UNIVERSITI PUTRA MALAYSIA

MODELING RIVER SEDIMENT DEPOSITION INTO THE KENYIR RESERVOIR, MALAYSIA

MANAL M. ABOOD

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in Fulfillment of the Requirement for the degree of Doctor of Philosophy

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Chair: Professor Thamer Ahmed Mohammed, PhD

Faculty: Engineering

Assessment of the amount of sediment inflow from the Berang river and the Kenyie river and the total quantity deposited to the Kenyir reservoir was made. Kenyir reservoir is the biggest man-made lake in Southeast Asia. Kenyir dam and reservoir are mainly designed for hydroelectric power generation and flood mitigation purposes.

This study was made to find an alternative solution to monitor the elevation changes with less cost and less efforts by using a computer program that can simulate the elevation accurately. For this purpose, the GSTARS3 program has been chosen. Due to limitation on data available, the prediction was undertaken using the hydrological modeling (HEC-HMS program) to fill the missing data in historical record and obtain a full set of data that is used in sediment transport modeling (GSTARS3 program). GSTARS3 was

integrated with GIS to display the output as sequences of grids. ArcView was used to convert the GSTARS3 output to Arc View GIS grid format.

GSTARS3 program was validated using two terms of validation, short term validation (ST validation) for the period from 1995 to 1998, and long term validation (LT validation) for the period from 1995 to 2006 for both Berang river and Kenyir river thalweg profiles and their selected cross sections. The results show a good agreement between the simulated and measured data with an error ranges from 5.5 % to 13.1 % for short term validation and ranges from 6.3 % to 14.7 for long term validation for both Berang and Kenyir rivers. Although, LT validation errors have higher values than that in ST validation, they have not increased more than 15 % in all cases

Statistical analysis was applied to check the accuracy of HEC-HMS output. The results show a reasonable agreement with an errors equal to 0.41 m^3/sec for Berang basin and equal to 0.67 m^3/sec for Kenyir basin. It was found that the combination of two programs (HEC-HMS and GSTARS3) helps to simulate the sediment when the hydrological data is limited and the results show that the computed values agreed well with the historical recorded data for the thalweg profiles and selected cross sections.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan unuk ijazah Doktor Falsafah

PEMODELAN SEDIMEN SUNGAI PEMENDAPAN KE RESERBOR KENYIR, MALAYSIA

Oleh

Manal M. Abood

November 2012

Pengerusi: Professor Thamer Ahmed Mohammed, PhD

Fakulti: Kejuruteraan

Kajian mengenai jumlah aliran kemasukkan sedimen dari Sungai Berang dan Sungai Kenyir dan jumlak kuantiti takungan yang disimpan di Tasik Kenyir. Tasik Kenyir merupakan takungan buatan manusia yang terbesar di Asia Tenggara. Empangan Kenyir direkan untuk Penjanaan kuasa hidroelektrik dan bagi mengelakkan banjir.

Kajian ini adalah untuk mencari alternatif lain untuk mengurangkan kos dan tenaga dengan menggunakan sistem computer untuk menjana pengalirannya. Untuk tujuan ini, program GSTARS3 dipilih. Disebabkan kekurangan data, ramalan telah dijalankan menggunakan model hidrologi (HEC-HMS program) untuk mengisi data yang hilang dan mendapatkan data penuh untuk digunakan dalam pemodelan pengangkutan sedimen (GSTARS3 program). GSTARS3 program telah disepadukan dengan GIS program untuk

memaparkan output yang selari. ARCVIEW digunakan untuk menukar GSTARS3 output kepada ARCVIEW GIS format.

Program GSTARS3 telah disahkan menggunakan dua kaedah pengesahan, pengesahan jangka pendek (ST pengesahan) bagi tempoh 1995-1998, dan pengesahan jangka panjang (LT pengesahan) bagi kedua-dua sungai berang dan sungai kenyir. hasil menunjukkan pengabungan yang baik antara data simulasi dan data yang diukur dengan julat ralat daripada 5.5% to 13.1% untuk pengesahan jangka pendek dan bagi pengesahan jangka panjang adalah dari 6.3% ke 14.7% bagi kedua-dua sungai berang dan sungai kenyir. Walaupun nilai LT pengesahan yang silap adalah tinggi daripada ST pengesahan tetapi nilai tersebut tidak lebih dari 15% dalam semua kes.

