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Sediment transport equation assessment for selected rivers in Malaysia

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ABSTRACT
This paper describes a total of 122 sediment data obtained from May 2000 until October 2002 at Kinta River Catchment in the river sediment collection and analysis project. Data collection including suspended load, bed load, bed material and flow discharge have been carried out at six study sites consisting of four rivers which are situated at Kinta River Catchment, namely Kinta River, Pari River, Raia River and Kampar River. The sediment transport equation assessments have been carried out using Yang, Engelund & Hansen, Ackers & White and Graf equations. The results of Yahaya (1999) and Ariffin (2004) studies for Kerayong River, Kulim River and Langat River catchment (224 sets of data) are also included in this present study.

Keywords: Sediment transport; alluvial river; flood mitigation; erosion; deposition.

1 Introduction

An alluvial river frequently adjusts its cross-section, longitudinal profile, course of flow and pattern through the processes of sediment transport, scour and deposition. In order to sustain cultural and economic developments along an alluvial river, it is essential to understand the principles of sediment transport for application to the solution of engineering and environmental problems associated with natural events and human activities.

The objectives of the present study (Ab. Ghani *et al.*, 2003) include the following:

(a) Establishment of a sediment transport database for alluvial rivers within a range of low and high flows for a different landuse and development.
(b) Establishment of relationship between flows and sediment loads for the assessment of the stability of river channel due to erosion and deposition for different type of catchment developments
(c) Establishment of relationship between flows and sediment loads for design and evaluation of new and existing flood mitigation projects.

2 Project site

This study includes collection and analyses of all sediment data related to sediment transport for various alluvial rivers (Abu Hassan, 1998; Yahaya, 1999; Ibrahim, 2002; Darus, 2002; Abdul Ghaffar, 2003; Ab. Ghani *et al.*, 2003). The study sites consist of four rivers, namely Kinta River, Raia River, Pari River and Kampar River, which are situated in Kinta River Catchment as depicted in Figure 1.

Six study sites for this study were chosen based on the following criteria:

(a) Natural reach: undeveloped upper or middle reach (less than 30% catchment development) – Kampar River @ KM 34 (Figure 2a).
(b) Natural reach: Developed middle reach (more than 30% development) – Raia River @ Kampung Tanjung (Figure 2b) and Batu Gajah (Figure 2c).
(c) Modified reach: Developed middle reach (more than 30% development) – Kinta River (Figure 2d), Pari River @ Manjoi (Figure 2e) and Buntong (Figure 2f).

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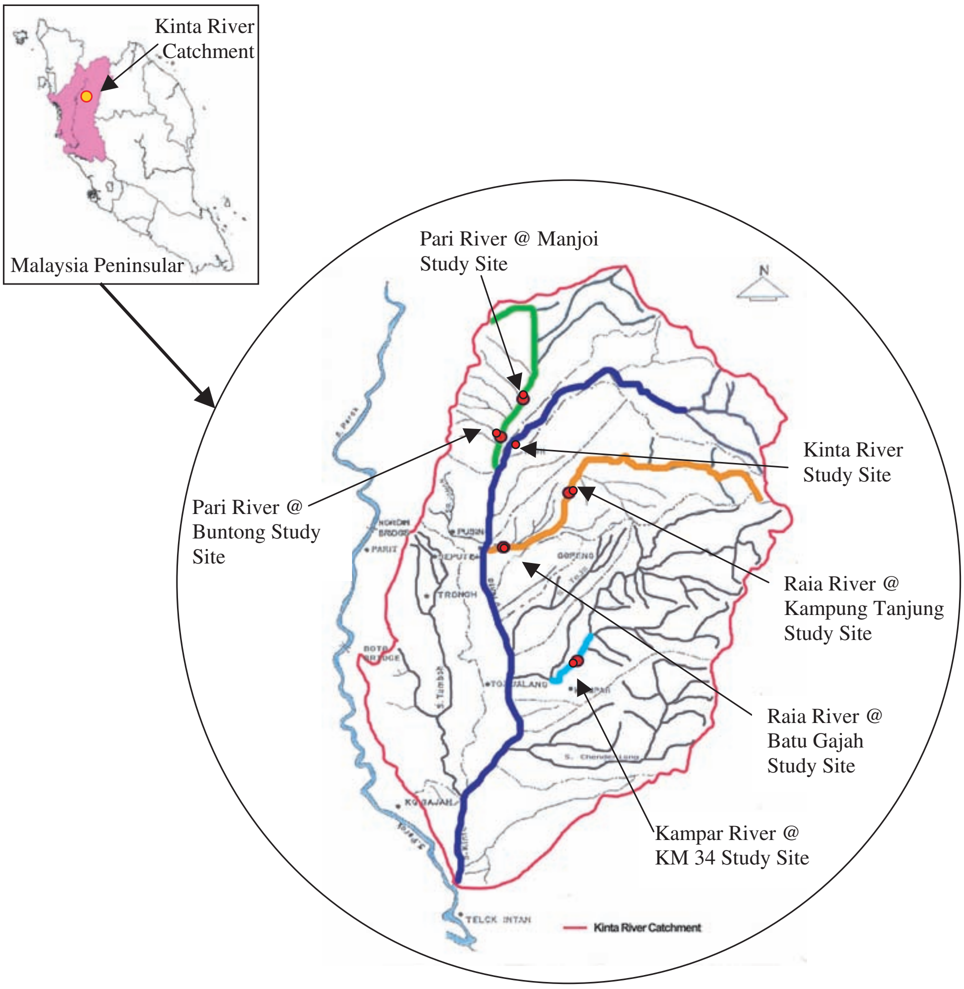


