WATER GLOBAL PRACTICE

WORLD BANK GROUP

GWSP GLOBAL WATER SECURITY & SANITATION PARTNERSHIP

HYDROPOWER AND DAMS (H&D)

Strengthening Climate-Informed Project Design

LEARNING NOTE

October 2022

KEY LESSON

The growing impact of climate change on the design and operation of dams and the inherent complexity of dam projects (often multipurpose) require the capacity to adopt increasingly strict global standards and to mainstream resilience and low-carbon considerations in water infrastructure in which dams are a critical component. Water storage reservoirs are instrumental in regulating intensified hydrological regimes and applying water resources management principles to help build resilience to climate change. On the other hand, these structures could themselves be vulnerable to climate change–related risks if the latter are not adequately reflected in their design and operation.

CHALLENGE

Increasing hydroclimatic variability and unpredictability, coupled with aging infrastructure, growing water demand, persistent watershed degradation, and lack of real-time data transmission and information networks are likely to affect the sustainability, operations, and safety of a dam over its life span. All these factors point to the need to revise hydrological models to account for climate change (e.g., extreme floods, low river flows, and reservoir evaporation) and adjust long-standing engineering norms and standards for dam design and operations while securing and enhancing the water supply, hydropower generation, and flood control functions of dams.

This learning note is the second of a 4-note-series developed by the Water Global Practice (GP) Climate Change Team to highlight successful examples of water operations that support climate change–related activities and provide useful lessons and recommendations for project design.

WHAT TO DO	HOW TO DO IT
• **Enhance the resilience of dams by addressing both engineering and operational aspects** when designing new dams or rehabilitating exiting ones. Considering the potential risk and uncertainty of climate change impacts on future water flows, factors such as sedimentation and evaporation rates, among others, should be key elements of the design/rehabilitation process. In addition, use design processes and tools to consider and evaluate several plausible future climate change scenarios. Select the optimal design taking into account their ranking/score in terms of robustness and flexibility under the alternative plausible future scenarios, considering the dam's potential risks and climate change–related uncertainties.	• **Ensure compliance with critical safeguard policies relevant to adaptation.** Countries that engage independent experts and use technical assistance (TA) are more likely to comply with environmental and social standards (ESSs) closely linked to climate change. Expert advice and strategic TA are particularly important for site investigations, technical design reviews, works supervision, and quality assurance. Moreover, the use of technical resources such as the report *Building the Resilience of WSS Utilities to Climate Change and Other Threats: A Road Map* and the *Resilient Water Infrastructure Design Brief* (see the Key Resources section) is recommended to incorporate adaptation and resilience considerations into project design.
• **Track the implementation of dam safety measures,** as design criteria and safety requirements for dams warrant a more careful review and examination—reflecting worldwide efforts to integrate climate-related factors that increasingly affect the safe and reliable operation of dams. Detailed information on all aspects of dam safety can be found in the *Good Practice Note on Dam Safety* and the accompanying seven Technical Notes, in particular "Technical Note 1: Hydrological Risk," published by the World Bank.	• **Define indicators** to monitor the implementation of dam safety measures and compliance with current international dam safety standards and practices. As climate change makes dam failures more likely to happen, sound risk management becomes increasingly important. Dam safety indicators should be included in the project's results framework. Having indicators to monitor the implementation of safety measures usually helps to ensure compliance with current international dam safety standards and practices.
• **Improve operations and maintenance (O&M) practices.** The increasing impact of climate change on dam operations makes the need for sound water storage management and regular surveillance and maintenance works to ensure infrastructure is safely managed, more acute.	• **Sustain O&M through trained staff and dedicated resources.** Make adequate provisions for sound reservoir/barrage management and regular maintenance. These require training of operators; technical advice from an independent panel of experts (PoE) on the design; coordinated operations of dams in the interconnected river system; dedicated financial and human resources; and a comprehensive, detailed maintenance plan that includes O&M and climate-related indicators.

- **Enhance the safety of dam operations** by implementing an early warning system that is based on functional hydrometeorological systems and flexible operating protocols. Doing so will increase the resilience of assets, local communities, and livelihoods to climate and disaster risks.

- **Rely on professionally trained operators with access to real-time data and clear operating rules for effective dam operations.** The use of real-time information by trained operators able to make decisions based on pre-agreed operating rules can encourage the introduction of a more adaptive reservoir operation—possibly aimed at increasing the water supply capacity, hydropower generation, and flood control—with due consideration for the dam's potential risks and uncertainties in real-time data. Also, more efficient, timely, and flexible operating protocols, in addition to increased storage capacity, will improve dam management during extreme weather events.

- **Dedicate time and resources to local capacity building**—a key element for robust design and development of dam projects under climate change.

- **Invest in capacity building.** The integration of ESS-related activities in a project can be facilitated by organizing tailored training sessions for project staff, consultants, and contractors; and regularly holding safeguard review meetings. Failure to comply with ESSs can erode stakeholders' support for the project and undermine the project's sustainability after its completion.

WHAT TO KEEP IN MIND

- **Ensuring basic dam safety measures is paramount in H&D projects potentially affected by climate change.** When essential elements are missing or not adequately considered to improve dam safety and the reliability of dam operations (based on strategic assessments, plans for sound O&M, capacity enhancement of operators, improved access to real-time data, and establishment of clear and flexible operating rules), the project could fail to achieve its (climate-related) objectives.
- **Best practices regarding the building of new dams or rehabilitation of existing dams under a changing climate** include decision making under deep climate uncertainty (based on stress testing against multiple future climate scenarios); carrying out strategic studies; developing dam safety reports; appointing an independent PoE; preparing and implementing emergency preparedness, O&M, and instrumentation plans; preparing a plan for construction supervision and quality assurance; facilitating technology transfer; and investing in capacity-strengthening and awareness-raising activities, through community consultation and participation programs for emergency preparedness planning and, if suitable, for basic surveillance and maintenance of small dams/reservoirs contingent on the training required.
- **A dam project should be developed by considering the larger picture.** It is vital to develop the project as part of an interconnected water system right from the identification stage. This is especially important when dealing with a multipurpose or transboundary dam project.

