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Downstream Impact Investigation of Released Sediment from Reservoir Desilting Operation

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ABSTRACT

In recent years, the issues related to sustainable active storage and water resources of the existing reservoirs are essentially important. Based on world reservoir survey data in 2007, the loss of reservoir storage regarding sedimentation was higher than the increase of reservoir capacity by construction and modification. Therefore, the reservoir sediment management is a vital issue in the world. Reservoirs in Taiwan encounter seriously sedimentation problem due to abundant sediment yield production in the watershed during typhoon event. The upstream river flow carries large amount of sediment from the watershed during floods. To mitigate the sedimentation problems in the Shihmen reservoir, a series of desiltation measures have been conducted to slow down sedimentation and sustain the life of Shihmen reservoir. However, operation of releasing sediment from reservoir should increase the suspended solid concentration of downstream river. The impact on public water supply and downstream river bed are needed to be investigated. The 1D model, NETSTARS model, is employed to simulate the impacts of downstream river during sediment releasing operation of the Shihmen Reservoir in this study. The NETSTARS model, is a mobile bed model consisting of hydraulic routing and sediment routing. Suspended load and bed load are treated separately in sediment simulation. In this study, the Typhoon Soulik in 2013 is selected for model calibration and verification. The venting tunnel at the powerhouse was operated for the first time during Typhoon Soulik in 2013. Abundant sediment was released by desiltation operation through the outlet of the venting tunnel into the downstream river. Based on the measured data, the suspended sediment concentration evolution in downstream river reach are simulated. The results of the presented study can provide the information of downstream impact and develop an estimated numerical model for reservoir sedimentation management.

KEY WORDS: reservoir sediment management, public water supply, NETSTARS model, desiltation operation, downstream impact.

INTRODUCTION

In Taiwan, there are two major nature hazards always affect the hydrological and geological condition. One is earthquake and the other is Typhoon. Earthquake-triggered landslides in mountainous areas accompany with heavy rainfall could supply large amount of sediment to river basin. Sediment produced in upper basins may not immediately deliver to lower basin owing to river aggradations. However, still great part of sediment can be transported and deposited in downstream river particularly during extreme rainfall events, which could generate turbidity current into a reservoir (Lee .et al., 2014, Kantoush et al., 2010]. In 1999, Taiwan suffered from an earthquake which magnitude reaches 7.3 Richter magnitude scale. After that earthquake, the soil and rock of the mountainside were collapsed. Therefore, when typhoon or heavy rainfall occurs in Taiwan, the watershed may generate huge amount of sediment yield. And, the land development in the watershed would accelerate soil erosion. As sediment moves into a reservoir, deposition occurs due to decrease of velocity and makes storage of reservoir decrease [Tan et al., 2011].

Typhoon Aere in 2004 attacked northern Taiwan. Flood-induced high sediment concentration more than 200,000 Nephelometric Turbidity Unit (NTU) was measured in the Shihmen reservoir. In the case of 2009 Typhoon Morakot attacked southern Taiwan, the inflow sediment concentration was more than 0.2×10^6 ppm during peak flow and caused about $90\times10^6 m^3$ sediment deposited in the Tsengwen reservoir. Total amount of the deposition in this event was more than 20 times annual value. The accumulative rainfall was more than 3,000mm within 3 days [South Region Water Resources Office, 2013]. Therefore, to deal with serious sedimentation in the Shihmen and Tsengwen reservoirs, specific budgets were granted by the central government of which the Water Resources Agency has been appointed to execute desiltation projects since 2006. The desiltation strategies were urgently needed for sedimentation problems, spatially in Shihmen reservoir. In 2013, the venting tunnel at the powerhouse of Shihmen reservoir was operated for the first time during Typhoon Soulik. After venting tunnel at the powerhouse was implemented in 2013, morphological impact ofriver below the Shihmen dam was also investigated [Lai et al., 2015, Lee et al., 2015].

