



**CLIMATE-RESILIENT DAMS AND  
HYDROPOWER INFRASTRUCTURE  
INTEGRATING  
ENVIRONMENTAL SUSTAINABILITY  
IN PLANNING AND DEVELOPMENT**

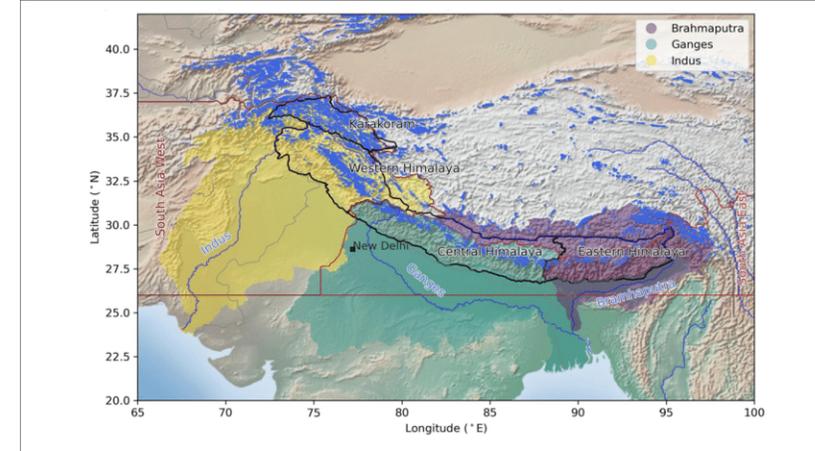
**Climate Change and Water Resources  
Management**

*Pierre-Yves Pitteloud – Senior Regional Advisor DRR,  
CCA & Rapid Response, Embassy of Switzerland*



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

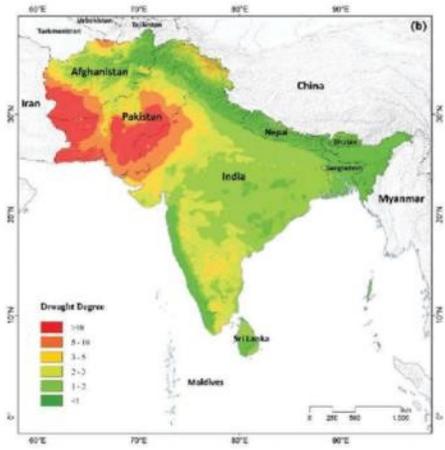
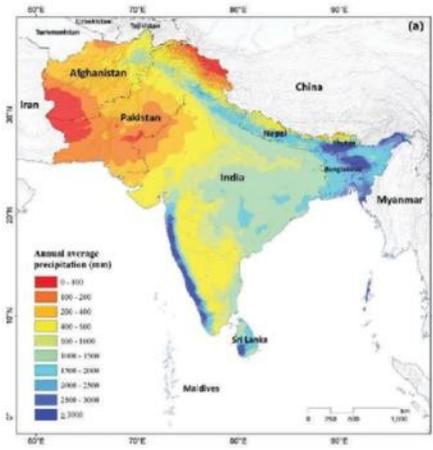
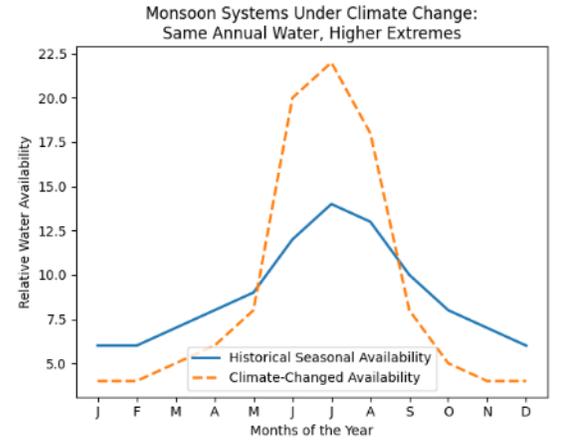
# Why Water Is a Climate Issue



