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SEDIMENT PATTERN ANALYSIS AT IJOK INTAKE USING CCHE2D

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ABSTRACT

Ijok Intake is located in district of Larut Matang, Perak, Malaysia and was constructed in year of 1936 to supplement the Kerian Irrigation Scheme via Ijok Canal. Sedimentation at the inlet and in the structure of the Ijok Intake has reduced the flow capacity into the Ijok Canal. A study to predict sedimentation behavior was carried Ijok Intake using a two-dimensional depth-average flow and sediment transport mathematical model, CCHE2D. Evaluation of the sediment transport equations is limited to two equations namely Englund Hansen (1967), and Wu et. al (2001). The results indicated that Englund Hansen equation was to be the suitable equation to represent the sediment transport in the study reach. The CCHE2D mathematical model gave good results for evaluation of velocity distribution, bed and bank changes. It shows that the velocities and the locations of erosion and depositions are in good agreement with the measured and observed data. In conclusion, CCHE2D model is capable to predict the sediment behavior at the Ijok Intake with reasonable accuracy and reliability.

***Keywords**: Sedimentation, Water Intake Structure, 2D modelling, CCHE2D*

INTRODUCTION

For the past 3 decade, Malaysia has undergone a very rapid development, urbanization, industrialization, expansion of agriculture, forest and mining activities. With these all activities, it can give impact on the environmental especially to the river systems. River is a dynamic system which changes their shape and morphology over time as a result of hydraulic forces and sediment transport process. These changes could be natural or human induced and may be gradual or rapid [1, 2].

There are several approaches in studying river hydraulics and sediment transport such as field measurements, mathematical model [3 - 7], physical model [8 - 11] and combination for both models [12 - 14]. In solving river engineering problems, mathematical models have been widely used. Mathematical models can be categorized into one, two and three- dimensional model. The choice of mathematical model depends on the problems to be analysed, evaluated and the complexity. Sometimes, combination of one-dimensional and two-dimensional or three-dimensional model is used to get better simulation results [4, 5and 15].

Sedimentation at the Ijok Intake is a common example of the impact of sediment transport process. Partial blockage by sediment restricted water flow through the intake structure and reducing its efficiency to deliver water through the Ijok Canal, also increasing the maintenance cost to remove sediment accumulated within the intake and river bed in front of the intake. The problems of sedimentation involve at water intake on rivers can be minimizing by knowing these sediment pattern that enters the intake structure [16 - 18]. Thus, the objectives of this study are to develop a 2D mathematical modelling for Ijok River and to investigate in detail the sedimentation behaviour and flow patterns in the vicinity of Ijok Intake. It is necessary to investigate the sedimentation pattern at this water intake in order to understand the sediments problem.

STUDY AREA

The study area is located in the northern part of Perak State (Figure 1). Ijok Canal is in the District of Larut, Matang and Selama, was constructed in the year 1936 to supplement water to the Kerian Irrigation Scheme which is in the District of Kerian. Kerian Irrigation Scheme was constructed in the year of 1902 and completed in the year 1906. Main water supply for Kerian Irrigation Scheme is from the Bukit Merah Reservoir which receives the most of its water from the Kurau River system. The Ijok Intake is located on the left bank of Ijok

River (a tributary of Kerian River system). The water is diverted from Ijok River through the intake. From the intake, the water is delivered via Ijok Canal to a 10m deep drop structure (known as Outfall) then joining one of the tributary of Merah River before entering the Bukit Merah Reservoir (Figure 1).