Analisis statistik digunakan untuk mengesan ketepatan output HEC-HMC. Hasil menunjukan ketepatan adalah sama diantara 0.40m^3/sec untuk kawasan tadahan Berang dan 0.67 m^3/sec bagi tdahan kenyir. Ini menunjukkan bahawa gabungan diantara dua program (HEC-HMS dan GSTARS3) membantu untuk mensimulasikan enapan walaupun data hidrologi yang diterima adalah terhad dan hasil menunjukkan nilai yang dikira adalah sama dengan data lama yang telah direkod bagi thalweg profil dan keratan rentas yang dipilih.

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APPROVAL

I certify that a thesis Examination Committee has met on 19th November 2012 to conduct the final examination of Manal Mohsen Abood on her thesis entiteled "Modeling River Sediment Deposition Into The Kenyir Reservoir, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

Members of Thesis Examination Committee were as follows:

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Faculty: Engineering
University Putra Malaysia
(Chairman)

Examiner 1, PhD
Professor Dr. Lee Teang Shui
Faculty: Engineering
University Putra Malaysia
(Internal Examiner)

Examiner 2, PhD
Associated Professor Dr. Wan Nor Azmin b Sulaiman
Faculty: Environmental study.
University Putra Malaysia
(Internal Examiner)

External Examiner, PhD
Professor Dr. Chih Ted Yang
Faculty: Engineering
University Colorado state university
Country: United State.
(External Examiner)

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
University Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

MANAL M. ABOOD

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CHAPTER 1

INTRODUCTION

1.1 Reservoir Sedimentation

Reservoir sedimentation is the process of sediment deposition into a lake formed after a dam construction. Reservoir sedimentation involves entrainment, transport and deposition. They originate from the catchments area, rivers system and settle in reservoir. As a river enters the reservoir its cross section of inflow is enlarged. Thus it causes a decrease in the water flow velocity. Subsequently the sediment carrying capacity of water is reduced. The major part, or all, of the sediment transport will deposit in the upstream part of the reservoir influenced by the backwater curve.

The sediment deposition within the reservoir depletes live storage and develops deltaic- shaped deposit in the upper reach of the reservoir. Such deposits may or may not be transported towards the dam at a faster rate when reservoir storage is small and flood flow enters the reservoir. As sediment accumulate in the reservoir, the reservoir gradually losses its capacity to store water for the purpose of which it is built.

There are more than 45,000 large dams (height more than 15 m) built all around the world for several purpose such as power generation, flood control, domestic or

industrial water supply. The top five dam-building countries account for nearly 80% of the dam world wide. China alone has built around 22,000 dam or closer to half the world's total number. Other countries among to top five dams building nation include United States with over 6390 dam, India with 4000, and Spain and Japan with between 1000 and 1200 dams each. Figure 1.1 shows distribution of dams world wide at the end of 20th century. Today, 19% of world energy is from hydropower. Nearly half the world dams were built exclusively or primarily for irrigation (WCD, 2000). Every year 0.5-1 % of the world reservoir capacity is lost due to sedimentation. Table 1.1 shows world wide number of dams and their annual loss due to sedimentation.

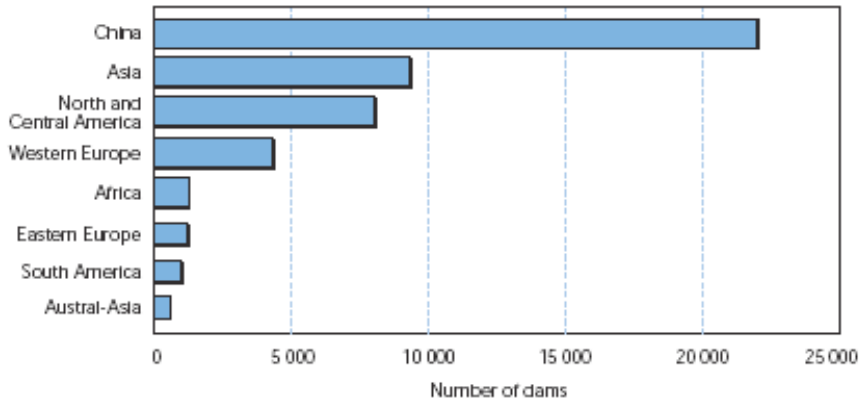

Figure 1.1: Regional distribution of dams at the end of 20th century (Source: WCD, 2000)

