Trade-off analysis of discharge-desiltation-turbidity and sediment simulation of a combined reservoir–river system under multi-phase and multi-layer conjunctive releasing operation

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Multi-objective reservoir operation considering the trade-off of discharge-desiltation-turbidity during typhoons and sediment concentration simulation modeling are the vital components for sustainable reservoir management. The purpose of this study is to analyze the multi-layer release trade-offs between reservoir desiltation and intake turbidity of downstream purification plants and thus propose a superior conjunctive operation strategy. To this end, this study proposed a methodology to develop (1) a series of multi-phase and multi-layer sediment-flood conjunctive release modes and (2) a specialized sediment concentration numerical model for a combined reservoir–river system. The conjunctive release modes involve (1) an optimization model where the decision variables are multi-phase reduction/scaling ratios and the timings to generate a superior total release hydrograph for flood control (Phase I: phase prior to flood arrival, Phase II/III: phase prior to/subsequent to peak flow) and (2) a combination method with physical limitations regarding separation of the singular hydrograph into multi-layer release hydrographs for sediment control. This study employed the featured signals obtained from statistical quartiles/sediment duration curve in mesh segmentation, and an iterative optimization model with a sediment unit response matrix and corresponding geophysical-based acceleration factors, for efficient parameter calibration. This study applied the developed methodology to the Shihmen Reservoir watershed in Taiwan. The trade-off analytical results using Typhoons Sinlaku and Jangmi as case examples revealed that owing to gravity current and re-suspension effects, Phase I+II can de-silt safely without violating the intake's turbidity limitation before reservoir discharge reaches 2238 m^3/s; however, Phase III can only de-silt after the release at spillway reaches 827 m^3/s, and before reservoir discharge reaches 1924 m^3/s, with corresponding maximum desiltation ratio being 0.221 and 0.323, respectively.

Keywords: Multi-phase sediment-flood management, Sediment concentration modeling, Sediment duration curve, Hydrological statistic, Multi-objective trade-off analysis, Multi-layer conjunctive releasing