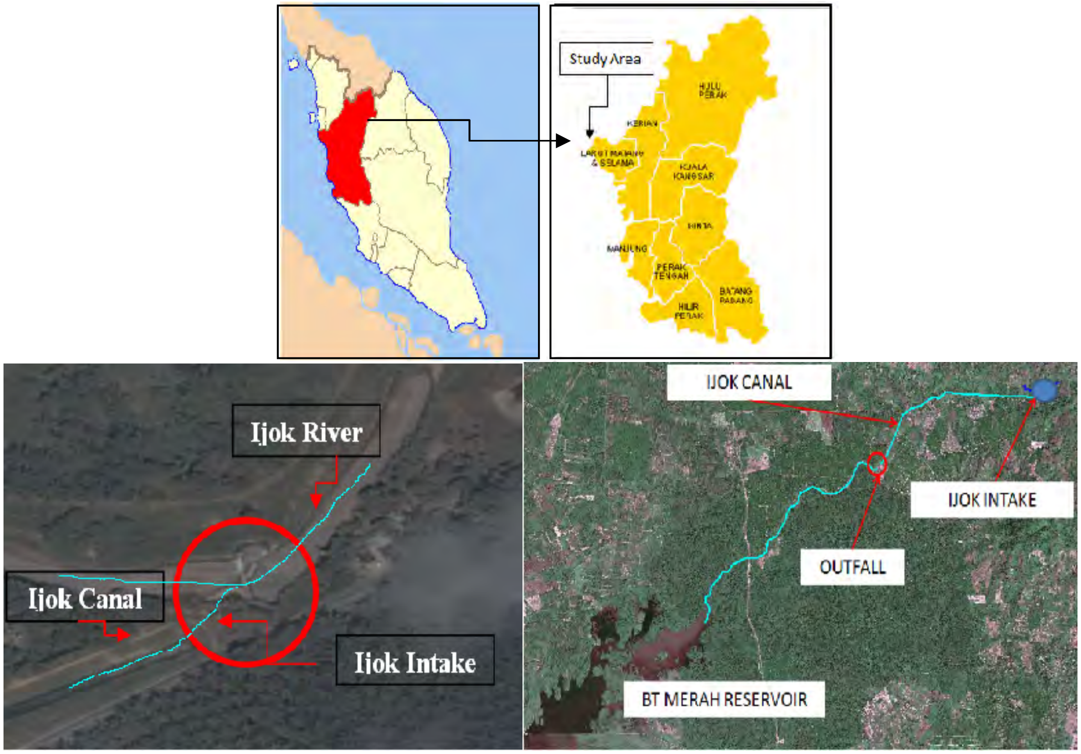


Figure 1: Location Map of the Study Reach on the Ijok Intake at District of Larut Matang, Perak, Peninsular Malaysia

MODEL DESCRIPTION

CCHE2D

The two-dimensional mathematical model, CCHE2D was applied to study the hydraulics and sediment transport of Ijok Intake. The CCHE2D mathematical model is a finite element based depth-integrate two dimensional designed for simulating turbulent, free surface flow in open channels, sediment transport, channel morphological change, bank erosion water quality evaluation which have been developed by National Centre for Computational Hydroscience and Engineering [20].The CCHE2D mathematical modelling is an integrated system which consists of a mesh generator (CCHE2D Mesh Generator) and Graphical User Interface (CCHE2D-GUI) as given in Table 1. For sediment transport cases, CCHE2D model is able to simulate total load, bed load and suspended load.

Table 1: CCHE2D Package

CCHE2D Package	Purpose	Input
CCHE2D Mesh Generator	➢ Generate mesh to construct geometrical layout (Figure 2)	➢ Topography data ➢ Bed elevation data
CCHE2D-GUI	➢ Initial and boundary condition ➢ Model parameter ➢ Run simulation ➢ Visualization results	➢ Discharge/hydrograph data ➢ Stage/rating curve data ➢ Sediment data

The capability and performance of CCHE2D mathematical modelling in evaluation of hydraulics and sediment transport in river has been assess by National Centre for Computational Hydroscience and Engineering [21].

Other studies that used CCHE2D mathematical model [4, 5, 7, 15 and 22] showed that CCHE2D was capable to simulate flow behaviour (specific discharge, shear stresses, velocity magnitude and distribution) and sediment transport (sediment transport rate, grain size distribution, bed and bank changes).

DATA COLLECTION

Data required to conduct the sediment transport modeling for this study are canal geometry data, flow discharge and sediment data. Flow discharges and sediment data were collected at three different cross sections (Figure 2b) along the study reach. Sediment data include bed material, bed load and suspended load. Table 2 listed the data, method of analysis, and purposes of the data. The summary of hydraulic and sediment data collected is shown in Table 3.