Figure 1 Kinta river catchment.

(a) Kampar River @ KM 34

(b) Raia River @ Kampung Tanjung

(c) Raia River @ Batu Gajah

(d) Kinta River

(e) Pari River @ Manjoi

(f) Pari River @ Buntong

Figure 2 Study sites.

3 Data collection program

Field measurements were obtained along the selected cross section at the six study sites at Kinta River Catchment by referring Hydrological Procedure (DID, 1976; DID, 1977) and recent manuals (Yuqian, 1989; USACE, 1995; Edwards and Glysson, 1999; Lagasse *et al.*, 2001; Richardson *et al.*, 2001). The data collection including flow discharge, suspended load and bed load were carried out from May 2000 to October 2002. Details of data collection and analysis is given in Ab. Ghani *et al.* (2003).

3.1 Flow discharge

A range of flow discharge measurements covering low and high regime were carried out using current meter (Figure 3). The procedure of flow discharge measurement is based on Hydrology Procedure No. 15: River Discharge Measurement by Current Meter (DID, 1976). Measurements taken include flow depth (yo), velocity (v), and river width (B).

3.2 Bed load

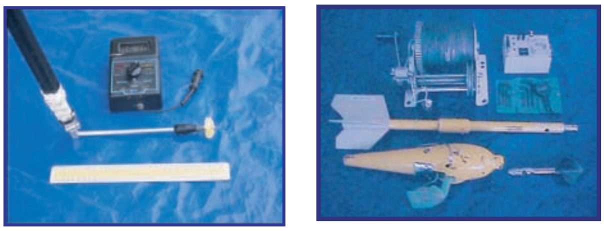
Bed load samples have been collected using Helley-Smith sampler (Figure 4) at seven measuring points for each cross section. The bed load transport rate (Q_b) was computed based on these seven samples.

3.3 Suspended load

Suspended load samples have been collected at each study site using DH 48 and DH 59 samplers (Figure 5) with depth integrating technique (DID, 1977). There are three measuring points for each cross section. The suspended load transport rate (Q_t) was computed based on these three samples.

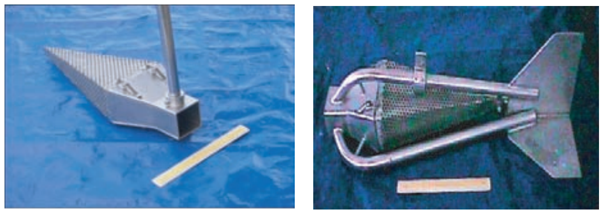
3.4 Bed Material

River bed material were collected using Van Veen grab sampler (Figure 6). Seven samples were collected at points similar to those of bed load. An average sediment size (d_{50}) was used for analysis.