Human-induced climate change is already changing hydrological systems, **affecting water availability, variability, and risk.**

# Water Resources Management (WRM) under Climate Stress: Impact on Rainfall

- Climate change affects **when** water is available, not only **how much**.
- Shorter, more intense monsoon periods
- Longer and more uncertain dry seasons
- Floods and droughts increase **simultaneously**
- Variability, not averages, becomes the main challenge



# WRM Under Climate Stress: Competing Demands in a Changing Climate

## Multiple competing users for the same seasonal flows

- Energy
- Irrigation
- Drinking water
- Ecosystems

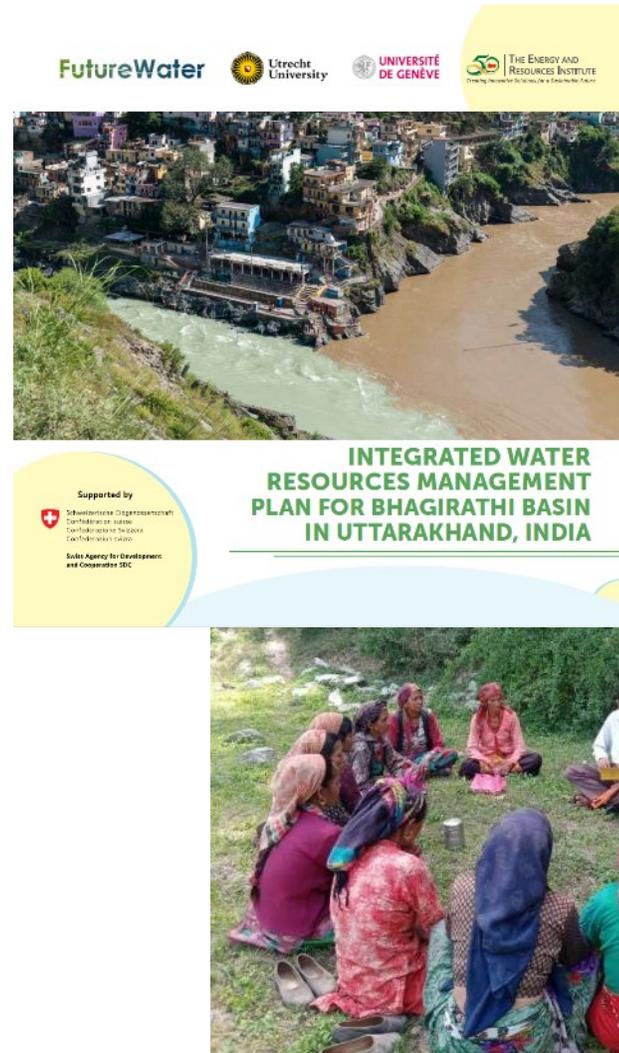
## Trade-offs sharpen during floods and droughts

- Climate variability compresses decision windows
- Peak demands coincide with peak risk periods



# WRM Under Climate Stress: Water Allocation Under Uncertainty

- Allocation decisions must be taken under high uncertainty
- Historical norms and “average years” are **no longer reliable**
- Flood and drought risks must be managed **simultaneously**
- Decisions increasingly shift from **annual planning to real-time management**
- Trade-offs during extremes have **system-wide consequences**



FutureWater | Utrecht University | UNIVERSITÉ DE GENÈVE | THE ENERGY AND RESOURCES INSTITUTE

INTEGRATED WATER RESOURCES MANAGEMENT PLAN FOR BHAGIRATHI BASIN IN UTTARAKHAND, INDIA

Supported by  
Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Agency for Development and Cooperation SDC