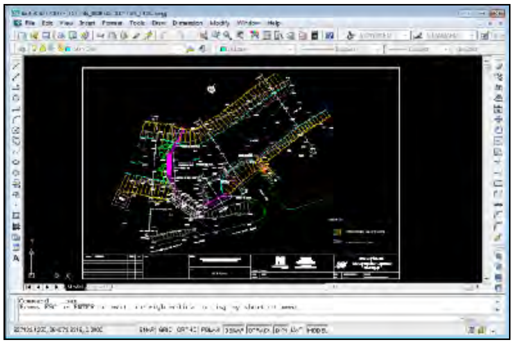
Table 2: Data Need for Model Simulation

Data	Method	Purpose
Survey Work	- Plot the cross section point in AutoCAD format - Converted into GIS format	- Use as geometrical input data
Flow Measurement	- Manual calculation	- To establish stage – discharge rating curve - Manning's number - Surface slope
Bed Material Sampling	- Sieve analysis - Laboratory works	- To develop the sediment size distribution curve
Bed Load Measurement	- Sieve analysis - Laboratory works - Manual calculation	- - To develop the sediment size distribution curve - To determine the bed load rate and suitable sediment transport equation
Suspended Load Measurement	- Laboratory works - Manual calculation	- - To determine the suspended load rate

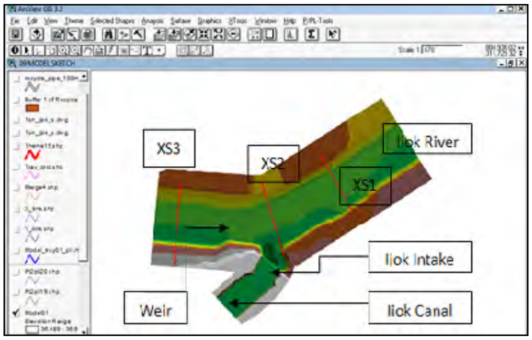
Table 3: Summary of Data Collection

No. of Sample Points	Flow Discharge Q (m^3/s)	Flow Velocity V (m/s)	Flow Width B (m)	Average Flow Depth Y_0 (m)	Surface Slope S_0	Manning Value n	Mean Diameter d_{50} (mm)	Bed Load T_b (kg/s)	Suspended Load T_s (kg/s)	Total Load T_j (kg/s)
7	6 - 8	0.7 – 0.88	15	0.5 – 0.70	0.0008	0.021-0.027	1.50 – 2.00	0.55 – 0.67	0.02–0.049	0.57 – 0.719

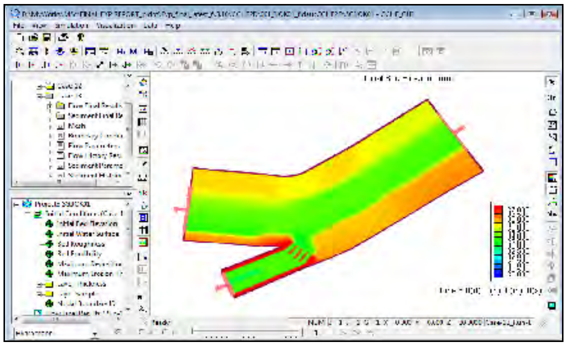
ArcView GIS with the 3D and spatial analysis extensions was use to generate geometry data for CCHE2D as shown in Figure 2.



(a) River Layout in AutoCAD Format



(b) River Layout in TIN Format



(c) CCHE2D Geometric Data

Figure 2: Preparation of Geometry Data

SEDIMENT TRANSPORT EQUATION EVALUATION

A sediment transport equation is required in the sediment transport modeling. The accuracy of sediment routing depends on the "correct" sediment transport equation used in the model. In this study, the bed load transport was used because it is directly related to the problem of sedimentation at the intake. Bed load occurs mostly at a non-equilibrium state and is usually simulated by non-equilibrium transport models. Non-equilibrium approaches are proposed for cases where sediment transport occurs mainly as bed load, suspended load or as full total load [13].

Several sediment transport equation have been proposed by many researchers and widely used in recent years as accounting to give an effect of non-uniform sediment transport capacity. CCHE2D model provide four bed load equations namely Wu et al, modified Ackers & White, modified Engelund & Hansen and SEDTRA formula. Selection of the "suitable" sediment transport equation was based on the analysis for a total of nine days set of data and was limited to two equations namely Engelund-Hansen (1967) and Wu et al (2001). Engulend-Hansen (1967) equation was found to be suitable equation to represent the sediment transport in the study reach due to discrepancy ratio (DR) within range 0.5 – 2.0 (Table 4) compared with Wu et al (2001) equation.

