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International Water Resources Association
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XIX WORLD WATER CONGRESS
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Kingdom of Morocco
Ministry of Equipment and Water

Hydrological Challenges and Operational Adaptations for the High Aswan Dam: Evaluating the Impact of Blue Nile Developments in Ethiopia

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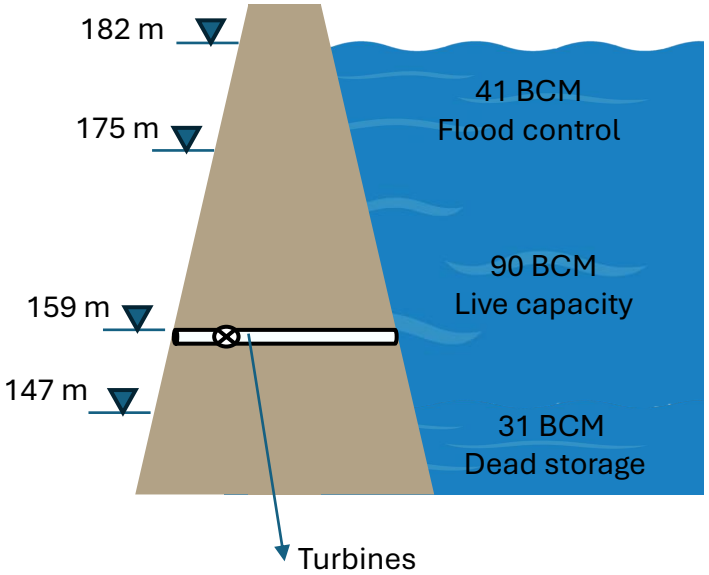
Introduction