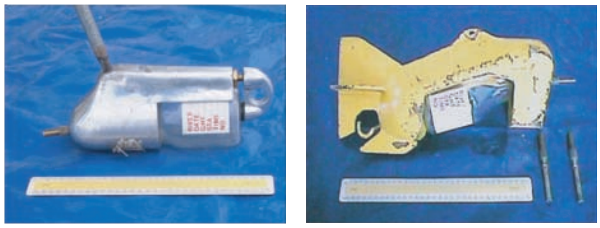
Swoffer 2100 Model Neyrflux Type 80

Figure 3 Current meter.



(a) Low Flow (b) High Flow

Figure 4 Helley-Smith sampler.



(a) Low Flow (b) High Flow

Figure 5 Suspended load sampler.

Figure 6 Van Veen grab sampler.

3.5 Total Load

Total load transport rate is estimated by summing bed load and suspended load transport rates. Table 1 shows the summary of the data collection and the total load transport rate against discharge are shown in Figure 7.

Table 1 Range of field data for Kinta River catchment (Ab. Ghani *et al.*, 2003).

Study sites	No. of sample	Discharge, Q (m^3/s)	S_o	B/y_o	d_{50} (mm)	Bed load transport Q_b (kg/s)	Suspended load transport Q_t (kg/s)	Total load transport Q_j (kg/s)
Kampar River @ KM 34	21	7.98–17.94	0.0010	17–38	0.85–1.10	0.40–1.25	0.10–1.49	0.57–2.47
Raia River @ Kampung Tanjung	20	3.60–8.46	0.0036	46–107	0.60–1.60	0.20–1.82	0.07–1.39	0.65–2.11
Raia River @ Batu Gajah	21	4.44–17.44	0.0017	12–45	0.50–0.85	0.25–1.37	0.09–2.04	0.47–2.69
Kinta River	20	3.80–9.65	0.0011	48–86	0.40–1.00	0.02–1.21	0.21–12.31	0.23–12.82
Pari River @ Manjoi	20	9.72–47.90	0.0011	11–29	1.70–3.00	0.40–0.80	0.79–16.81	1.25–17.62
Pari River @ Buntong	20	9.66–17.04	0.0012	22–29	0.85–1.20	0.35–0.79	0.67–4.41	1.03–4.89