Table 4: Summary of Sediment Transport Equation

Location	Sediment Transport Equation Discrepancy Ratio (DR = 0.5 – 2.0)					
	Engelund-Hansen (1967)			Wu et al (2001)		
	Computed	Measured	DR	Computed	Measured	DR
XS 1 (Upstream)	1.500	0.717	2.00	0.0320	0.717	0.044
XS 2 (Middle)	1.073	0.602	1.78	0.0150	0.602	0.025
XS 3 (Downstream)	1.630	0.613	2.00	0.0059	0.613	0.010

MODEL SIMULATION

Boundary Condition

Computational of CCHE2D model are conducted in a limited portion of free surface flows, boundary condition are the driving mechanism with the flow in the simulated area behave [20]. Flow boundary condition of two outlets (Ijok River and Ijok Canal) and one inlet (Ijok River) were specified as in Table 5. Hydrograph chosen for the simulation was the highest measured discharge and rating curves has been constructed by using river modelling software HEC-RAS (developed by River Engineering Centre of US Army Corps of Engineer) based on steady flow simulation. HEC-RAC modelling is not described in this paper.

Table 5: Boundary Condition of Simulation Needs

Boundary Type	Flow Boundary Condition
Inlet (Ijok River)	Hydrograph (steady flow of 7 m^3/s)
Outlet (Ijok River)	Rating Curve
Outlet (Ijok Canal)	Rating Curve

Sediment Transport Parameter

A complete simulation of sediment transport needs some information on sediment properties, sediment transport capacity, sediment size classes, and movable bed roughness. The sediment properties include the sediment grain size, specific gravity (default value: 2.65), grain shape factor (default value: 0.7) and bed material porosity. The sediment transport capacity used is Engelund-Hansen (1967) formula and bed erodibility was set as non-erodible at intake inlet and weir to replicate the real condition at the study reach.

RESULTS

The CCHE2D produce three sets of results namely the Final Flow Results (Flow), the Sediment Final Results (Sediment) and bank erosion. For this paper, three most relevant outputs are discussed which are the velocity distribution, shear stress, and bed changes.

Velocity Distribution (Flow)

Figure 3 shows the result of velocity distribution at the end of simulation time. The water flows slowly at the upstream of intake entranced and from the flow rate and velocity analysis, location where accumulation of sediment can be determined. The result also shows that the velocity is slightly higher at meandering area near the left bank compared to the right bank from upstream of the weir and velocity increases immediately downstream of the weir.

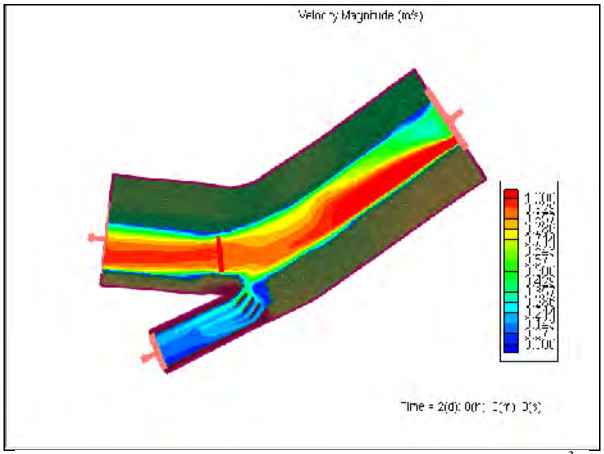


Figure 3: Velocity Distribution of Simulated Flow at $Q = 7m^3/s$

Shear Stress (Flow)

The result as depicted in Figure 4 shows that the shear stress concentrated on the left bank of the upstream portion of Ijok River. The shear stress gradually decreases at the upstream of the Ijok Intake. Shear stress in the Ijok Canal is very low.

