ANALYTICAL SEDIMENTATION MODEL FOR A RIVER SYSTEM WITH A DETENTION POND

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Keywords: analytical model, continuity equation, detention pond, sediment concentration, trap efficiency.

Introduction

Due to soil erosion by rainfall and subsequently the runoff water, a considerable amount of sediment is transported by the flowing water into the river system, especially during flood period, causing various environmental and economical problems. The function of a detention pond is not only to reduce the peak of the inflow hydrograph but also to reduce the sediment load in the outflow water from the pond. A permanent detention pond in the river system can provide an extremely effective quality polish for floodwater and, if properly designed, sized and maintained, can achieve high sediment removal rates. In this study, an analytical sedimentation model was proposed to predict the sediment concentration in the outflow water of a detention pond of a river system. The modelling of the sediment movement through detention pond will provide the engineers with the necessary information, which will help in implementing economical and efficient maintenance of the ponds.

Materials and Methods

The proposed analytical sedimentation model is a mathematical model simulating the flow of water and sediment through a detention pond. This model was based on the hydrological continuity equation, which was applied for the flow of water and sediment through the detention pond. The resulting first order differential equation from the simulation was solved mathematically to get the final form of the model. A good mixing was assumed in the pond to facilitate the model formulation. Due to this assumption the sediment concentration in the pond is equal to the sediment concentration in the outflow water from the pond. A typical hydrological data was used to run the model. The model was calibrated by computing the value of the model coefficients Ω_1, Ω_2, and Ω_3. The model was verified by comparing the output obtained from running the proposed analytical sedimentation model with the output obtained from running the numerical sedimentation model. which was proposed by Hall et al. (1993). The same hydrological data was used in running the two models. A computer program was written in Q-basic to perform the computation of the analytical sedimentation model.

Results and Discussion

The inflow water to the detention pond is carrying sediment particles of various sizes, therefore the settling velocities of the sediment would typically vary over several orders of magnitude. To accommodate this range of characteristics, sediment load are conceptually divided into three particle classes. These sediment classes are Class I which represent the fine clay, Class II which represent the clayey silt, and Class III which represent the medium sand. Class I involves sediment sizes which is less than 4 μm with a settling velocity of 1.77×10^{-6} m/s and sediment concentration of 53 mg/l. Class II involves sediment sizes of a range between 4-62 μm with a settling velocity of 0.00074 m/s and the sediment concentration of 185 mg/l. Class III involves sediment sizes with a range between 62 - 500 μm with a settling velocity 0.0077 m/s and sediment concentration of 100 mg/l. A value of 338 mg/l for a typical total sediment concentration in the inflow water was obtained by the summation of the sediment concentration of the three mentioned classes. The values of settling velocities for the three sediment classes, which are mentioned above, were adjusted for the effect of turbulence. The analytical sedimentation model was applied for the above three typical sediment classes using the inflow values at a time interval of 0.5 hour. The value of the sediment concentration in the outflow water from the detention pond at the previous time has a relation with that of the present time as required by the analytical sedimentation model. The subscript n and n+1 in the model refers to the previous time and the present time respectively. Sediment concentration of the inflow water assumed to consist of a mixture of these three classes in different amounts. A typical hydrologic data for the flow through the pond was used to run the analytical sedimentation model. Analytical sedimentation model is classified as a time variant model in which the model parameters vary with the time and model variables. Model calibration was conducted by calculating the values of the model parameters Ω_1 and Ω_2 for each time step. To verify the output obtained from running the analytical sedimentation model, this output was compared with the output obtained from running the numerical sedimentation model which was proposed by Hall et al. (1993) using the same data. The output from the proposed model was found in agreement with the output of the analytical sedimentation model which was proposed by Hall et al. (1993). The trap efficiency (η) can be defined as a measure to the amount of the sediment load which is retained in the pond. The efficiency is dependent mainly on the sediment class (sediment size). The average computed efficiency of the pond was found to be 50%, 77% and 96% for Class I, Class II and Class III respectively.

Conclusions

A general model which can be used to predict the sediment concentration in the outflow water from any detention pond or a sedimentation basin along the river system. In a detention pond in trapping the sediment, it was found that the pond was highly efficient in reducing the coarser sediment load (over 90% efficiency), while for the finer sediment, the efficiency was about 50%.

References

Hall, M.J., Hockin, D.L. and Ellis, J.B. 1993. Design of Flood Storage Reservoirs. CIRIA Publishing Company.

Supported by IRPA Grant 08-02-04-0001