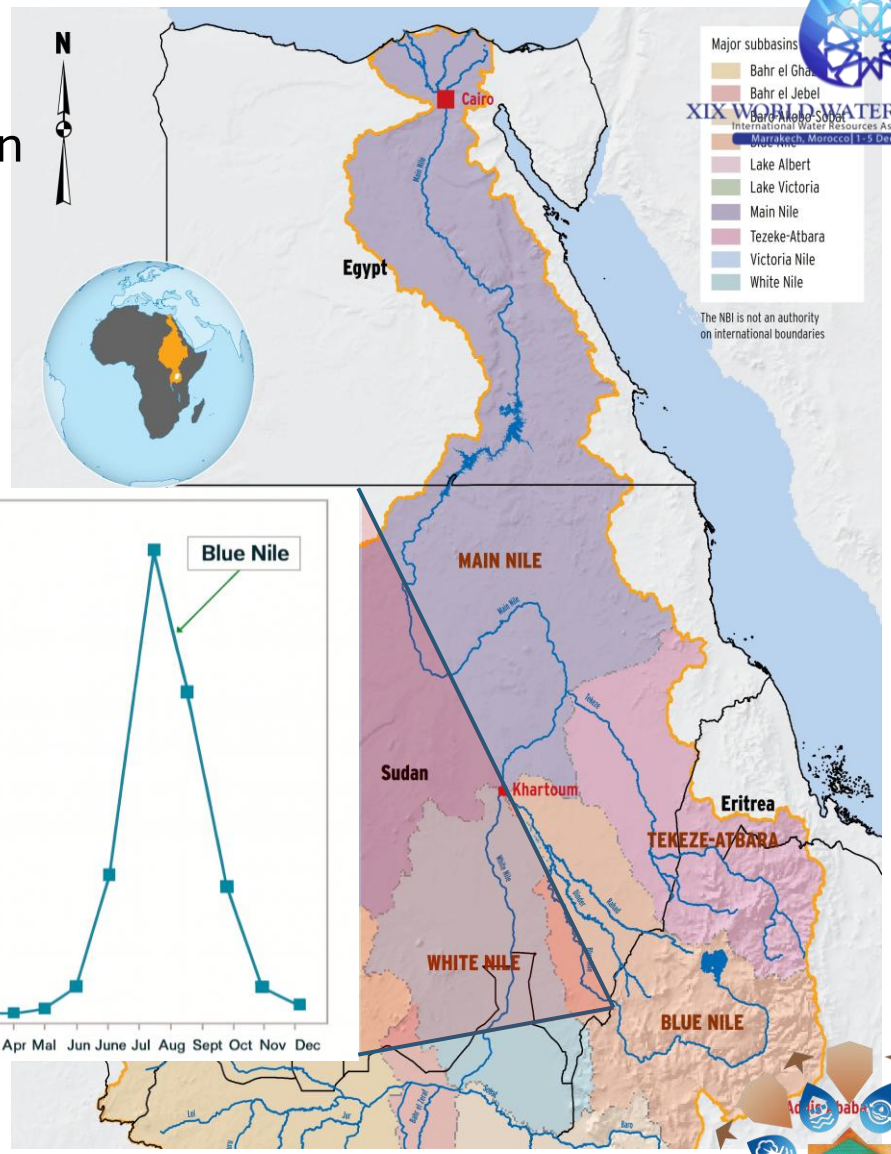
High Aswan Dam

- Constructed in 1969
- Designed for long-term storage, flood and drought protection, and hydropower generation
- 12 turbines with total capacity 2100 MW
- Total storage 162 Billion Cubic meter

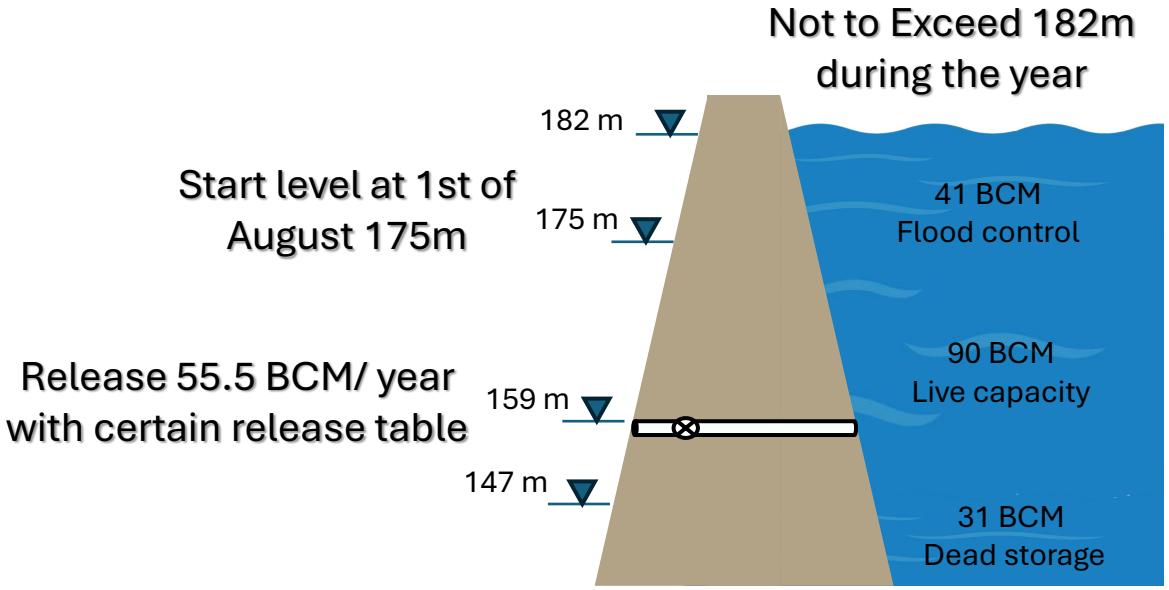


Introduction

- 🌊 Average annual flow: ~49 BCM at the Sudanese–Ethiopian border
- ☔ Flood season: July–September (may extend to October)
- 📈 Seasonal concentration: About 70–80% of annual flow occurs during flood months
- 💧 Dry season: Very low flow from November to May



