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1D morphological adaptation of Lower Zambezi River to dam construction

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Dams impose changes in water flow and sediment transfer that cause large-scale alterations in the downstream river morphology. The Lower Zambezi River's hydrology and morphology regime changed due to the two large impoundments in the middle part of the basin. The main goal of this study is to analyze the long-term effect of damming on the Lower Zambezi River and its delta based on analytical methods and 1D morphological modeling. The geographical, hydrological, and morphological data are analyzed to describe the current and past river conditions and infer morphological trends. The water and sediment balances of the basin developed by Carimo (2020) form the basis for the present study. The land cover of the Lower Zambezi river basin from 1989 to 2019 is determined using Google Earth Engine (GGE), a web-based image analysis tool. The long-term morphological changes of the river are assessed using the Modified Normalized Difference Water Index (MNDWI). The satellite image analysis revealed a deposition trend in Zone B and Zone C, while the Zambezi delta remained stable between 1986 to 2019. Data analysis shows that the river's width increased significantly after the dam (2007), with the highest river width change observed in Zone C. Besides, a reduction of thalweg was observed in Zone B, while the average bed level increased in most sections of the river. There has also been a reduction in bed levels in Zone D after the construction of the dam. The impact of damming on the river is further analyzed using a 1D morphological model. Appropriate flow and sediment boundary conditions, grid size, and initial conditions are provided to the model based on measured data complemented by indirect assessments where data are missing. The model calibration based on Chézy's coefficient results in good agreement between measured and simulated water levels. The model output revealed that it could reproduce the river's average bed level for 1962 and 2007. The simulations of future developments have been carried out for 300 years (2007 to 2307), starting from the 2007 bed level profile and cross-sections. The discharge regimes of the Zambezi River and tributaries have been modified based on published discharge projections for 2100 to include the impact of climate change. The downstream boundary condition has also been adjusted based on IPCC mean sea level rise scenarios. The model predicts that there will be erosion in the first 200 km downstream of Cahora Bassa, but no significant bed level changes are expected in the other reaches. Deposition in the bifurcation channel in the delta does not cope with sea-level rise for both scenarios. This shows a "river drowning" trend due to the delta's lack of sediment input to cope with the predicted future sea-level rise. In general, river bed erosion due to the effect of the Cahora Bassa dam will be limited to the first 200 km of the river.