UNIVERSITI PUTRA MALAYSIA

ASSESSMENT OF SEDIMENT TRANSPORT ESTIMATION METHODS IN SELECTED CHANNELS

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By

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In this study, equations for estimating sediment transport in channels are assessed using field data of 15 rivers located at different part around the world, in which 14 are existing data and 1 is a new measured data. The new field data is for Al-Garraf river, Iraq measured using devices Son Tek River Surveyor (to measure hydraulic and geometric parameters), Van veen grab sampler (to collect bed materials), and Van Dron horizontal water bottle (to obtain suspended sediment load). Data sets related to other rivers is acquired from Brownlie (1981). The acquired data is widely used worldwide and known with its reliability. Several sediment transport equations have been computed and tested in order to recommend their accuracy. The tested equations include most river hydraulic and morphological characteristics.

For bed load estimation in rivers, the results of computations show that there are variations of computed values with significant difference associated with applying Shield equation compare with other computed equations. The differences of computed values are referring to the concepts and methods of each equation.

For estimation of suspended load, the results of comparisons show that Bagnold, Einstein and Van Rijin gave the least error in estimating the suspended load among the other tested equations. The least values of Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) are equal 0.012 and 0.015 (kg/s/m) respectively. It is found that this least error was associated with applying Bagnold equation.

Moreover, an equation was proposed for computing suspended load in rivers based on the Einstein, Ackers and White, Shield parameters and Regression analysis. The coefficient of determination (R^2) for proposed equation is found to be 0.80. The results obtained from applying the proposed equation show a reasonable performance when compared with other tested equations using field data for rivers Atchafalaya, Red, South American, Rio Grande, and Al-Garraf. The ranges of Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) are 0.005 to 0.007 and 0.09 to 0.289 (kg/s/m) respectively. The proposed equation is easy to apply compared with Einstein equation that requires complex procedure and longer time. The proposed

equation will assist engineers to estimate suspended sediment load in natural rivers because it require short procedure and give a reasonable accuracy.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN KAEDAH ANGGARAN PENGANGKUTAN SEDIMEN DI DALAM SALURAN TERPILIH

Oleh

HYDAR LAFTA ALI

April 2015

Pengerusi: Profesor Thamer Mohammed Ahmed, PhD
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Dalam kajian ini, persamaan untuk menganggar pengangkutan sedimen di saluran dinilai menggunakan data lapangan dari 15 sungai yang terletak di serata dunia, yang mana 14 daripadanya adalah data sedia ada dan satu adalah data lapangan yang baru diukur. Data lapangan yang baru ialah bagi Sungai Al-Garraf, Iraq yang telah diukur menggunakan peranti seperti *Son Tek River Surveyor* (untuk mengukur parameter hidraulik dan geometri), *Van Veen Grab Sampler* (untuk mengumpul bahan-bahan dasar sungai) dan *Van Dron Horizotal Bottle* (untuk mencerap beban sedimen terampai). Set data yang berkaitan dengan sungai-sungai lain diperolehi daripada Brownlie (1981). Data yang diperolehi ini digunakan secara meluas di seluruh dunia dan diiktiraf kebolehpercayaannya. Beberapa persamaan pengangkutan sedimen telah digunakan untuk mengira beban dasar dan beban terampai. Persamaan yang diuji termasuk ciri-ciri hidraulik dan morpologi sungai.

Untuk anggaran beban katil di sungai, keputusan pengiraan menunjukkan bahawa terdapat variasi nilai yang dihitung dengan perbezaan penting yang berkaitan dengan menggunakan persamaan Shield membandingkan dengan persamaan yang dihitung lain. Perbezaan nilai yang dihitung merujuk kepada konsep dan kaedah bagi setiap persamaan.

Untuk anggaran beban terampai, keputusan perbandingan menunjukkan antara persamaan yang diuji, persamaan Bagnold, Einstein dan Van Rijin memberikan ralat terendah dalam menganggarkan beban terampai. Nilai-nilai *Mean Absolute Error (MAE)* dan *Root Mean Square Error (RMSE)* masing-masing adalah sama dengan 0.012 dan 0.015 (kg/s/m). Didapati ralat terkecil ini terhasil daripada pengunaan persamaan Bagnold.