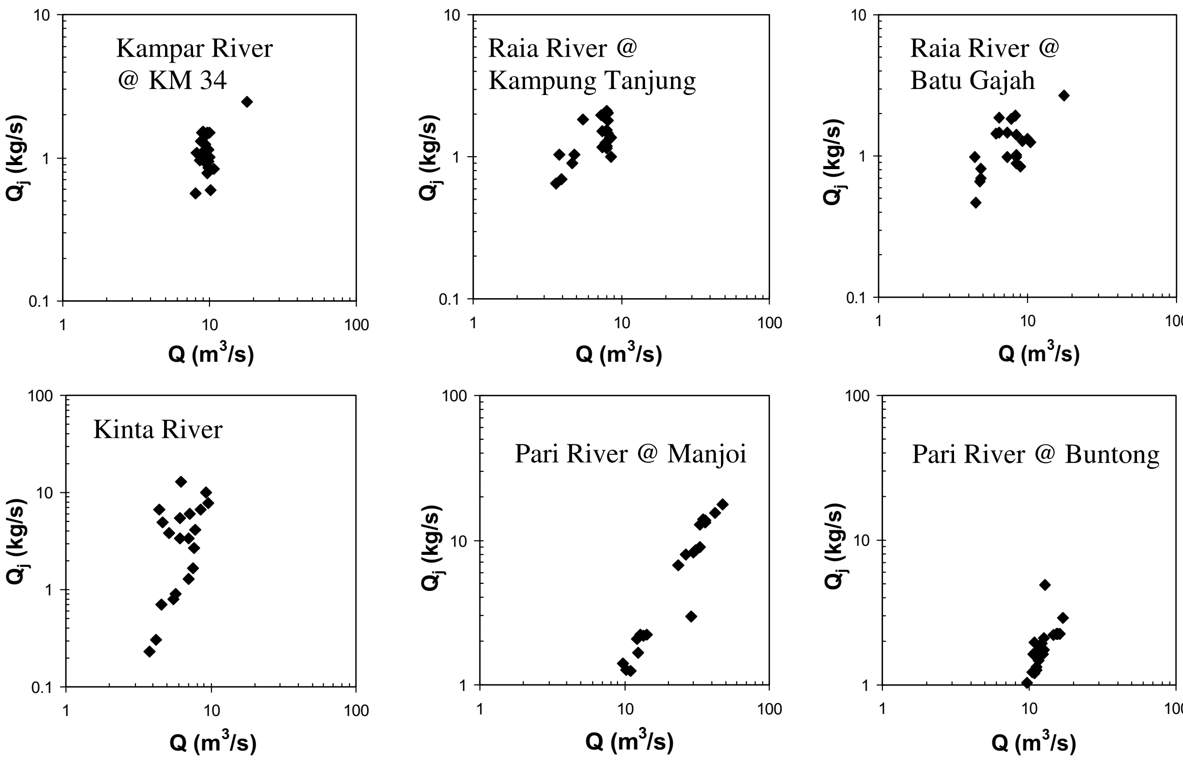


Figure 7 Total load transport rating curves (Ab. Ghani *et al*., 2003).

Table 2 Range of field data for Yahaya (1999) and Ariffin (2004).

Study sites	No. of sample	Discharge, Q (m^3/s)	S_o	B/y_o	d_{50} (mm)	Bed load transport Q_b (kg/s)	Suspended load transport Q_t (kg/s)	Total load transport Q_j (kg/s)
Kerayong River	27	0.85–6.08	0.00125	31–82	2.00–3.10	0.31–0.75	0.12–15.04	0.47–15.78
Kulim River	16	1.39–11.14	0.0010	18–46	3.00–4.00	0.07–0.34	0.26–6.78	0.34–7.08
Pari River @ Taman Merdeka	16	5.28–24.35	0.00125	34	2.00–3.10	0.31–0.75	0.12–15.04	0.47–15.78
Langat River @ Kajang	20	3.75–39.56	0.0043–0.0060	14–33	0.37–2.13	0.02–1.29	0.65–77.51	0.78–77.86
Langat River @ Dengkil	3	33.49–87.79	0.00167	9–17	0.52–0.95	0.27–0.65	18.69–118.30	18.96–118.95
Lui River @ Kg Lui	92	0.74–17.17	0.0003–0.0093	17–66	0.50–1.74	0.04–1.55	0.05–5.77	0.27–6.16
Semenyih River @ Kg Sg Rinching	50	2.60–8.04	0.0023–0.0150	17–41	0.88–2.29	0.65–3.16	0.24–10.77	1.08–12.08

Table 3 Summary of sediment transport assessment (Ab. Ghani *et al*., 2003).

Equation	Discrepancy ratio (0.5–2.0)					
	Present study		Yahaya (1999) and Ariffin (2004) studies		All data	
	No. of data	Percentage	No. of data	Percentage	No. of data	Percentage
Yang	**22**	**18.03**	**60**	**26.79**	**82**	**23.70**
Engelund and Hansen	**30**	**24.59**	**46**	**20.54**	**76**	**21.97**
Ackers and White	7	5.74	37	16.51	44	12.72
Graf	10	8.20	36	16.07	46	13.41
Modified Graf (Eq. (1))	**33**	**27.05**	**37**	**16.51**	**70**	**20.23**
Total	**122**	**100**	**224**	**100**	**346**	**100**