Table 1.1: World wide dams and Annual loss due to sedimentation (Source: Oguz. 2006)

Region	Number of dams	Annual loss due to sedimentation (% of residual storage)
Europe	5,497	0.17-0.2
North America	7,206	0.2
South and Central America	1,498	0.1
Africa	1,246	0.23-1.5
Middle East	895	1.5
Asia(excluding china)	7,230	0.3-1.0
China	22,000	2.3

Malaysia had a total of 56 dams, of which 32 were more than 15 m high (large dams). The total dam capacity is estimated as 23.72 km^3 (FAO, 2010).

In 2009, the Department of Irrigation and Drainage, at the Ministry of Natural Resources and Environmental, manage 16 dams having a total capacity of 450 million m^3, located in various states. These dams fulfill the department's role in providing adequate irrigation water, flood mitigation and silt retention (FAO, 2010).

In 1995, the gross theoretical hydropower potential of peninsular Malaysia was 123,000 GWh/year, and that of Sabah and Sarawak together 107,000 GWh/ year. In 1995, total hydropower generation was about 5,800 GWh or 30 percent of all

power production in Malaysia. Some of dams in Malaysia, their capacity, purpose and construction date are shown in Table 1.2.

Table 1.2: Major Dams in Malaysia (Source: FAO, 2010)

Dams	**Capacity(million m^3)**	**Purpose**	**Construction date**
Bakun	4,380	Electric power	1980
Batang Ai	750	Electric power	1985
Chenderoh	95	Electric power	1920
Kenyir	13,600	Electric power	1986
Temenggor	6,050	Electric power	1972
Pergau	6,060	Electric power	2000
Beris	122	Irrigation and flood mitigation	2004
Bukit Merah	75	Irrigation and flood mitigation	1985
Timah Tasoh	40	Irrigation and flood mitigation	1992
Pontain	40	Irrigation and flood mitigation	1985
Enak Endau	38	Irrigation and flood mitigation	1985
Batu	37	Irrigation and flood mitigation	1985
Klang Gate	25	Water supply	1958
Sg. Kinta	29.9	Water supply	2006

Some of reservoirs in Malaysia have been subjected to increasing losses of their storage. According to Department of Irrigation and Drainage (DID), it is estimated that Bukit Merah reservoir which is constructed for the purpose of irrigation in Perak, loss 0.4 % of its volume every year due o sedimentation and the capacity of reservoir only remain about 60-65 % (IEA, 2006). Tenaga National Berhad (TNB) reported that Ringlet reservoir in Cameron Highlands which is man made lake created upstream of the concrete dam (Sultan Abu Bakar dam) on Bertam River has lost nearly 53% of its gross storage due to sedimentation since its operation in 1963, which is presently estimated as reaching a volume of about 3.5-4.0 million m^3. The currently estimated sediment deposition rate in the Ringlet reservoir is in the range between 350,000 to 400,000 m^3 per year (IEA, 2006).

1.2 Problem Statement

All rivers carries sediments. A river can be considered a body of flowing sediment as much as flowing water. When the flowing water is stilled behind a dam, the carrying sediment sinks to the bottom of reservoir. As the sediments accumulate in a reservoir, it gradually loses its capacity to store water for the purpose for which it was built. Sediments accumulation in a reservoir also causes problems to dam operators due to the abrasion of turbine and other dam components.

Sediment affects water quality and suitability for human consumption or use in various enterprises. Numerous industries cannot tolerate even the smallest amount of sediment in the water that is necessary for certain manufacturing processes and public pays a large amount price for the removal of sediment from the water it consumes every day. Sediment not only considers as a major water pollutant, but also serves as a carrier and storage agent of other forms of pollution. Sediment also degrades water quality for aquatic life.