Selain itu, satu persamaan telah dicadangkan untuk pengiraan beban terampai di sungai berdasarkan analisis parameter Einstein, Ackers and White, Shield dan analisa regresi. Pekali penentuan (R^2) bagi persamaan yang dicadangkan ialah 0.80. Keputusan yang diperolehi dari penggunaan persamaan tersebut menunjukkan prestasi yang manasabah jika dibandingkan dengan lain-lain persamaan yang diuji

menggunakan data sungai Atchafalaya, Red, Amerika Selatan, Rio Grande dan Al-Garraf. Julat ralat *Mean Absolute Error (MAE)* dan *Root Mean Square Error (RMSE)* adalah masing-masing 0.005 hingga 0.007 dan 0.09 hingga 0.289 (kg/s/m). Persamaan yang dicadangkan lebih mudah untuk digunakan berbanding dengan persamaan Einstein yang memerlukan prosedur yang kompleks dan masa yang lebih lama. Persamaan yang dicadangkan akan membantu Jurutera untuk menganggarkan beban sedimen terampai di sungai-sungai kerana ia memerlukan prosedur yang ringkas dan memberikan tahap ketepatan yang munasabah.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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CHAPTER ONE

INTRODUCTION

1.1 General

Sediment is defined as the grainy material that transport particles within the range of size that is originally from physical or chemical degradation of rocks by flow from the basin (Van Rijin, 1993; Yang, 2010). Sedimentation involves the processes of erosion, entrainment, transportation, deposition and compaction (Graf, 1971). Sediment transport has great concern for Engineers, Geologists, and Environmental researchers due its importance. The mechanism of sediment transport has been a subject of study for many years as it enables scholars to understand the movement of sediment particles. To date, there are many equations for the computing sediment discharge in natural rivers. Basically there are three types of sediment equations bed load, suspended load, and total load. Total load can be obtain directly by empirical equations or indirectly as the summation of the bed load and suspended load equations. The categories of bed load and suspended load are not rigid because they depend on the velocity of the flow. For instance, in high velocity or very turbulent water, gravels and large size of sediment can travel most of them in suspension. On the other hand, in very low velocity or very low turbulent, the small size of sediment particles such as silt and clay move totally in bed load (Chien and Wan 1999). The importance of sediment transport referring to the positive and negative aspects arising from this phenomenon which is considering in may locations as a harmful due to movement of soil erosion imperceptible.

1.2 Problem Statement

Sediment causes many problems such as reducing capacity of rivers, canals and reservoirs and this lead to significant impacts on water resources planning, development, utilization, and sustainability. As mentioned above, effect on water quality by sediment is originally from physical or chemical degradation. Therefore, there are some problems that caused by sediment transport and one of the important impacts is on the water quality and suitability of water consumption for human, and industry. There is a vital connection between sediment transport and water quality (Chao et al., 2010; Hantush et al., 2013). Moreover, operational problems of turbine, pumping stations, and erosions at other hydraulic structures such as scour at bridge pier. Sediment has also many positive aspects, like the delivery of nutrients for aquatic ecosystems, as well as for agricultural purposes, the formation and preservation of river deltas, the provision of sand as a building material and so on. Therefore, it is important to study sediment transport in natural rivers. On the other hand, calculating sediment loads in river section is not easy to obtain (Ab. Ghani et al., 2010). The applications of sediment transport equations for estimating sediment load require tedious and long procedure. The estimation of sediment load is essential to protect rivers and structures. Thus, finding accurate methods for estimation sediment load will help to control sedimentation at critical locations and those having direct effect on the economy. In this study, assessment of existing sediment transport equations new and old equations are assessed, also an equation which is easy to apply is proposed to determine suspended sediment load in rivers. The field data of rivers used in this study is located at different part around the world, one of these field data of sediment transport measurement is conducted at the tail of Al-Garraf river, Iraq in order to determine the suspended sediment load in the river beside using the data for validation of the sediment transport equations. There are no studies and field works related to the sediment transport at Al-Garraf river, Iraq although such studies are essential to understand suspended sediment load, sediment distribution, and hydraulic characteristics of the river.

1.3 Objectives

The main objective of this study is to assess sediment transport methods using field data while the specific objectives are as stated below:

1. To compute bed load based on the characteristics of field data
2. To assess the performance of suspended load sediment transport equations using field data
3. To propose an equation to estimate the suspended sediment load in channels

1.4 Scope and Limitation of the Study

The scope and limitation of this study are listed below:

1. The field data of 15 rivers located at different parts around the world have been used in this study. One of these rivers data is Al-Garraf river that was measured using available equipment such as Son Tek River Surveyor, Van Dron horizontal water battle, and Van Veen grab sampler to collect sediment and hydraulic parameters. Other field data of 14 rivers are acquired from Brownlie (1981) and these rivers are Indian canal, Colorado, Middle Loup, Mississippi, Niobrara, Oak Creek, Portugal River, Rio Grande Conveyance Channel, Snake and Clearwater, Trinity, Red, Rio Grande, Atchafalaya, and South American
2. The computed bed load equations are limited to selected equations of Einstein, Bagnold, Du Boys, Shield, Meyer-Peter, Kalinskie, Meyer-Peter Muller, Schoklitsch, Van Rijin, and Cheng
3. The tested suspended load equations are limited to selected equations of Einstein, Bagnold, Lane and Kalinske, Brook, Chang, Simons and Richardson
4. The Proposed equation for computing suspended load is limited to the median diameter D_{50} less than 0.4 mm.

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