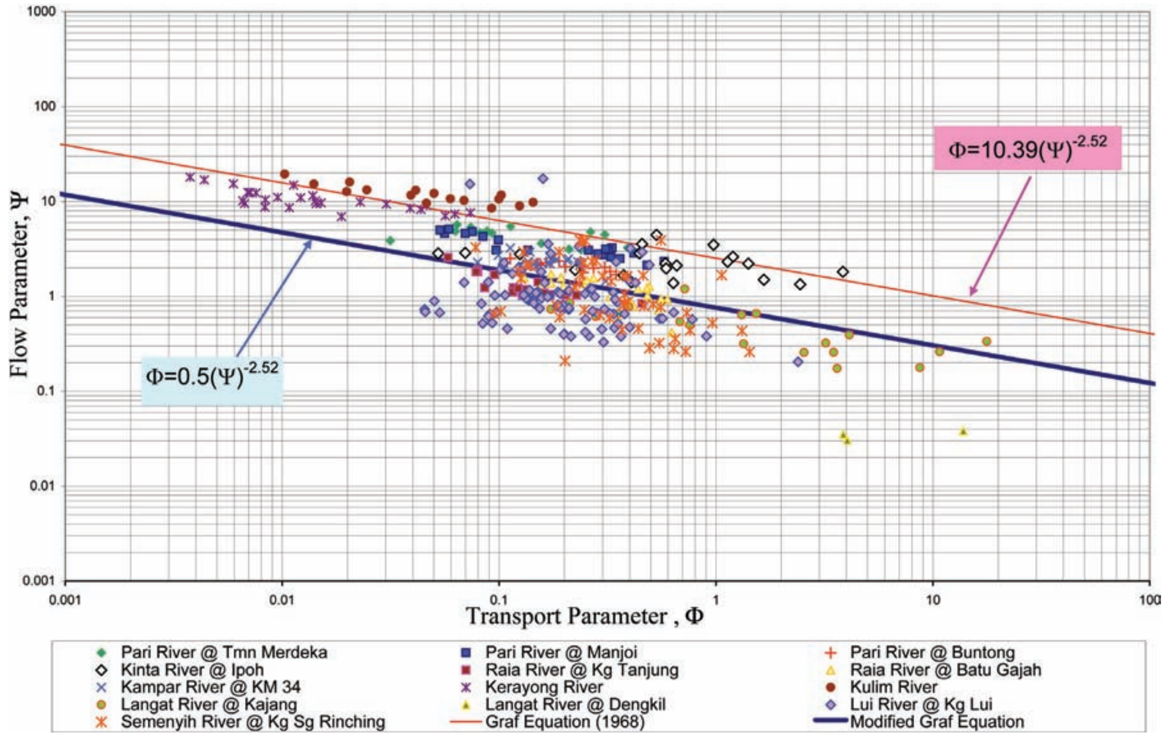


Figure 8 Relationships between transport parameter (Φ) and flow parameter (Ψ).

4 Sediment transport equation assessment

The analysis for a total of 122 set of data was made for four sediment transport equations including Yang, Engelund and Hansen, Ackers and White and Graf. The analysis also included 224 sets of data from Yahaya (1999) and Ariffin (2004) studies for Kerayong River, Kulim River and Langat River catchment (Table 2). Table 3 shows the summary of the sediment transport assessment. The result shows that Yang and Engelund and Hansen equations gives better prediction of measured data. The assessment was based on average size of sediment (d_{50}). It is expected that using fraction size of sediment will give better estimation of measured data.

Figure 8 below shows that the relationship between transport parameter (Φ) and flow parameter (Ψ) for the total 346 data. Comparison with Graf equation shows that the Malaysian sediment transport data consisting of mainly coarse sand (Kerayong River and Kulim River) agrees well with the equation. However, for fine sand, the modified Graf equation seems to suit better:

$$\Phi = 0.5\,\Psi^{-2.52} \tag{1}$$

where:

$$\Psi = \frac{(S_s - 1)d_{50}}{RS_o} \tag{2}$$

$$\Phi = \frac{C_v VR}{\sqrt{g(S_s - 1){d_{50}}^3}} \tag{3}$$

S_s is the specific gravity of sediment, R the hydraulic radius, S_o the water surface slope, C_v the volumetric concentration and g the gravity acceleration.

5 Conclusions

From the results of sediment transport assessment for total load (346 sets of data), it can be concluded that Yang and Engelund and Hansen equations can be used to predict sediment transport rate for sand-bed rivers in Malaysia. The modified graph equation is recommended as alternative equation for rivers in Malaysia (Figure 8).

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