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

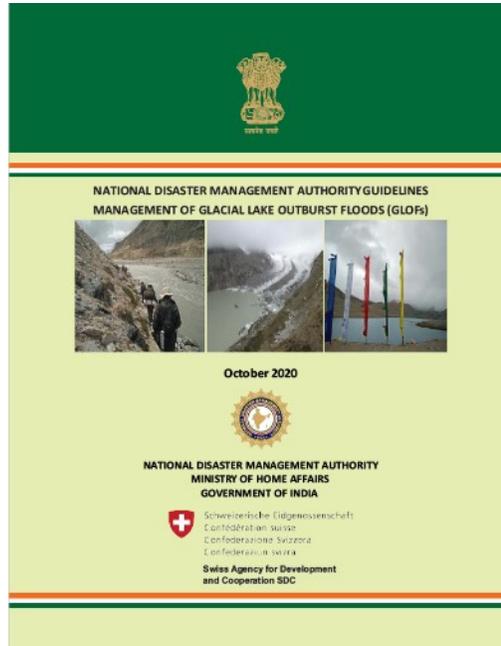
# WRM Under Climate Stress: From Allocation to Risk-Informed Management

Hazard and exposure mapping for outburst floods from Shako Cho and South Lhonak glacial lakes in Sikkim, India



Technical study in the frame of the project «Strengthening Climate Change Adaptation in the Himalayas» (SCA-Himalayas)

November 2022, Final Draft

NATIONAL DISASTER MANAGEMENT AUTHORITY GUIDELINES  
MANAGEMENT OF GLACIAL LAKE OUTBURST FLOODS (GLOFs)

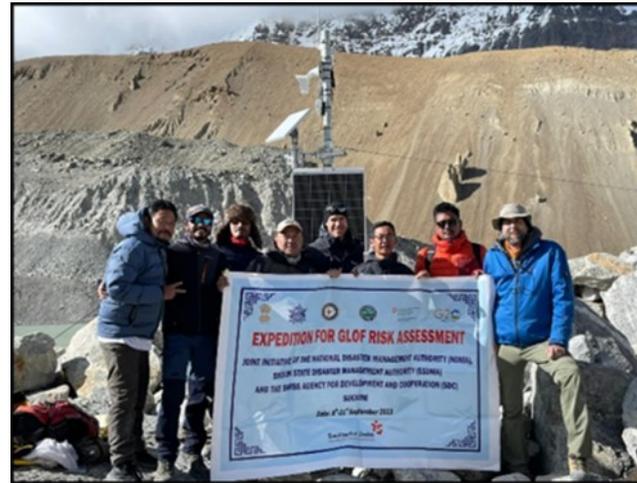
October 2020

NATIONAL DISASTER MANAGEMENT AUTHORITY  
MINISTRY OF HOME AFFAIRS  
GOVERNMENT OF INDIA

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

- Climate uncertainty cannot be eliminated — it must be **managed**
- Focus shifts from **optimisation** to **risk reduction**
- Accepting residual risk becomes part of governance
- Preparedness matters as much as infrastructure

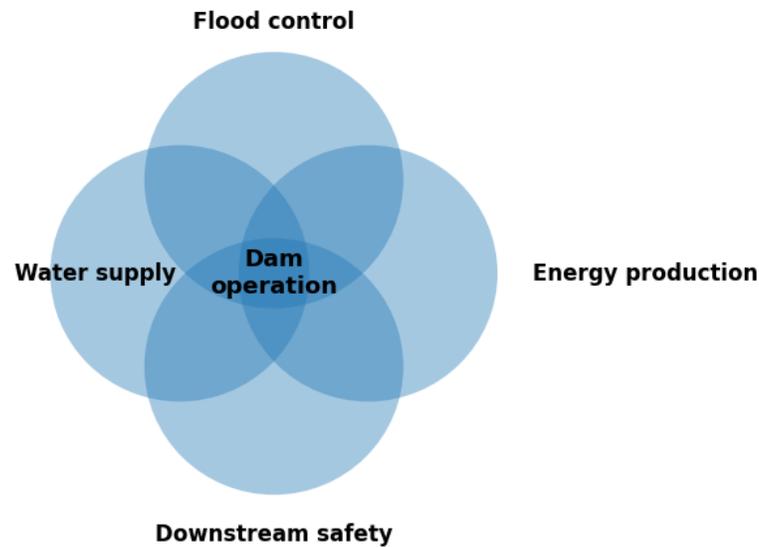


 Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

# WRM Under Climate Stress: What Risk-Informed Management Means for Dams



Dams operate at the intersection of:



Climate change increases operational stress  
Safety depends on decisions, not only structures.