HAD Operation Policy



Rationale for Operational Adaptations of HAD

HAD

Flood Management

- Higher initial reservoir levels
- Smaller free capacity
- Preserve flexibility for unexpected releases

However, without a binding agreement, the timing and volume of releases from GERD remain uncertain

Drought Management

- Multi-year deficit distribution distribution rules
- Mitigate drought impacts
- Sustain downstream water availability

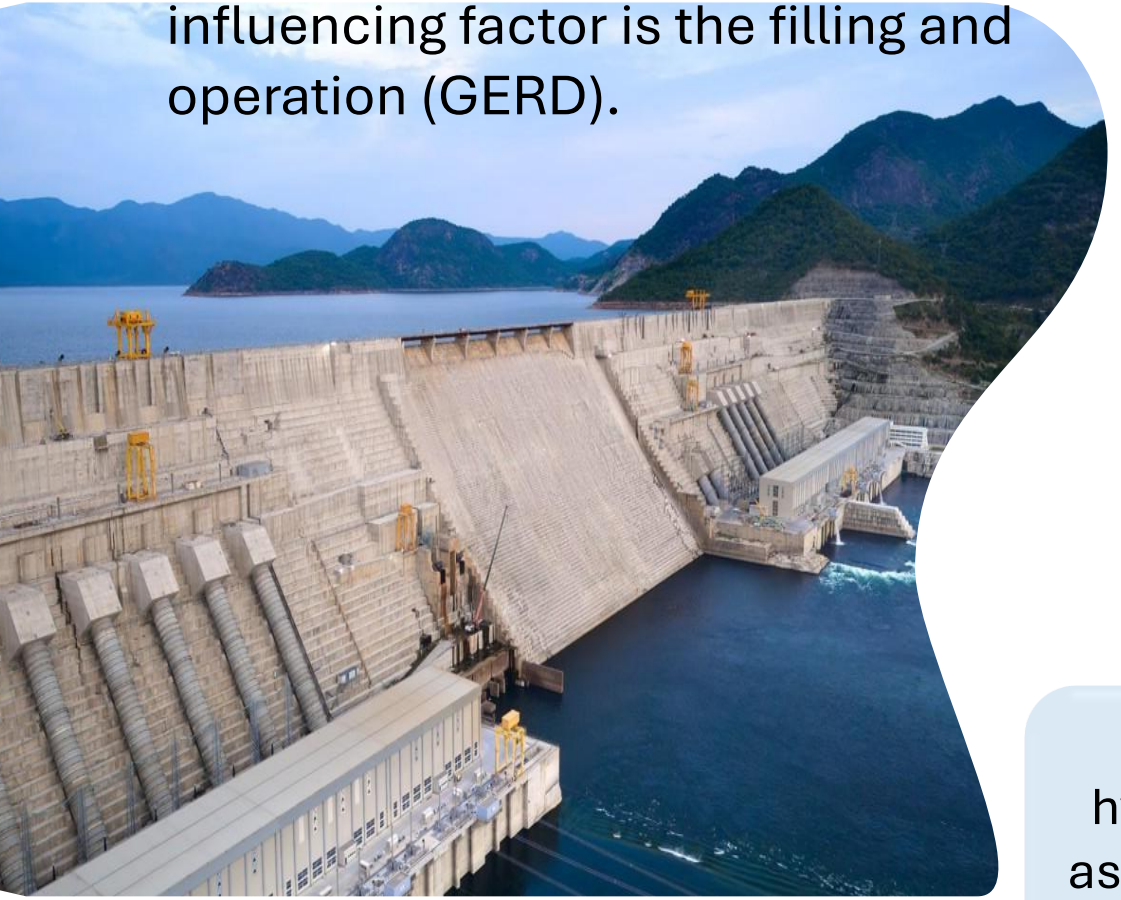
GERD is designed to regulate flows, reducing natural flood peaks and increasing dry-season flows.

