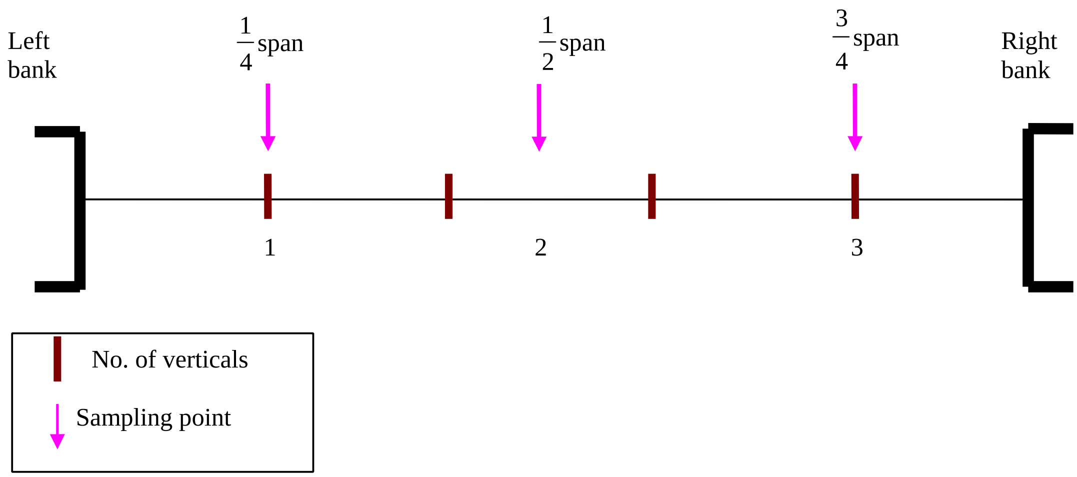
Bedload measurements in the field and sampling strategy are as shown in Figure 6 below.



$$Q_{bi} = \frac{(W_2 - W_1)\, h}{t \times A} \; \left(\frac{\text{kg}}{\text{m\_s}}\right)$$

$$Q_b = \frac{(Q_{b1} + Q_{b2} + Q_{b3} + Q_{b4} + Q_{b5} + Q_{b6} + Q_{b7})}{7} \times \text{span} \; \left(\frac{\text{kg}}{\text{s}}\right)$$

Figure 6 Sampling strategy for bedload measurement (Ariffin, J, 2004)



$$C = \frac{(C_1 + C_2 + C_3)}{3}$$

$$C_V = \frac{C}{S_s}$$

$$Q_s = C_V \times Q \times \rho_s$$

Figure 7 Sampling strategy for suspended load measurement (Ariffin, J, 2004)

4.2.2 Suspended load measurements in the field and sampling strategy

The sampling verticals for suspended sediment concentrations are at one-quarter, middle and three-quarter of the span (Drainage and Irrigation Department Malaysia, Hydrological Procedure No.19, 1994) as shown in **Figure 7**.

Volumetric concentration can be estimated using the following **Equation 1**.

$$C_V = \frac{\text{Weight of sediment} \times 10^6}{\text{Volume of sediment water mixture}}$$ **Equation 1**

4.3 LABORATORY MEASUREMENTS

4.3.1 Bedload measurements

The bed load samples to be placed in pans that are initially weighed. The samples to oven dried under a temperature of 105°C. The weight of the dried bed load samples is to be recorded and the average bed load for each observation can be obtained by averaging the all bed load samples. Unit for bedload is kg/s.

4.3.2 Suspended load measurements

Filtration method (The ASCE Task Committee for the Preparation of the Manual on Sedimentation of the Sedimentation Committee of the Hydraulics Division, 1977) is to be adopted for measurement of suspended sediment load. This method is best for samples of lower sediment concentrations than 2,000 mg/millilitre. The unit for expressing suspended-sediment concentration is milligrams per millilitre computed as 1,000,000 times the ratio of the dry weight of sediment in grams to the volume of water-sediment mixture in cubic centimeters which is also defined as parts per million of sediment in a sample (Pierre, J, 2010).

Procedure

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 2** below:

Total suspended sediment concentration (mg/L) = $[W_{sand + silt + clay}/V_{sample}] \times 10^6$ **Equation 2**

4.3.3 Sediment Size Determination

Sieve analysis and hydrometer test can be used to determine the particle size distribution of the sediment size. Sieve analaysis is for sediment size greater than 0.063mm and hydrometer test is for sediment size less than 0.063mm.

Reference should be made to the following standards.

i) ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils
ii) British Standard, BS 5930:1981 consisting of test for the classification of soil and for the determination of basic physical properties.