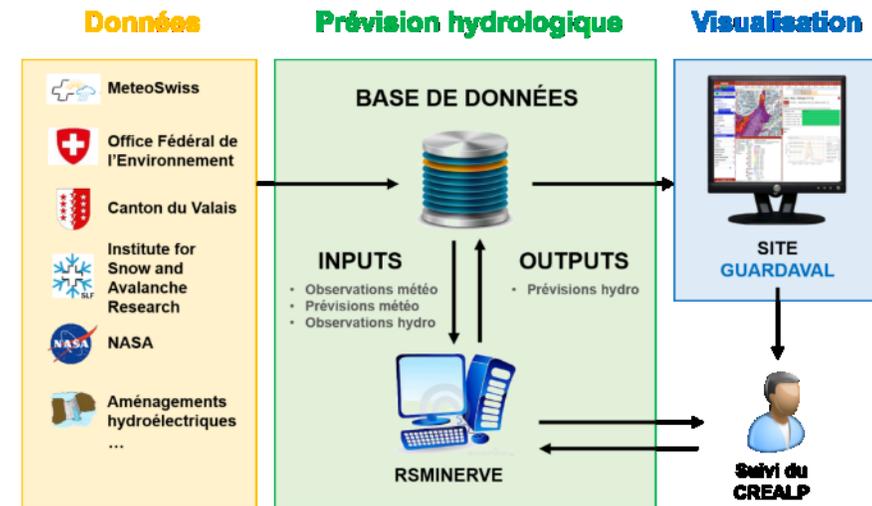
# WRM Under Climate Stress: What Risk-Informed Tools Change in Practice

- Decisions are taken with **ranges, not single forecasts**
- Reservoir levels are managed **ahead of extremes, not in reaction**
- Flood and drought risks are **assessed together, not separately**
- Operators act with shared **situational awareness, not fragmented data**
- Emergency response is **triggered before thresholds are exceeded**



