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ScienceDirect

Procedia Engineering 154 (2016) 557 – 564

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Hydroinformatics, HIC 2016

Sediment transport characteristic of the Ping River basin, Thailand

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Abstract

This study examined the river sediment transport characteristics of the Ping River basin, which is one of the major river basins in Thailand. River surveys of the Ping River were carried out nine times between 2011 and 2013. Survey data included river cross sections, flow velocities, suspended sediment concentration, and bed load transport in the river. Analyzes of these data indicated that suspended transport rates in the Ping River during normal flow conditions in 2012-2013 ranged between 107 and 9,562 metric tons/day (mt/d), but increased to 35,300 mt/d during high flooding conditions (Thailand's Great Flood of 2011). The rate of bed load transport was 1,401 mt/d during the Flood of 2011. However, the measured bed load in 2012-2013 varied between 0 and 482 mt/d. The bed-to-suspended load ratio in the Ping River fluctuated in the broad range of 0-2.0. Estimates of total sediment transport in the Ping River were made using some of the classic equations from the hydrologic literature. The results obtained from the different methods show that the Laursen-Copeland formula gives the best estimate of total sediment transport rate of the Ping River compared to other methods. Results from this study also reveal that the Bhumibol Dam, constructed in 1964, has had a significant effect on suspended sediment load reduction downstream of the dam.

Peer-review under responsibility of the organizing committee of HIC 2016

Keywords: Suspended sediment load; bed load; total sediment load; sediment estimation; river basin

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Peer-review under responsibility of the organizing committee of HIC 2016
doi:10.1016/j.proeng.2016.07.552

1. Introduction

Changes in the sediment loads of the world's rivers are influenced by many factors, such as deforestation for agriculture, population pressure, water resources development, dam construction, and climate change. A more complete understanding of river response to human activities and climate change is necessary to better manage natural resources.

The Ping River basin (Fig. 1) is one of the major sub-catchments of the Chao Phraya basin, which is the largest river basin in Thailand [1]. In 1952, Thailand started to pursue a 25-year irrigation development program. The program began in 1953 with the Chao Phraya project, which was considered to be the largest irrigation project in Asia. The Bhumibol Dam (Fig.1) was constructed on the Ping River (completed in 1964) as an additional component of the Chao Phraya Project for water supply, flood control, hydroelectric power generation, and river integrity. With a normal storage capacity of 9.7 x 10^9 m^3, the Bhumibol Dam controls runoff from about 16 percent of the area of the entire Chao Phraya River basin. Later, other large dams, such as the Sirikit and Kiew Lom Dams, including barrages and numerous canal systems, have been constructed within the Chao Phraya River basin to increase the surface water storage and to deliver water to the lower Chao Phraya River basin irrigation systems. The changes in the hydrologic regime of the Ping River basin caused by the Bhumibol Dam's water regulation may have changed the sediment balance in the basin [2].

The objectives of this study were to determine sediment transport characteristics of the Ping River, which is the major sediment source to the Chao Phraya River, and to study sediment functions for predicting total sediment loads of the Ping River. The Ping River's sediment characteristics were studied based on river survey data during 2011-2013. The observed river flow and sediment data were used to evaluate the applicability of five classical sediment transport prediction methods for the Ping River. By comparing sediment data observed at two locations downstream from the Bhumibol Dam between 2011 and 2013, effects of the Bhumibol Dam on sediment characteristics of the Ping River can be assessed.

2. Study area

The Ping River basin is located in the northern Thailand between latitudes 15° 45′ N to 19° 45′ N and longitudes 98° 06′ E to 100° 12′ E (Fig. 1) with a catchment area of 34,453 km^2 [3]. The river basin is mainly characterized by terraced mountains and valleys with elevations ranging from 330 to 2000 m. above MSL [4]. The length of the Ping River is approximately 740 km [2] with the river gradient varying from 1:1,600 to 1:2,300 [5]. The channel is 150- to 350-wide with river depths of 5 to 15 m [5]. The average annual discharge of the Ping River is 62 m^3/s [4], which contributes about 24 percent of the total average annual river flow of the Chao Phraya River [6].

The climate of the basin is dominated by the southwest monsoon (mid-May through September wet season) and the northeast monsoon (November to mid-March dry season). Annual rainfall averages about 1,097 mm, and 90 percent of rainfall occurs during the wet season [6,7]. The Bhumibol Dam, which is the largest dam in the Chao Phraya system, was completed on the Ping River in 1964 for water storage, hydroelectric power generation, flood mitigation, fisheries and saltwater intrusion control [8]. The dam has a maximum storage capacity of about 13.4 billion m^3, compared to mean annual inflow of 5.7 billion m^3 from the catchment area of about 26,400 km^2 [9].

In 1960, subtropical forest covered about 70 percent of highland areas in the northern part of Thailand, and more than 27 percent of forest areas had been converted to agricultural areas by 1998 [4].

3. Methods

Historical data on river discharge and sediment load observed at the gauging Station P.2A (Fig. 1) operated by Royal Irrigation Department (RID) were collected for studying average river flow conditions and sediment characteristics of the Ping River. Unfortunately, the sediment data are insufficient for systematic sediment study, especially bed load analysis. Because sediment transport processes are complex, site-specific, field observation data are necessary for evaluating the sediment characteristics of the Ping River. Hydrologic surveys were conducted on nine occasions between 2011 and 2013 at Stations SP-01 and SP-02, which are located downstream 70 and 230 km