Mozambique Case Study: National Water Resources Development Project

FY12–FY20, IDA: US$102 million (incl. Additional Finance)

The project's main activities include: completion of works to increase storage capacity of the Corumana Dam; adoption of technology and operating protocols for improved dam management during extreme weather events; development of a national hydro-climatic information management system and a water allocation and revenue management framework; elaboration of water resources development plans and the Limpopo River Flood Management Plan; emergency rehabilitation of civil works of the Macarretane Barrage; and longer-term interventions based on integrated flood management studies.

Objectives	• **Parent project:** To strengthen the development and management of national water resources and increase the yield of the Corumana Dam to augment water supply for the Greater Maputo Metropolitan Area (GMMA) to reduce the growing water shortages • **Additional financing:** To strengthen flood protection works in the Limpopo River Basin (the Macarretane Barrage), following the 2013 floods
Aspect	**Lesson**
Dam safety measures (good practices implemented during project preparation)	The project covered the Corumana Dam's completion—that is, civil and hydromechanical works, and environmental and social aspects, as well as the country's water resources development and management aspects, which contributed to the project's positive climate-related results. A technical services and dam safety consultancy reviewed the systems for the management and operation of the Corumana Dam, carried out a dam safety audit, and prepared an instrumentation plan, an O&M Plan, and an Emergency Preparedness Plan. In addition, dams were periodically inspected to ensure their safety and a dam safety PoE was appointed, which provided independent review and support during implementation and toward impoundment to the new water supply level. The results framework included indicators to promote safety measures and comply with stringent standards and practices.
Climate resilience and mitigation	The Corumana Dam's storage capacity was increased, enhancing hydropower generation, serving as supplemental supply in times of drought and as a buffer during floods; a water license was granted to Maputo Water Supply, increasing the resilience of the capital's residents to drought; the Macarretane Barrage was upgraded with functioning hydromechanical works, a gate control system, and reinforced foundations, which improve flood control; and transboundary cooperation was strengthened (thanks to reviewed and updated agreements on international waterways).
Unforeseen changes in local conditions during the project cycle	It is crucial to monitor local conditions for any changes in the implementation stage with respect to the design that may affect project outcomes relevant to adaptation. The dam's technical design was revised to (1) meet the safety requirements of the dam, based on an updated hydrological assessment and the government's new dam safety regulations; and (2) avoid the risk of flooding a downstream area that had been uninhabited during project preparation but was subsequently populated, thus also requiring a thorough resettlement process.

KEY RESOURCES

Bonzanigo, Laura, Julie Rozenberg, Gregory C. Felter, Robert J. Lempert, and Patrick M. Reed. 2018. ***Building the Resilience of WSS Utilities to Climate Change and Other Threats: A Road Map.*** Washington, DC: World Bank.

Engle, Nathan L., Daniel Medina, Gregory C. Felter, and Sean Nelson. 2020. ***Resilient Water Infrastructure Design Brief.*** Washington, DC: World Bank.

Hallegatte, Stéphane, Jun Rentschler, and Julie Rozenberg. 2019. ***Lifelines: The Resilient Infrastructure Opportunity.*** Sustainable Infrastructure Series. Washington, DC: World Bank.

Hallegatte, Stéphane, Rubaina Anjum, Paolo Avner, Ammara Shariq, Michelle Winglee, and Camilla Knudsen. 2021. ***Integrating Climate Change and Natural Disasters in the Economic Analysis of Projects: A Disaster and Climate Risk Stress Test Methodology.*** Washington, DC: World Bank.

Martin, Nancy L., and Sundus N. Siddiqi. 2020. ***Guidance Note on Climate Indicators.*** Internal report. Washington, DC: World Bank.

Ray, Patrick A., and Casey M. Brown. 2015. ***Confronting Climate Uncertainty in Water Resources Planning and Project Design: The Decision Tree Framework.*** Washington, DC: World Bank.

Stip, Clémentine, Zhimin Mao, Laura Bonzanigo, Greg Browder, and Jacob Tracy. 2019. "**Water Infrastructure Resilience – Examples of Dams, Wastewater Treatment Plants, and Water Supply and Sanitation Systems**." Sector note for Lifelines: The Resilient Infrastructure Opportunity. Washington, DC: World Bank.

Ueda, Satoru, Ximing Zhang, Marcus J. Wishart, Felipe J. Lazaro, Luciano C. Vicente, and Kimberly N. Lyon. 2020. ***Good Practice Note on Dam Safety*** (Report and Annexes). Washington, DC: World Bank.

Wishart, Marcus J., Satoru Ueda, John D. Pisaniello, Joanne L. Tingey-Holyoak, Kimberly N. Lyon, and Esteban Boj García. 2020. ***Laying the Foundations: A Global Analysis of Regulatory Frameworks for the Safety of Dams and Downstream Communities.*** Washington, DC: World Bank.

Connect with the Water Global Practice

www.worldbank.org/water worldbankwater@worldbank.org @worldbankwater blogs.worldbank.org/water

WORLD BANK GROUP

GWSP GLOBAL WATER SECURITY & SANITATION PARTNERSHIP

Photos: © Direcção Nacional de Gestão de Recursos Hídricos - DNGRH. Graphic Design: matmedya