New hydrological reality requires HAD strategy adaptation

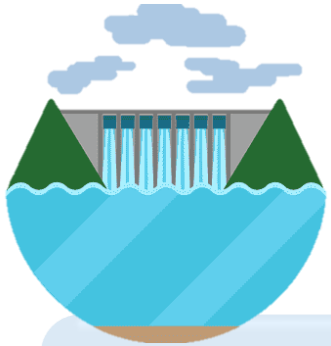
GERD

Rationale for Operational Adaptations of HAD

- The key and most immediate influencing factor is the filling and operation (GERD).



- Other long-term factors that could significantly impact HAD's operation include:



The effects of climate change on rainfall and runoff patterns.

Future Ethiopian agricultural and hydropower projects.

Extreme or abnormal hydrological conditions, such as poor upstream management or potential dam failures.

Methodology

Using RIBASIM and other Developed Excel models

25 years of simulation scenarios (1987-2003).

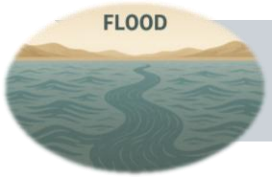
Completion of GERD filling for two years (2024–2025), followed by the operation of GERD after 2025 under different operational scenarios

Number of alternative rules were tested during drought periods to identify the optimal rule that minimizes total deficits and improves their distribution.

An operational rule for low-inflow years (descending inflow pattern)

115 years of simulation scenarios

The highest-inflow years were identified



Annual simulations were then conducted to determine the starting water level for each hydrological year at HAD

An operational rule for high-inflow years (ascending inflow pattern).

The operation rule for low inflow years (Sliding Scale)

- Simulation started with HAD level = 179.5 m (August 2024)
- 25 years of simulation scenarios (1987-2003)
- Two main operation scenarios:
  - Scenario1 – Minimum Annual Release from GERD: 37 BCM, GERD level will not drop below 605 m.
  - Scenario 2 – High Level Maintain: GERD levels maintained between 625–640 m.