5.0 WORKED EXAMPLES

5.1 SEDIMENT LOAD ESTIMATION

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

Bed load discharge equation after Blanchard et al, 2011

$$Q_b = K \text{ x } \left(\frac{Wt}{Tt}\right) \text{xMt}$$ **Equation 3**

Q_b = Bed load discharge in tons per day

K = Conversion factor (0.381)

W_T = Total width of the stream which the sample was collected

T_t = Total time the sampler was on the streambed

Mt = Total mass of sample collected, in grams

Suspended load discharge equation after Blanchard et al, 2011.

$$Q_s = Q_w \text{ x SSC x K}$$ **Equation 4**

Q_s = suspended load discharge in tons per day

Q_w = instantaneous water discharge (ft^3/s)

SSC = Suspended Sediment Concentration (mg/L)

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.

5.2 TOTAL MAXIMUM DAILY LOAD CALCULATION

The methodology for calculating and allocating the wet weather TMDLs for sub-watershed is described below:

Step 1. Quantify Total Existing Wet Weather Loads;

Step 2. Quantify Allowable Loads;

Step 3. Quantify Allowable Exceedance Loads;

Step 4. Quantify Wet Weather TMDLs;

Step 5. Classify Land Use Types as Point and Nonpoint Sources, and Classify Nonpoint Sources as Controllable or Uncontrollable;

Step 6. Quantify Relative Contribution of Pollutant from each Land Use type;

Step 7. Combine landuse types

Step 8. Distribute TMDL among landuse categories.

Basic equation for TMDL (Total Daily Maximum Load) is as given in **Equation 5**.

The calculation for TMDL must include a margin of safety for both point and nonpoint control, which accounts for scientific uncertainty and future growth. Seasonal variations are also included.

A TMDL is a pollution budget and includes a calculation of the maximum amount of a pollutant that can occur in a waterbody and allocates the necessary reductions to one or more pollutant sources. (EPA, 2016). Basic equation of TMDL as following:

$$TMDL = \sum LA + \sum WLA + MOS \qquad \textbf{Equation 5}$$

where:

Load Allocations (LA) : Non-point sources (in this study the focus will be on the concentration of SS & WL)

Non-regulated : Waste Load Allocations (WLA)

Point source : SS concentration come from PS like pipe from resort, restaurant

Margin of safety (MOS) : accounts for uncertainty in estimates of WLA and LA

Worked examples on Sediment Load and Total Maximum Daily Load estimation are given below.

<u>WORK EXAMPLE 1 – Sediment Load Estimation</u>

Bedload can be estimated using **Equation 3** as shown below.

$$Q_b = K \text{ x } \left(\frac{Wt}{Tt}\right) \text{xMt}$$

Total mass of bed load in the sampler for 15minutes duration = 3.69 g

= 0.381*(Width/Time)*Mass of Bedload

= 0.381 x (6.8/ (15*60)) x 3.69

= 0.0106 tonnes / day

= 10.62 kg/day

Suspended load can be estimated using **Equation 4** as shown below.

$Q_s = Q_w$ x SSC x K

Average Velocity = 0.051m/s; SSC 38mg/L

Q = V*Width*Average Depth (m^3/s)

= 0.051 x 6.8 x ((0.25 x 0.62) + (0.5 x 1.68) + (0.25 x 0.58))

= 0.397 m^3/s

Qs = (0.397 x 35.5) x 7 x 0.0027

= 0.2666 Tonnes/day

= 266.6 kg/day

Total Sediment Load =10.62 + 266.6 = **277.18 kg/day**

WORK EXAMPLE 2 – Total Maximum Daily Load (TMDL) Estimation

TMDL for suspended sediment concentration can be estimated using Equation 4. Since data on drainage area and estimated soil loss is required for the estimation, this worked example has adopt data on drainage area and soil loss by Sujaul et al., (2012) in the calculation.

Table 1 Drainage area and estimated soil loss from selected sub-catchments in Tasik 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

Assuming a Margin of Safety (MOS) of 25%, the TMDL can be estimated as follows.

TMDL = Load Allocations + Margin of safety + Future Growth

TMDL **=** 5.77 T/km^2/year * (0.9046km^2)+ 0.25*[5.77 T/km^2/year * (0.9046km^2)] +0.62 *[5.77 T/km^2/year * (0.9046km^2)] **= 9.76 T/year. = 0.027 T/day = <u>27 kg/day</u>**

6.0 CONCLUSION

Estimation of sediment yield has many important uses that include soil loss estimates from the upland areas, sediment transport studies, river profile estimation, and sediment concentration estimation in waterbodies. There are many other techniques/methods suggested by many investigators in this field of engineering and adoption of measurement methods are not limited to the methods proposed in this manual.

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