Impact of hydropower operation in the surface hydrological dynamics and the interconnections between the surface and groundwater hydrology in the Zambezi River Basin

Inception Report

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Project overview

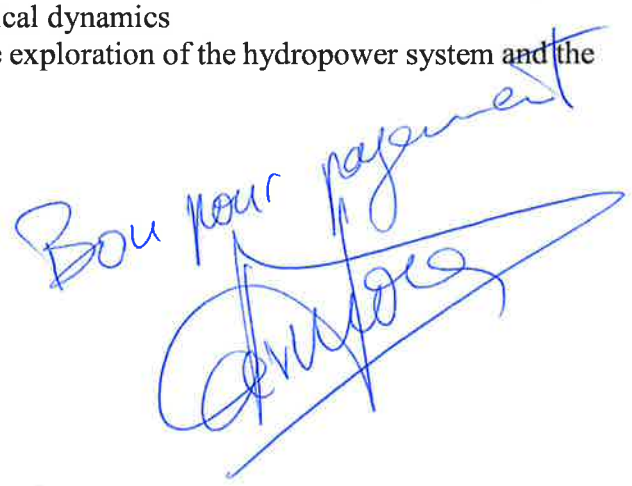
The work proposed in this inception report falls within the project: "The African Networks of Centres of Excellence on Water Sciences PHASE II (ACE WATER 2)" that aims at fostering sustainable capacity development at scientific, technical, and institutional level in the water sector. The project supports twenty (20) AU-NEPAD African Network of Centres of Excellence in Water Sciences and Technology (CoEs) organized in three regional networks, in conducting high-end scientific research on water and related sectors, in order to provide effective scientific and educational support to governments. In the framework of the project scientific component, the SANWATCE (Southern Africa Network of WATer Centers of Excellence) identified the Zambezi River Basin as a case study area for the WEFE nexus assessment to be jointly undertaken with the technical/scientific support and coordination of the JRC, because highly representative of the Southern Africa River Basins.

The recent acquisition of new datasets from ZAMWIS (Zambezi Water Resources Information Systems), mainly consisting of hydrological time series and reservoir management information, provided an opportunity to further refine the calibration/validation of the the SPATSIM/Pitman model of the Rhodes University's Institute for Water Research, enhancing the reliability and robustness of the hydrological simulations. In addition, the information also facilitate the development of a revised application of the Water Evaluation and Planning System (WEAP) tool for the case study area. The overall objective is that once calibrated and validated using the most updated observations, the model settings could be used for the development of future water use and climate scenarios and to inform subsequent river basin management and planning options, within a wider Water-Energy-Food-Ecosystem (WEFE) nexus approach. This is the second phase of activities in the Zambezi, and it entails the assessment of climate change and infrastructural development scenarios on surface hydrological dynamics.

Objectives

The general objective of this project is to analyse the impact of hydropower operation in the surface hydrological dynamics and the interconnections between the surface and groundwater hydrology in the Zambezi river basin. Specifically, this project will address three sub-objectives:

1. Represent the existing hydropower system of the ZRB in a modeling framework similar to the HEC ResSim and investigate the possible dynamics based on the hydrological information
2. Analyze groundwater dynamics extending it for the whole basin and investigating the interaction with the surface water hydrological dynamics
3. Incorporate the feedbacks received from the exploration of the hydropower system and the groundwater dynamics in river hydrology.



Activities

Task 1: Represent the existing hydropower system of the ZRB

This task, carried out by M.E. Arias, will assess the effects of hydropower operations on river flows. The overall goal is to provide feedback on how historical and future dam operations affect surface hydrology, so that this information can be used in refining the SPATSIM/Pitman model. This will entail the synthesis of existing GIS and monitoring data provided by the JRC, ZAMWIS, and project partners, hydrological data analysis to detect past trends in indicators of hydrological alteration, approximation of operation rules based on historical water levels and discharge, development of a reservoir operation simulation model, and evaluation of future scenarios of reservoir operations and river flows. Overall, this task will be subdivided into 5 stages:

1.1. Compilation of GIS and design information need to create river and infrastructure network: Information related to the location of dams along river networks, and their corresponding watershed will be synthesized. In addition, data specific to the design and operations of dams (for example, total volume, design discharge, spillways, etc.) will be compiled.

1.2. Analysis of indicators of hydrological alteration: Historical flow data will be used to detect how indicators of hydrological alteration, which are flow-derived seasonal or annual indices known to be affected by dam operations, have changed through time in river reaches downstream from dams.

1.3. Development of reservoir operation model: based on the GIS and monitoring data, a model to represent the routing of river flows through reservoirs and dam structures will be developed using HEC-ResSim, a tool from the US Army Corps of Engineering that has been widely used for reservoir planning purposes. The model will initially be setup with simulated natural flows from SPATSIM/Pitman, and reservoir operations will be inferred from historical observations of water levels and flows.

1.4. Evaluation of future scenarios: Once the reservoir operations model is developed, river flows driving the model will be substituted with projected future river flows. These river flows will be simulated in SPATSIM/Pitman using downscaled data from the CORDEX Africa project.

Task 2: Analyze groundwater dynamics extending it for the whole basin and investigating the interaction with the surface water hydrological dynamics

In this activity, surface water – groundwater dynamics in the sub-catchments of the Zambezi Basin will be investigated. It is well noting that there is scare data to support detailed calibration of the groundwater-surface dynamics for the whole basin. The approach in this activity will therefore be exploratory in nature. The main thrust will be to investigate surface water - groundwater interchange and collaborate this information against regional/global estimates available. Specifically, water balance budgets will be generated from the SPATSIM/Pitman model and examined to determine the section of the river network that have the largest exchange as aquifer recharge. These recharge estimates will be compared to groundwater recharge estimates from the World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP). The groundwater dynamics will further be invested in terms of which factors influence change such as evaporation or anthropogenic activities.

Task 3: Incorporate the feedbacks received from the exploration of the hydropower system and the groundwater dynamics in river hydrology.

The feedbacks from the more detailed analyses of the hydropower system and the groundwater dynamics can be incorporated into the existing model setup as part of the next phase of the project that looks at scenarios of climate and water use changes into the future. In the current model setup, the hydropower release patterns are largely based on historical observations. For the modelling of future scenarios these need to be replaced by operating rules that are considered appropriate based on the outputs of Task 1.4 above.

In a similar manner, the current model setup has not used any explicit information about the groundwater dynamics of the different parts of the basin. Any information that results from Task 2 will therefore be incorporated into the model setup through some re-calibration of the groundwater recharge parameters and subsequent adjustment of other parts of the model to ensure that a satisfactory water balance is still achieved by the revised model. The groundwater information may also help when future water uses are included in the model as part of the scenario analysis, particularly if this information includes any ideas about present day and future trends in groundwater abstractions.

Outputs

1. Table and diagram of operation rules for each dam
2. A reservoir operation simulation model
3. A dataset with results from the baseline and future scenario results, including water levels, flows, and indicators of hydrological alteration.
4. Map showing the Zambezi network and sections with high aquifer recharge.
5. Map showing the groundwater head change based on precipitation data

Timeline

Task	Responsible	January	February	March	April
1.1. Compilation of GIS information	Arias				
1.2. Indicators of hydrological alteration	Arias				
1.3. Operations model					
1.4. Future scenarios					
2.0 Evaluation of water balance budget	Kawawa				
2.0 Assessment of groundwater dynamic change	Kawawa				
Final report	Everyone				April 15