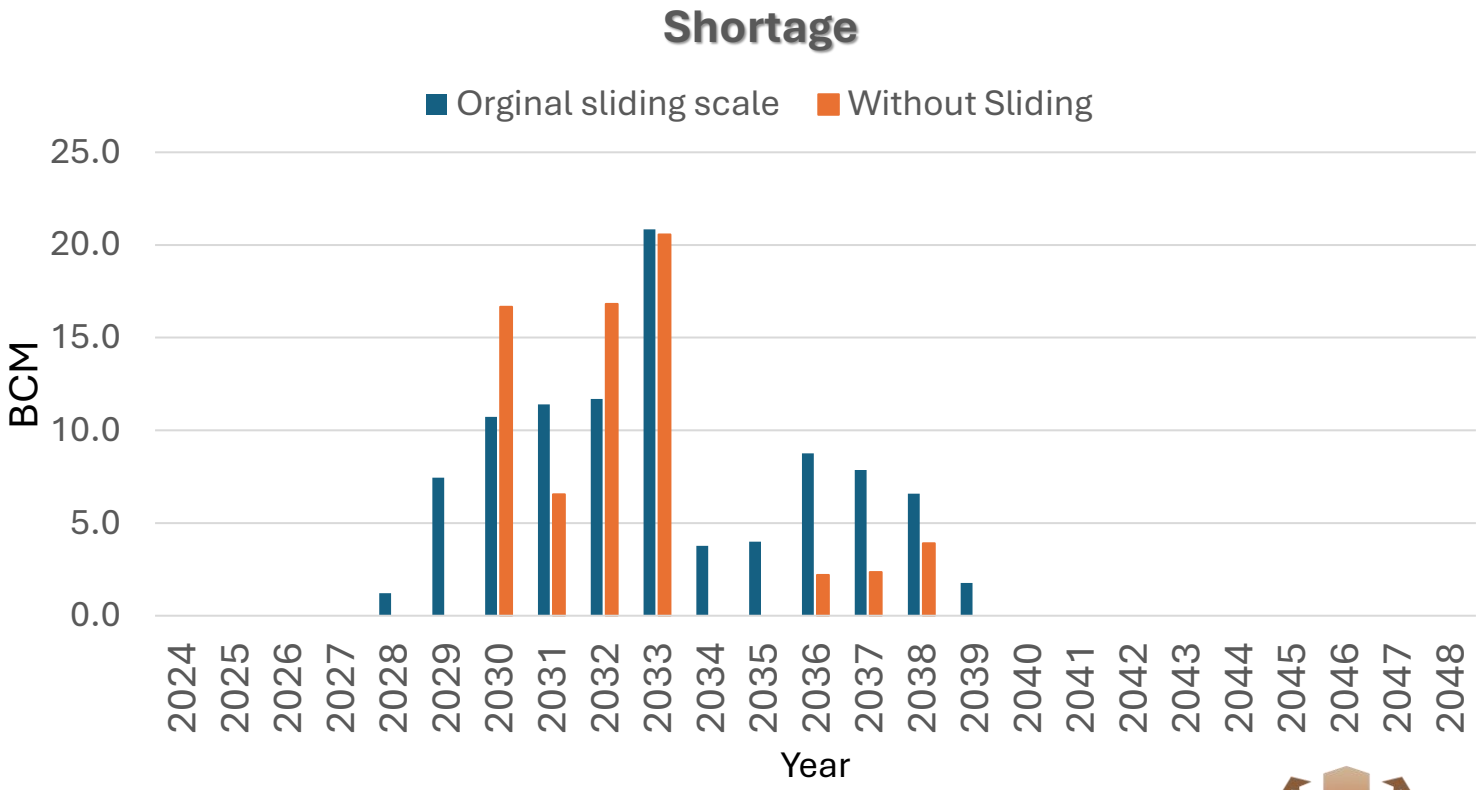
Dry period (1987-2003)	S1(min. annual Release)	S2(high GERD Levels)
Mean HAD Level	160.2 m	160.4 m
Drop to level 147m (dead storage)	During 6 years from the simulation period	During 5 years from the simulation period
Total Shortage	72.7 BCM	74.8 BCM

15 years of the Simulation period With no Power Generation

The operation rule for low inflow years (Sliding Scale)

