

Hydrological modelling of fine sediments in the Odzi River, Zimbabwe

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Abstract

Siltation of reservoirs is a major concern in Zimbabwe. Therefore, development of prediction tools is of great importance. In the present study a recently developed empirical sediment model (HBV-SED) based on a daily rainfall-runoff model was applied to simulate riverine fine sediment transport in a 2 486 km² catchment in eastern Zimbabwe. The model performance was evaluated and changes in the model structure were suggested. The modelling was, however, associated with many uncertainties due to the adopted simplification of transport processes. An analysis of the model structure and a comparison with the rating curve function was done. The required length of data for calibration purposes was evaluated and model validation through split sample and proxy basin comparison was performed. Furthermore, since the empirical model was dependent on monitored runoff and fine sediment concentrations for calibration purposes, a field measurement campaign was conducted to assess the accuracy of observed data at the station studied. The field measurements showed large errors in monitored runoff and fine sediment concentrations for the 1998/99 wet season, which illustrated the uncertainty in predictions of fine sediment transport based on observed data. The HBV-SED model, which was applied over a period when data were believed to be fairly accurate, simulated the fine sediment transport volume well for the validation period if it was calibrated for a minimum of four years. A shorter calibration period led to a significant increase in prediction uncertainty. The model failed to simulate individual high fine sediment peaks accurately mainly due to poor performance of the rainfall-runoff model on a daily time-scale even if the seasonal flow dynamics were described properly. In the studied catchment the HBV-SED model application resulted in equally poor R^2 -values as the rating curve technique, while the estimated fine sediment volume was more accurate.

Introduction

Background

Sediment transport in natural streams is a problem all over the world and a major concern in southern Africa. Apart from loss of valuable top soils three problems can be distinguished (see *e.g.* Chenje and Johnson 1996):

- deposition of sediment material (siltation) in reservoirs which decreases the storage capacity and thus also the potential water yield
- reduced primary production of plankton and altered bottom vegetation due to turbidity caused by high sediment concentrations
- increased transport of pollutants, for instance pesticides, heavy metals and nutrients, which are adsorbed to the sediment particles.

In addition, flooding, due to river meandering and buried wetlands has been reported as threats caused by riverine sediment loads (Chabwela, 1991).

Siltation of reservoirs, in particular, has significant economic impacts (*e.g.* Lahlou, 1996). Although sediment transport is generally considered when new reservoirs are constructed, many examples of extreme reservoir sedimentation are reported in the literature. For instance, Chanson (1999) lists a number of reservoirs

located in five continents with extreme siltation rates (174 to 25 714 m³·km⁻²·yr⁻¹). Heavy riverine sediment yield is also reported in many other countries; 2 000 to 25 000 t·km⁻²·yr⁻¹, in the Yellow River, China, 1 050 to 3 500 t·km⁻²·yr⁻¹ in Pakistan, 100 to 1 500 t·km⁻²·yr⁻¹ in Cyprus, 94 to 1 089 t·km⁻²·yr⁻¹ in USA (Jansson, 1982). In Southern Africa, Rooseboom (1992) estimated the average sediment yield in nine defined sediment yield regions to vary between 30 and 330 t·km⁻²·yr⁻¹.

In Zimbabwe, the problem of erosion and siltation of reservoirs has been a major concern over a long period of time (*e.g.* Hudson 1957; Ward, 1980). An increasing population creates a demand for additional reservoirs for water storage and contributes to accelerated erosion due to further cultivation and an increased number of live-stock. Recently several new dams have been constructed in the erosion-prone areas of the country despite the risk of rapidly decreasing capacities due to siltation. A countrywide reservoir siltation survey in the 1980s displayed rates of 10 to 704 t·km⁻²·yr⁻¹ (NORAD, 1983). Despite the gravity of the problem no attempts have so far been made to predict riverine sediment transport in Zimbabwe using deterministic models. Development and tests of prediction tools of this kind are therefore called for. In the present study a deterministic empirical model for fine suspended sediment transport was applied to the Odzi River basin (2 486 km²) located in the eastern mountainous part of Zimbabwe.

Estimation of sediment transport

Riverine sediment transport may be divided into bedload and suspended load. Some authors further divide the suspended load into current-related load and washload. The washload particles are near to permanently in suspension because of the low falling

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