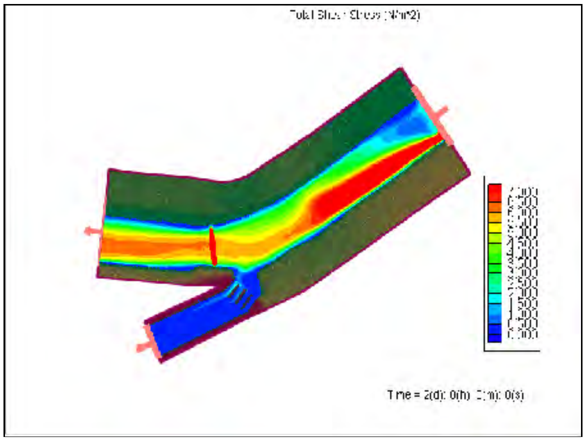


Figure 4: Shear Stress Distribution of Simulated Flow at $Q = 7m^3/s$

Bed Changes (Sediment)

The sedimentation pattern after two days simulation is illustrated in Figure 5. The simulation shows that sediments mostly accumulated in front of Ijok Intake (high concentration represents by red in colour) that has low velocity. The negative values represent the location of erosion at study reach (represent by blue in colour). Erosion occurred at the inner-side of river bend where higher velocity and shear stress were identified. Higher erosion rate occurred immediately after the weir because of rough turbulent flow passes through the weir.

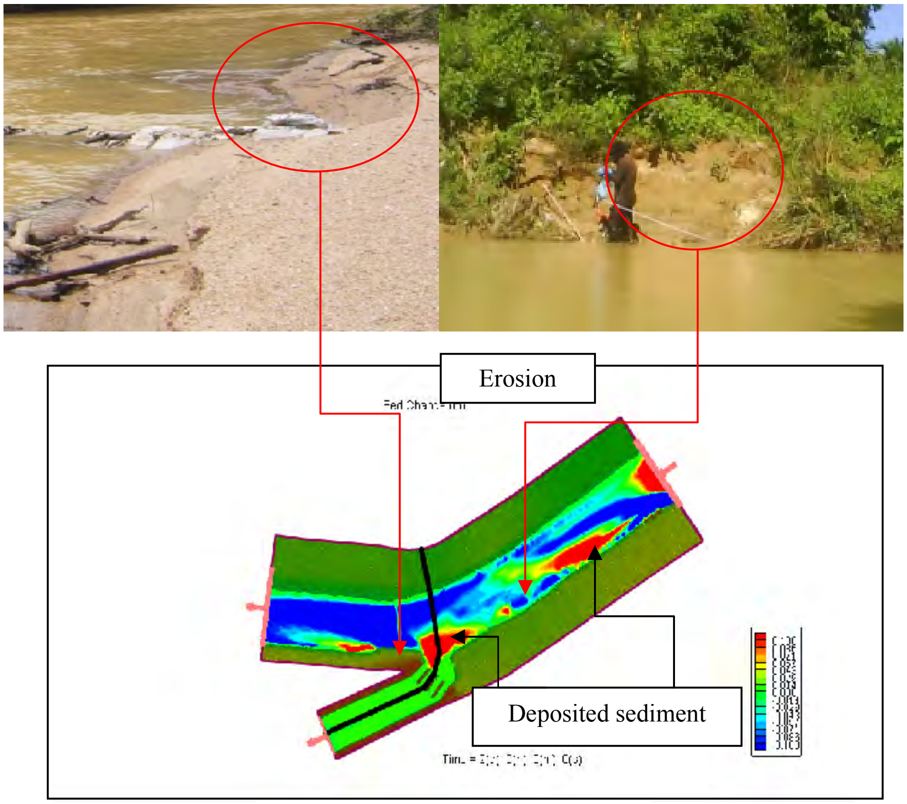
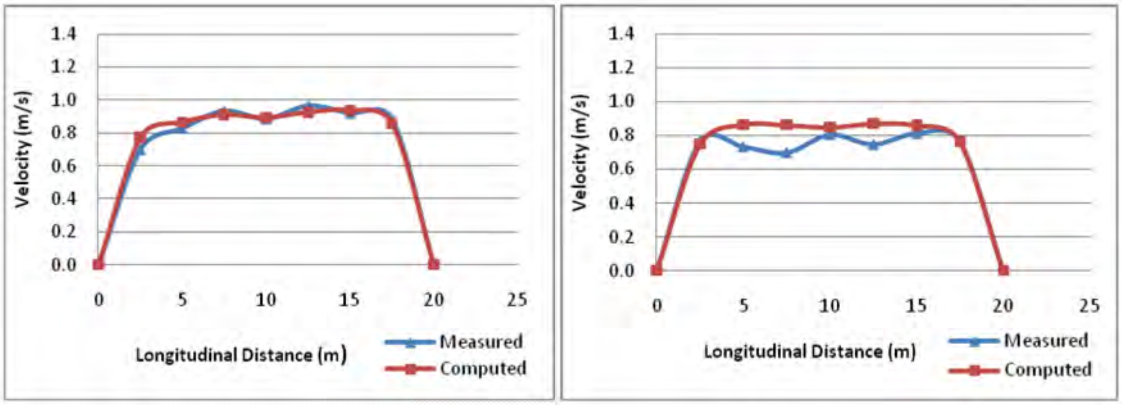