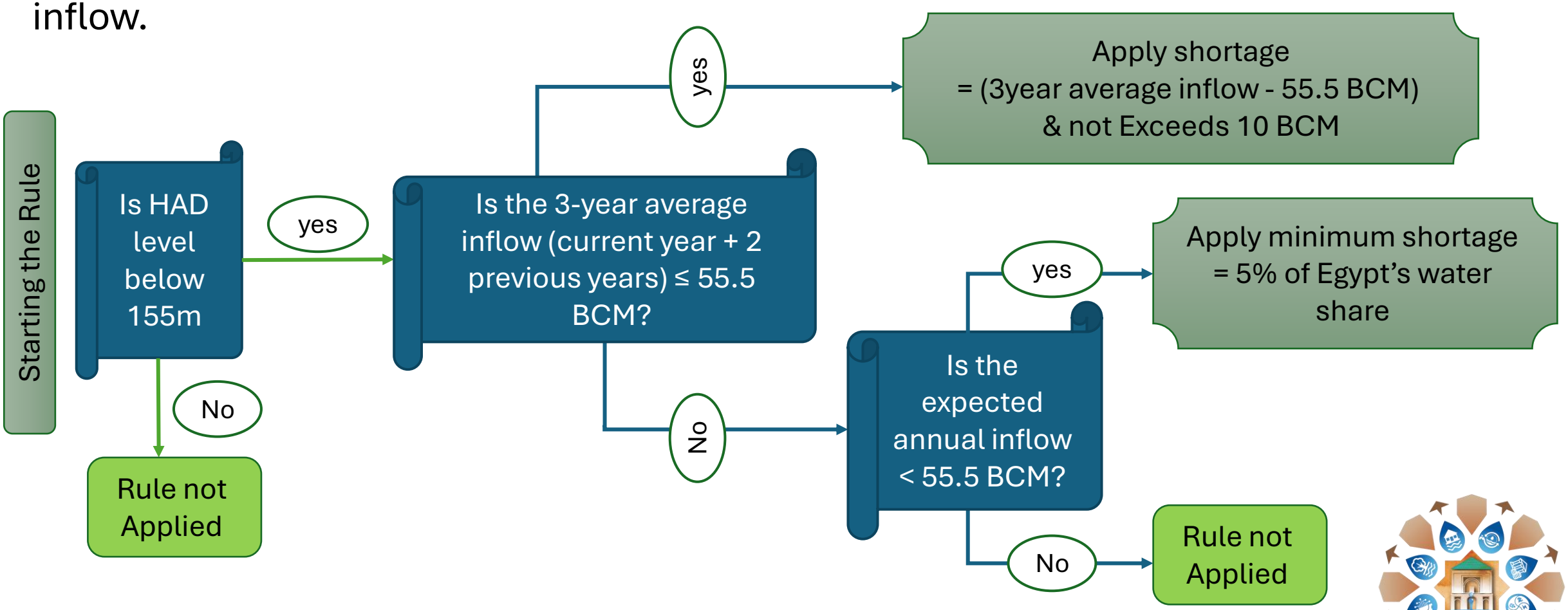
- Sliding Scale Rule: Gradual reduction of water consumption based on HAD level starting from 160 m.a.s.l:
  - 160–158.3 m → 5% reduction
  - 158.3–156.1 m → 10% reduction
  - 156.1–154.3 m → 15% reduction

- However, applying the rule increased total shortage to 96.1 BCM compared to 75 BCM without Sliding Scale, **showing the need for optimization.**



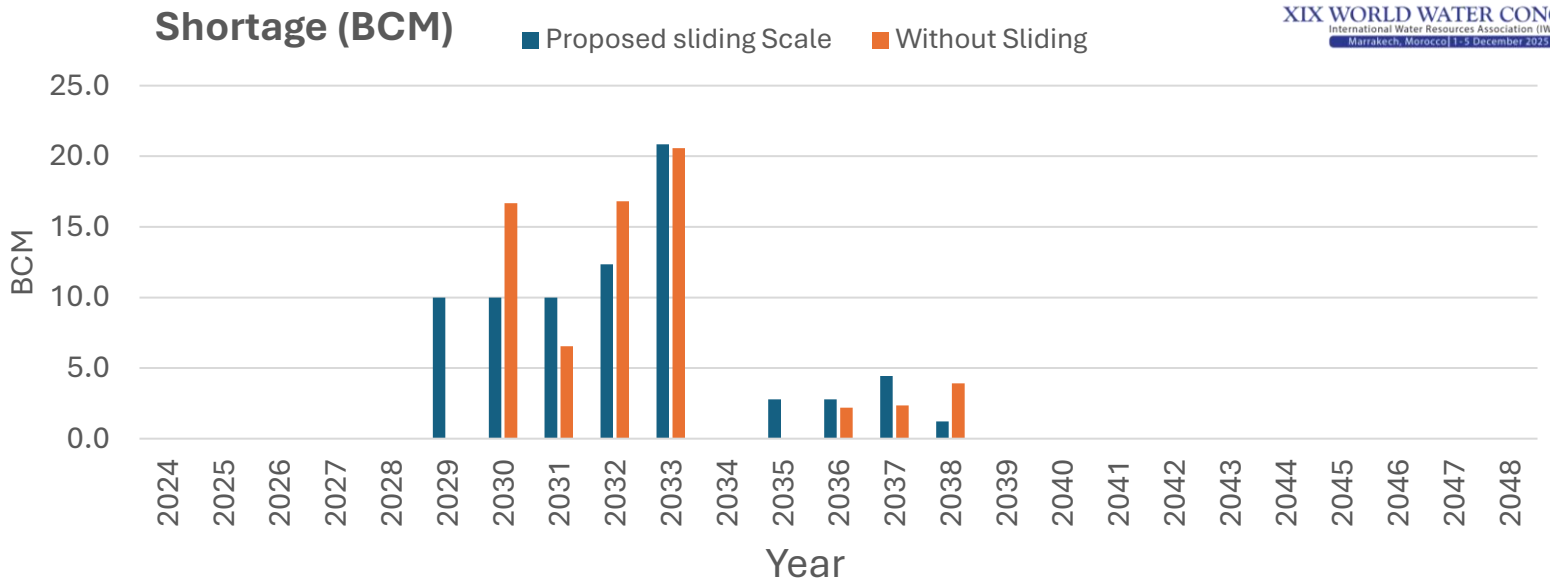
Proposed new operation rule for low inflow years (Sliding Scale)