Therefore, the Typhoon Soulik event is selected for downstream impact investigation of released sediment from reservoir desilting operation in this study. The simulation area of downstream river started from Shihmen dam to the Yuanshan weir. The total length is about 16,440 m. Fig. 1 shows the average bed elevation from 1969 to 2014 of Dahan River between Shihmen dam to the Yuanshan weir. In Fig. 1, it shows that river bed variation concentrates near the backwater area of Yuanshan weir. In addition, based on field survey of grain size in study

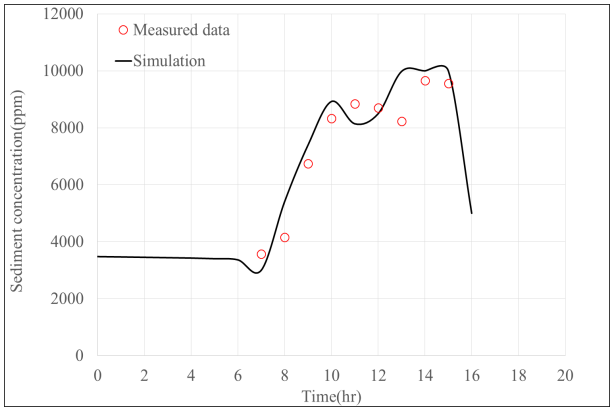

Fig. 6 Comparison of sediment concentration at Yuanshan weir during first reservoir desilting operation of Shihmen reservoir

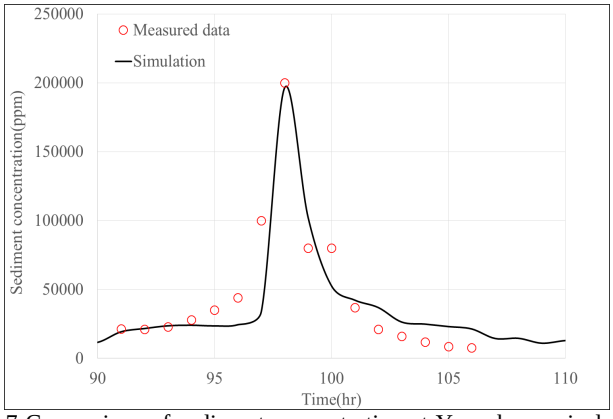

Fig. 7 Comparison of sediment concentration at Yuanshan weir during second reservoir desilting operation of Shihmen reservoir

CONCLUSIONS

In this study, the 1-D model, NETSTARS model, is employed to simulate the impacts of downstream river during sediment releasing operation of the Shihmen Reservoir. The sediment transport formula of Wilcock and Crowe (2003) is selected to simulate the bed load movement and convection-diffusion equation is adapted to simulate suspended load transportation. Owing to the venting tunnel at the powerhouse was operated for the first time during Typhoon Soulik in 2013. Abundant sediment was released by desiltation operation through the outlet of the venting tunnel into the downstream river. Two stages of sediment releasing operation during Typhoon Soulik in 2013 are both investigated. Based on the measured data, the suspended sediment concentration evolution in downstream river reach are simulated. According to the comparison of sediment concentration at Yuanshan weir during the first and second reservoir desilting operation of Shihmen reservoir, the adapted 1-D numerical model can appropriately describe the sediment concentration hydrograph and catch the peak sediment concentration during the simulation duration very well. Due to the water level controlled by Yuanshan weir are different during the first and second reservoir desilting operation of Shihmen reservoir, the sediment concentration at Yuanshan weir of second reservoir desilting operation is larger than the first one. However, the duration of high sediment concentration (more than 50,000 ppm) is only about 4 hours and decreasing rate of sediment concentration is very fast. It means the water turbidity of Yuanshan weir can reduce water turbidity lower than 6,000 Nephelometric Turbidity Unit (NTU) that water treatment plant can deal with after empty the storage of impounding area. Therefore, the results of the presented study can provide the information of downstream impact and develop a suitable numerical model for reservoir sedimentation management issues.

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