Impact of shape and land use on sedimentation in green flood retention reservoirs

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Introduction: Flood induced release of contaminated sediment leads to a conflict situation between objectives of flood protection and land use in green flood retention reservoirs. Sustainable flood and reservoir management requires an investigation on sediment associated pollutants retention by green flood retention reservoirs. The presented work is focused on the effect of different basic shapes of retention reservoirs as well as vegetation and land use on the sedimentation patterns and efficiency. Due to the high adsorption capacity of fine suspended sediments of some micrometer diameter to toxicants such as heavy metals or agrochemicals the very fine sediment fractions are considered.

Methods: The retention effect of green flood retention reservoirs regarding potentially contaminated suspended sediment is investigated by means of 2D-numerical flow (TELMAC-2D) and transport simulations (SUBIEF-2D). The known affinity of pollutants to the sediment fraction in the range of few micrometers offers the possibility of simulating only the polluted sediment fraction without explicit simulation of the pollutants. The masses of deposited sediments and adsorbed contaminants on the flooded area then are assumed to be directly proportional, depending on the concentration of the particle bound pollutants.
A series of simulations of filling and emptying phases of different shaped, idealised reservoirs is performed for two hydraulic scenarios. One inflow hydrograph with a peak discharge of 36 m³/s is used for all calculations, whereas two constant outflow discharges of 14 m³/s and 21 m³/s lead to maximum volumes of about 10^6 m³ and $0.5*10^6$ m³ in the reservoirs with periods of operation of 51 h and 29 h, respectively. A linear relation between discharge and suspended sediment concentrations is used as transport inflow boundary condition. Different grain sizes from 20 µm to 150 µm are chosen to show the influence of settling behaviour on spatial distribution and total mass of deposits in the computational domain [1]. To elaborate on the unsteadiness of sedimentation in green flood retention reservoirs, detailed transport simulations are performed for the smallest grain size by adding discrete portions of suspended sediment at different times during filling as well as emptying phases. The effect of land use on sedimentation is captured by the impact of roughness coefficients. On the one hand, the roughness is assumed to be constant over the whole reservoir area, Strickler values k_{str} from 10 $m^{1/3}/s$ to 35 $m^{1/3}/s$ are chosen. On the other hand, two simulations are performed with a random distribution of typical types of land use with dimensions of land parcels.

Results: Amount and patterns of sedimentation in green flood retention reservoirs strongly depend on the combination of grain size of suspended sediment and reservoir shape. For a grain size of 20 µm the maximum deposition (45.3 % of total inflow mass) occurs in the widest but shortest reservoir, whereas the maximum deposition of the grain size of 150 µm (78.3 %) occurs in case of the longest and narrowest reservoir. The detailed transport simulations show a big influence of the respective time of sediment inflow into the reservoir on the amount of deposition. Most important factor in this context is the hydraulic short circuit during the filling phase which depends on reservoir shape, water level as well as outflow discharge during operation. Deposition patterns vary considerably depending on type of land use within the reservoir as well as the transported grain fraction. The influence of land use on amount of deposition is small.

Discussion: The results of this work show the impact of the factors shape and land use on sedimentation in green flood retention reservoirs and provide a basis for the estimation of the accumulation of particle adsorbed pollutants for a given constellation. This knowledge is essential for the development of an integrated management strategy for green flood retention reservoirs.

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References:

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