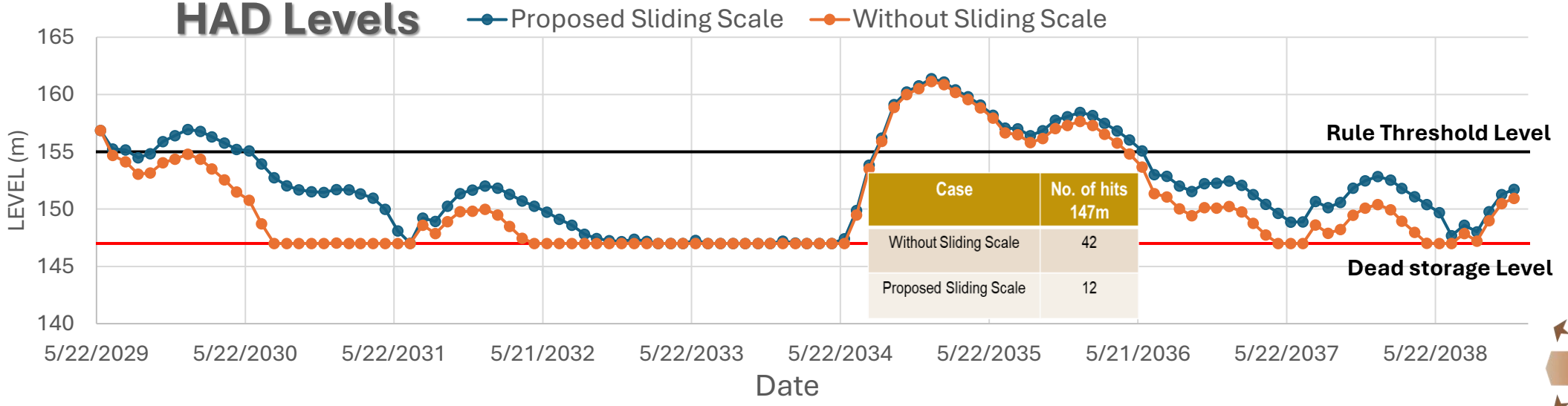
- An Optimized rule was derivative as result of many trails:
- The new proposed rule starts at 155 m, considering both storage level and monthly inflow.



Proposed new operation rule for low inflow years (Sliding Scale)

- Results:
  - Number of critical level events (147 m) reduced from **42 → 12 times**.
  - Total shortage improved to **~74.4 BCM**.
  - Better shortage distribution and more stable HAD levels.