In Malaysia and due to extensive development and deforestation, the sediment load in rivers is high, this cause extensive sedimentation of dam reservoirs. And reduction of reservoir design age. Continuous dredging of reservoir is costly and needs surveying for reservoir sections. Modeling of the sediment deposition area in the reservoir will help in reducing the cost of reservoir dredging.

This study will help to reduce the cost of dredging by predicting the sediment deposition using appropriate models. Kenyir reservoir has been selected to demonstrate the proposed methodology.

Kenyir dam is one of the most important hydroelectric power generation and flood mitigation dams in Malaysia. One operational problem is the increase of sediment accumulation in front of the intake structure and murky water has been discharged from the turbine during the rainy seasons. This area should be monitored and extra survey works should be done, therefore using a computer program to predict the

sediment deposition to Kenyir reservoir as alternative solution than the survey works will save a lot of time and costs. The study area is located in a tropical region and it has a limited hydrological data, thus the chosen program should have an ability to run with a small amount of data for calibration and testing.

1.3 Objectives

The main objective of the present study is the prediction and visualization of the sediment inflow into Kenyir reservoir and its deposition. This will be achieved through the following specific objectives:

1- To predict the rainfall-runoff for Kenyir and Berang rivers using HEC-HMS to obtain a complete set of discharge data that is necessary to run the GSTARS3.

2- To predict the quantity and location of sediment deposition by using GSTARS3 Sediment Transport Program.

3- To produce visualization maps of the sediment deposition by integrating the output from GSTARS3 program with ArcView GIS.

1.4 Scope and Limitation

Generally the scope of this study includes the following:

1- Selection of study area, data collection and field survey

Kenyir reservoir, Terengganu, Malaysia is selected as a case study. The daily data from four rainfall gage stations within the study area for the period from 1st September 1990 to 31st December 1990 and daily data from two streamflow gage stations within the study area for the same period of time were collected from Department of Irrigation and Drainage, Malaysia (DID) and Tenaga National Berhad research center (TNB) are used to calibrate and validate the hydrological program (HEC-HMS), in addition to the topographic and bathymetric data (contour line, landuse, soil map and vegetation cover). A field survey was done to collect and analyze the particle size distribution of different soil types of the catchment area. All these data are used together to run the GSTARS3 sediment transport program.

2- Sedimentation Modeling (GSTARS3)

The sediment transport program GSTARS3 is selected to predict sedimentation deposition. The input data are the hydrological data (discharge and rating curve), channel reach geometry, and sediment data (sediment inflow, sediment rating curve and particle size distribution). GSTARS3 was selected in this study because it has never been applied to simulate the sediment movement in a reservoir located in a tropical region, in addition to its ability to simulate the sediment deposition and sediment movement with a minimum amount of field data required for calibration and testing. Two limitations were faced in

applying GSTARS3, first limitation is the lack of available cross section along the reach. This is needed in GSTARS3 process for defining the channel reach geometry. This was overcome by using interpolation between available cross sections. Second limitation is the shortage in the available discharge data; this was overcome by applying the HEC-HMS program to fill all the missing data in historical records. Sediment load, sediment rating curve and particle size graduation were obtained from field data and experimental work respectively.

3- Hydrological modeling (HEC-HMS)

The rainfall data for the Kenyir and Berang rivers since the operation of Kenyir dam is available, but unfortunately, there is inadequate data for streamflow. To overcome this limitation the hydrological program HEC-HMS is used to determine the surface runoff for the two rivers (Kenyir and Berang) and fill the missing data in historical record for the period from 1991 until 2006. The computed runoff data are used as input to the sedimentation program (GSTARS3).

4- GIS database

Organize the sediment output from GSTARS3 in a raster-based database that includes the topographic information, channel geometry as well as bathymetric information to visualize the sediment deposition and to identify the amount and

location of sediment accumulation in the Kenyir reservoir. GSTARS3 integrated with ArcView were used for this purpose.

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