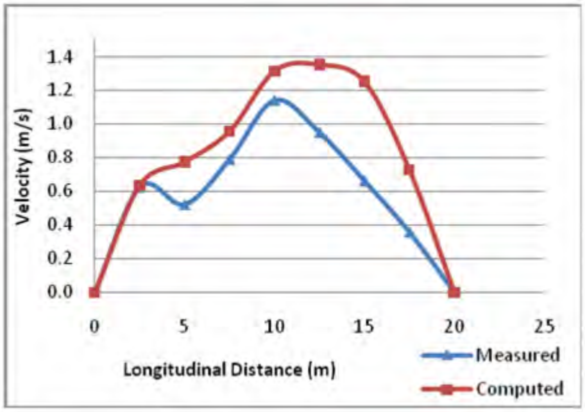
Figure 5: Analysis Results for Bed Changes

MODEL VERIFICATIONS

Verification is the most important step in the mathematical model in order to check the ability of model in predicting the physical phenomena correctly as it has been designed for [21]. Therefore, comparisons of the modelling outputs with measured value were conducted. This is the best way to check if there is any error occurred in the simulation process because the accuracy of mathematical model is limited by the quality and quantity of the input data [6, 21]. In this study, simulation using flow discharge, $Q = 7\ m^3/s$ has been used. Comparison of the velocity distribution for three different cross-sections is shown in Figure 6. It can be seen, the computed values for the velocity distributions are quite close to the measured data for XS1 and XS2 but not at the XS3 which is located after the weir. The water that flow passes through the weir are rough turbulent and can give effect to measured data.



(a) XS1 (Upstream) *(b) XS2 (Middle)*



(c) XS3 (Downstream)

Figure 6: Comparison of Computed Results and Measured Data for Velocity Distribution

CONCLUSION

The sedimentation problem at water intake has reduced the capability of water to flow through canal. The selection of sediment transport equation for simulation is based on range of discrepancy ratio and Englund Hansen equation showed the suitable equation to represent the sediment transport. In this study, a CCHE2D accounting for unsteady flow and bed load transport to predict the pattern of sedimentation at vicinity of Ijok Intake. Simulation results show that sediment accumulated at areas of low velocity and higher velocities show erosion. The verification of velocity was made by comparing the computed values with the measured values. For sedimentation behavior, the simulated results were compared with the visuals observations. It shows that the velocities and the locations of erosion and depositions are in good agreement with the measured and observed data. It can be concluded that CCHE2D is capable to predict the sedimentation behaviour at the Ijok Intake.

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REFERENCES

[1] Chang, H.H. (1988) Fluvial Processes in River engineering, Wiley and Sons Publication, NY.
[2] Garcia, M.H. (2008) Fundamentals of Fluvial Geomorphology, Sedimentation Engineering Processes, Measurements, Modeling, and Practice. In Biedenharm, D.S., Watson, C.C. and Thorne, C.R. ASCE Publication.

[3] Wang, S.S.Y. and Wu, W. (2004) River Sedimentation and Morphology Modeling- The State of the Art and Future Development. Proceedings of the Ninth International Symposium on River Sedimentation, October 18-21. Yichang, China

[4] Abu Hasan, Z., Ab. Ghani, A. and Zakaria, N.A. (2007) Application of 2D-Modelling for Muda River Using CCHE2D. Proceeding of 2nd International Conference on Managing Rivers in the 21st Century: Solutions towards Sustainable River Basins, June 6-8. Kuching, Sarawak, Malaysia.

