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Modelling sediment transport in a mountain stream and comparison of the morphologic changes with LiDAR data

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1. Calculation of morphologic changes with airborne LiDAR data

A digital elevation model represents the morphology of an area at a certain point in time. High resolution digital elevation models can be used for the calculation of morphologic changes by subtracting one elevation model from the other. Figure (1) shows a channel reach of the Suggadin mountain stream (Austria) after an extreme flood event that occurred in August 2005. The morphologic changes have been calculated with the digital terrain model before and after the flood event and have been completed with records from sediment dredging. The calculated volumes contain pore volumes and fine sediments. The calculated erosion and deposition volumes can be accumulated for the whole channel starting from the most upstream point. The difference between erosion and deposition is the transported sediment volume (Figure 2). One has to consider the time span between the generation of the two elevation models. For torrents and mountain streams it is generally assumed, that major morphologic changes are only caused by major flood events. During the considered time period no other flood events took place in the catchment.

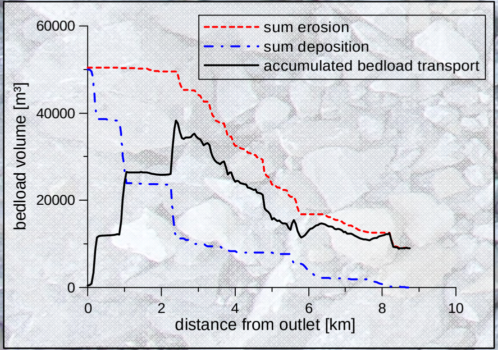

Figure 2: Calculated erosion and deposition after the August 2005 flood event for a river reach at the Suggadinbach. About 50 000 m³ of bedload were mobilized during the event.

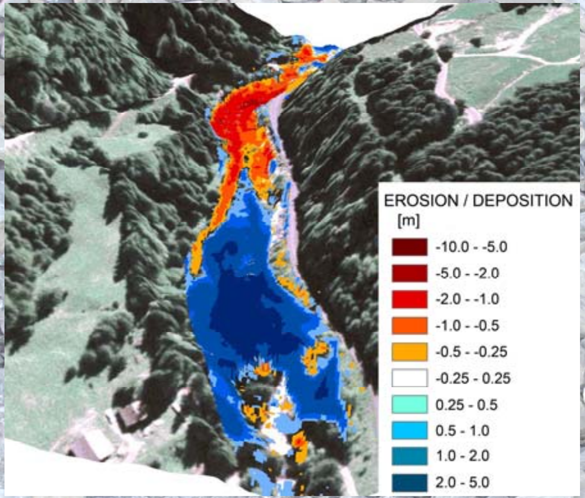

Figure 1: Calculated erosion and deposition heights for a river reach of the Suggadinbach. Two high resolution elevation models have been used to calculate the morphologic changes caused by the August 2005 flood event.

2. Form roughness losses

Rickenmann proposed a procedure to estimate flow resistance losses due to form drag as a function of slope and relative submergence.

$$\frac{n_r}{n_{tot}} = 0.092 S^{-0.35} \left(\frac{h}{d_{90}} \right)^{0.33} \qquad (1)$$

To use the form roughness approaches in combination with bedload transport capacity formulas, the slope of the energy line S can now be partitioned into a fraction S_{red} associated with skin friction only:

$$S_{red} = S \left(\frac{n_r}{n_{tot}} \right)^{a} \qquad (2)$$

where possible values are $1 < a < 2$ to adopt the reduction to different roughness structures.

References:
Chiari, M., Rickenmann, D. (2007): The influence of form roughness on modelling of sediment transport at steep slopes. In: Kostadinov, St., Bruk, St., Walling, D. (Hrsg.), International Conference, Making 100 years of experience with erosion and torrent control in Serbia, Conference Proceedings on CD, Erosion and torrent control as a factor in sustainable river basin management, 25.-28. September 2007, Belgrad.
Rickenmann, D., Chiari, M., Friedl, K. 2006. SETRAC A sediment routing model for steep torrent channels. In R. Ferreira, E. Alves, J. Leal & A. Cardoso (eds), River Flow 2006, Taylor & Francis, London, pp. 843-852.

3. Comparison with bedload transport volumes obtained by the SETRAC model

A one-dimensional sediment routing model for steep torrent channel networks called SETRAC has been developed at the University of Natural Resources and Applied Life Sciences, Vienna (Rickenmann et al. 2006). Three flow resistance approaches appropriate for steep channel gradients have been implemented. Four formulas are established to take into account the effect of flow resistance due to form roughness on sediment transport. The extent of the reduction can be related to different roughness structures (Chiari and Rickenmann 2007). These formulas can be combined with different bedload transport equations for steep slopes. Changes due to erosion and deposition as well as fractional bedload transport can be considered. Without consideration of form roughness losses the bedload transport is overestimated (Fig. 3). Considering a constant exponent (*a=1.5*) in equation (2) results in a better agreement with the reconstructed bedload transport. A variable exponent (*1.1 < a < 1.5*) depending on the roughness structures allows for a better calibration of the model (Fig. 4).

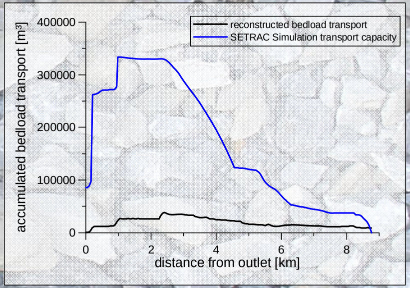

Figure 3: Comparison of the reconstructed bedload transport and bedload volumes obtained by a SETRAC simulation.Form roughness losses have not been considered.

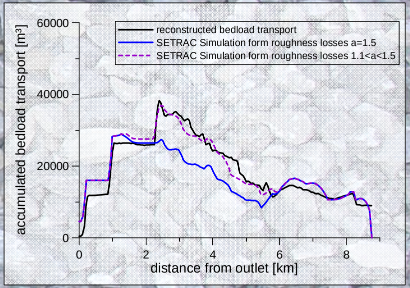

Figure 4: Comparison of the reconstructed bedload transport and bedload volumes obtained by SETRAC simulations .Form roughness losses have been considered with a constant exponent and a variable exponent a (Equation 2).

4. Conclusion

Morphologic changes can be calculated with high resolution digital elevation models in order to be compared with results obtained by numerical simulations. The elevation of the riverbed cannot be derived for submerged regions, but in areas with low relative flow depth and protruding roughness elements the accuracy of the elevation model is good enough for the purpose of estimating the processes of erosion and deposition caused by a flood event. The presented case study demonstrates the capability of the SETRAC model to compute sediment transfer in steep mountain streams. Using a set of formulas appropriate for the entire slope range, a reasonable agreement has been obtained between simulated and observed sediment loads. The simulation results show the importance of the consideration of form roughness losses for steep mountain streams.