Proposed new operation rule for High inflow years

1900 — RIBASIM — 2015

115-year simulation of GERD under various operation policies

Identify the scenario that would maximize inflows to (HAD)

GERD maintain high levels preserving flood patterns

We Examine the highest flow patten years

1946 | 1964 | 1998 | 2023

Assumptions

- Demands
- Toshka
- Ending level

Variables

Initial HAD Levels
179.50 - 179.00 - 178.50 – 178.00

178 m

Operational Adaptations of HAD (Proposed New Rules)

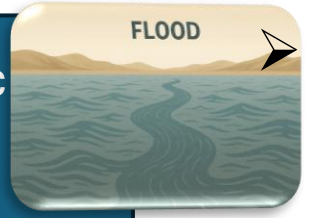
- Evaluating the flood condition during the first week of August.
- Simulation of the High Dam operations is carried out; Operating procedures are then applied according to the flood conditions as follows:

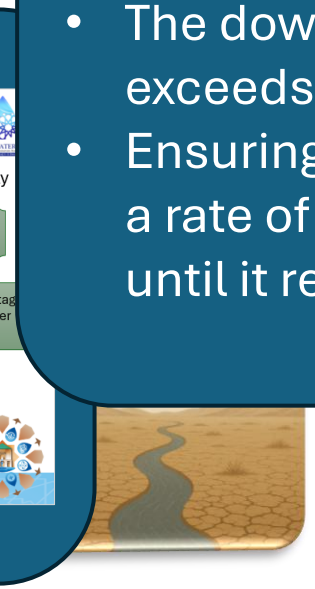
- 178 m max level of HAD at 1st of August (hydrological year)
- 55.5 BCM/year released downstream from HAD and can be increased to ensure that HAD level not exceeds 178m at the end of July

Operational Adaptations of HAD (Proposed New Rules)

- Evaluating the flood condition during the first week of August.
- Simulation of the High Dam operations is carried out; Operating procedures are then applied according to the flood conditions as follows:

- Toshka Spillway will be opened at full capacity if HAD would reac 181.5 during the any hydrological year
- The downstream discharge of HAD shall be increased but not exceeds annual release of 71 BCM
- Ensuring that HAD level shall then be reduced starting from April at a rate of 0.5 m per month through increased downstream outflows until it reaches 178 m by the end of July each year





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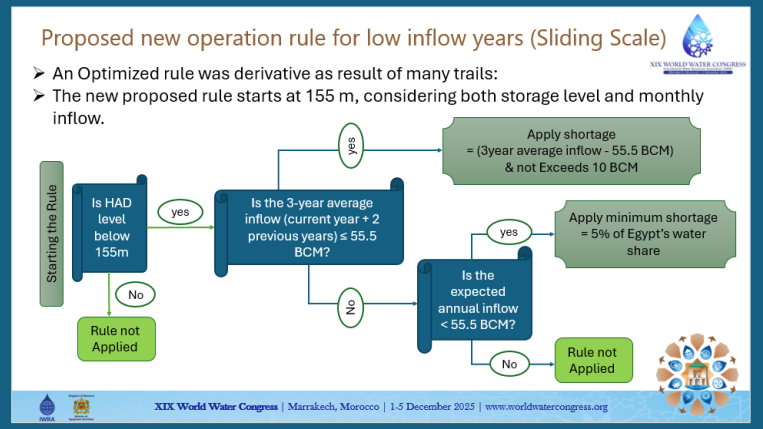
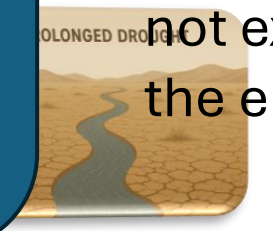
Operational Adaptations of HAD (Proposed New Rules)

- Evaluating the flood condition during the first week of August.
- Simulation of the High Dam operations is carried out; Operating procedures are then applied according to the flood conditions as follows:

- IF HAD level would reach <155 m
- Releases should be Lowered according to the New sliding scale Rule





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