[5] Formann, E., Habersack, H.M. and Schober, S. (2007) Morphodynamic River Processes and Techniques for assessment of Channel Evolution in Alpine Gravel Bed Rivers. Journal of Geomorphology. 90: 340-355.

[6] Chang, C.K., Ab Ghani, A., Abdullah, R. and Zakaria, N.A. (2008) Sediment Transport Modeling for Kulim River – A Case Study. Journal of Hydro-environment Research. 2: 47-59.

[7] Zhou, G., Wang, H., Shao, X. and Jia, D. (2009) Degradation in the Yangtze River Channel Downstream of three Gorges Reservoir. Journal of Hydraulic Engineering. 135(9): 729-790.

[8] Devries, J.J., ASCE, M. and Hartman, W. (1988) Sediment Modeling for the Sacramento River Diversion to the Peripheral Canal. Proceedings of the International Symposium, August 9-11, California.

[9] Peakall, J., Ashworth, P. and Best, J. (1996) Physical Modelling in Fluvial Geomorphology: Principles, Applications and Unresolved Issues. Proceedings of the 27th Binghamton Symposium in Geomorphology, September 27-29.UK.

[10] Maynorld, S.T. (2006) Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model. Journal of Hydraulic Engineering. 132(4): 343-353.

[11] Gill, T.M. and Pugh, C.A. (2009) Sediment Transport Similitude for Scaled Physical Hydraulic Modeling. Proceeding of the 33rd IAHR Congress, August 9-14. British Columbia, Canada.

[12] Shams, M., Ahmadi, G. and Smith, D.H. (2002) Computational Modeling of Flow and Sediment Transport and Deposition in Meandering Rivers. Journal of Advances in Water Resources. 25(4): 689-699.

[13] Kantoush, S.A., Bollaert, E. and Schleiss, A.J. (2008) Experimental and Numerical Modelling of Sedimentation in a Rectangular Shallow Basin. International Journal of Sediment Research. 23(3): 212-232.

[14] Schuster, G., Jugovic, C.J. and Nachtnebel, H.P. (2009) Application of Hydrodynamic Numeric Models on Complex Sediment Transport Processes. Proceedings of the International Symposium on Water Management and Hydraulic Engineering, September 1-5. Vienna, Austria.

[15] Mohamed Yusof, N. (2009) Modelling of Sedimentation Pattern In Bukit Merah Reservoir. M.sc Thesis, Universiti Sains Malaysia, Penang, Malaysia.

[16] Nakato, T., and Ogden, F.L. (1998) Sediment Control at Water Intakes along Sand-Bed Rivers. Journal of Hydraulic Engineering. 124(6): 589-596.

[17] Ma, Y. and Zhou, S. (2001) Sediment Control for Irrigation Intakes. Journal of Hydrodynamics. 122-126.

[18] Michell, F., Ettema, R. and Muste, M. (2006) Case Study: Sediment Control at Water Intake for Large Thermal-Power Station on a Small River. Journal of Hydraulic Engineering. 132(5): 440-449.

[19] Zhang Y. 2006, CCHE-GUI-Graphical Users Interface for NCCH Model User's Manual-Version 3.0, Tec. Rep. No. NCCHE-TR-2006-3, National Center of Computational Hydroscience and Engineering, Univ. of Mississippi, Ole Miss, Oxford.

[20] Jia, Y. and Wang, S.S.Y. (1998) Capability Assessment of CCHE2D in Channel Flow Simulations.

[21] Abu Hasan, Z., Hamidon, N., Zakaria, N., Ab. Ghani, A. and Leow, C.S. (2009) Incoperating GIS in Water Resources Modelling: Application of SWAT 2005 Model in Sungai Kurau, Perak and CCHE2D Model in Tasik Harapan USM, Penang. Proceedings of The 2nd National Conference on Society, Space &Environment 2009: Towards sustainable Heritage and Future, June 2-3. Universiti Sains Malaysia, Penang, Malaysia.

NOMENCLATURE

B	Water surface width (m)
d_{50}	Mean sediment size (mm)
Q	Discharge (m^3/s)
V	Velocity (m/s)
Y_0	Flow depth (m)
S_0	Water surface slope
n	Manning's roughness coefficient
T_b	Bed load (kg/s)
T_s	Suspended load (kg/s)
T_j	Total bed material load (kg/s)