From Flood Control to Water Resource Optimization: Hydrological Insights and Operational Challenges of the Friendship Dam (Djibouti)

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ABSTRACT

The Friendship Dam, located on the Ambouli wadi upstream of Djibouti City, represents a key hydraulic infrastructure designed to mitigate flash flood risks while providing a strategic water storage capacity in a semi-arid and volcanic environment. With a total storage capacity of approximately 14 million m³ and controlling nearly 65% of the watershed, the dam plays a crucial role in protecting downstream urban areas from recurrent flood events.

This study aims to analyze the hydrological functioning of the dam based on observed events, to quantify water losses, and to propose operational scenarios for optimizing water use. The analysis relies on detailed datasets collected during significant hydrological events in 2019 and 2020, including reservoir water levels, storage volumes, and downstream loss measurements. The results highlight the dominant role of infiltration processes, accounting for more than 94–96% of total water losses, while evaporation represents a minor component (approximately 4–6%). Under high storage conditions, when the reservoir approaches its maximum capacity, infiltration rates can reach approximately 300,000 m³/day, illustrating the extremely high permeability of the volcanic and fractured substratum. These findings are consistent with the geological context of the region, which enhances subsurface water transfer.

A key contribution of this study is the establishment of a height–discharge relationship for water losses, derived from empirical observations. A power-law relationship was identified, with a strong correlation ($R^2 \approx 0.99$), allowing reliable estimation of infiltration rates as a function of reservoir level. This relationship provides a valuable tool for predicting reservoir behavior under varying hydrological conditions.

Furthermore, a surface water balance approach was applied to reconstruct inflows and better understand the hydrodynamic functioning of the reservoir. Results indicate that flood inflows represent more than 99% of total inputs, emphasizing the episodic and highly variable nature of water resources in this semi-arid context.

Based on these analyses, several operational scenarios are proposed to improve water resource management, including the construction of downstream storage reservoirs to reduce infiltration losses, controlled releases for groundwater recharge, and optimized strategies balancing flood control and irrigation needs. The absence of clearly defined operational rules currently limits the full potential of the dam.

This study provides new insights into the functioning of reservoirs in data-scarce and highly permeable environments and highlights the importance of integrating hydrological processes into operational decision-making. The findings contribute to improving flood risk management and water resource planning in arid regions facing increasing climate variability.

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Keywords: Semi-arid hydrology, Flash floods, Reservoir management, Operational scenarios