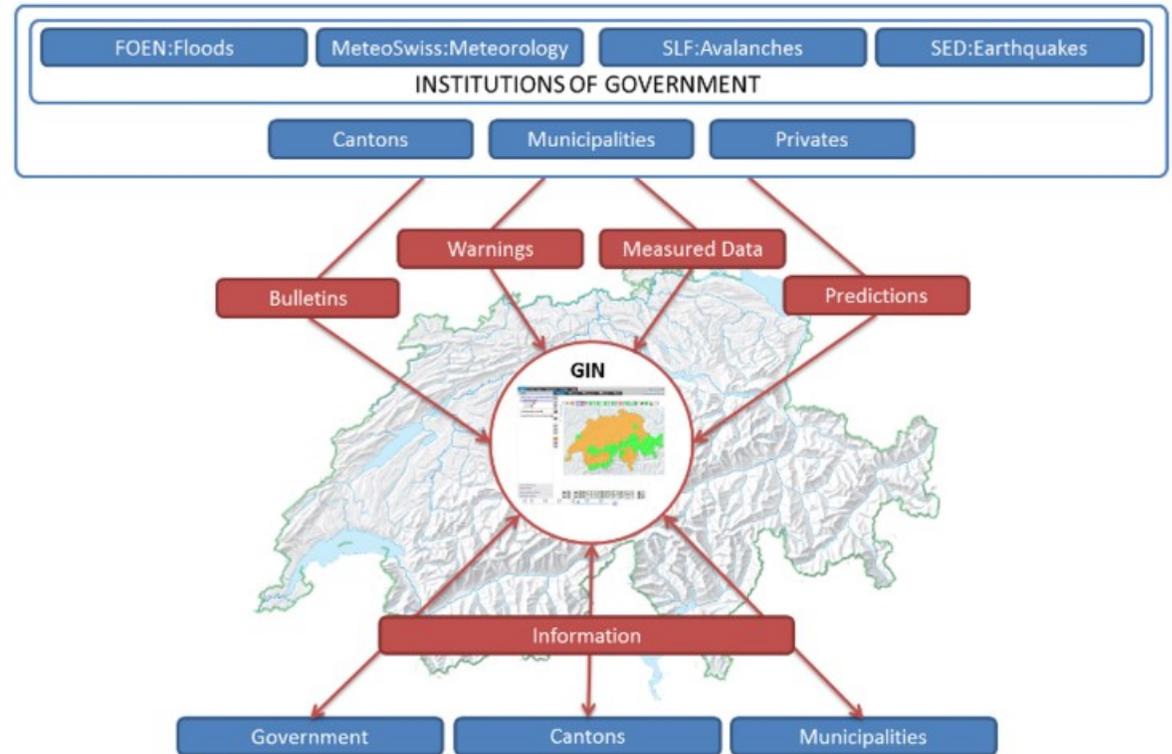
# WRM Under Climate Stress: How Switzerland enables risk-informed decisions (in practice)

- **Decisions are taken with ranges, not single forecasts**  
→ Switzerland uses **ensemble and probabilistic forecasts** produced by **Federal Office for the Environment (FOEN/BAFU)** and **MeteoSwiss**, explicitly communicating uncertainty rather than one “best” value.
- **Reservoir levels are managed ahead of extremes, not in reaction**  
→ In basins like the Rhône, tools such as **MINERVE system** link weather forecasts, hydrology, and reservoir operations to support **anticipatory releases and storage decisions**.
- **Flood and drought risks are assessed together, not separately**  
→ Swiss basin management combines **snowpack, inflows, storage levels, and seasonal outlooks**, avoiding siloed flood-only or drought-only planning.



# WRM Under Climate Stress: How Switzerland enables risk-informed decisions (in practice)

- **Operators act with shared situational awareness, not fragmented data**  
→ The **GIN (Joint Natural Hazard Information Platform)** provides a **common, real-time operational picture** shared across federal agencies and cantons.
- **Emergency response is triggered before thresholds are exceeded**  
→ Forecast-based warnings are translated into **predefined response actions** through national warning chains (e.g. **Alertswiss**), linking forecasts directly to civil protection.



# WRM Under Climate Stress: Himalayan Context: Why This Matters More Here

- **Steep and fragile terrain:** Rapid runoff and high hazard intensity
- **Cryosphere–monsoon interactions:** Complex and highly sensitive hydrology
- **High downstream dependence:** millions exposed across river basins
- **Cascading risks:** floods, landslides, GLOFs, and infrastructure failures



# WRM under Climate Stress: Swiss Experience: What Is Transferable

- **Risk-based decisions** designed for uncertainty
- **Strong, formal links** between science and dam operations
- Shared, **real-time situational awareness**
- Pre-defined **roles** and trigger-based **protocols**
- **Preparedness** embedded as a permanent function





# WRM Under Climate Stress: Take-Home Messages



- Climate change is reshaping **when** and **how** water arrives — challenging how dams are designed, built, and operated.
- Water allocation and dam operation are no longer engineering or optimization questions alone; they are fundamentally **risk management decisions**.
- Dam safety in a changing climate depends on **anticipation, system-wide coordination**, and continuous **preparedness**.
- Resilient dam systems are built through **partnerships** — linking science, operators, authorities, and communities at risk.



**Thank You**