# Design Considerations for Addressing Climate Change Vulnerabilities of Dams and Reservoirs

Tackling Global Water Challenges
Water Week 2009

THE WORLD BANK

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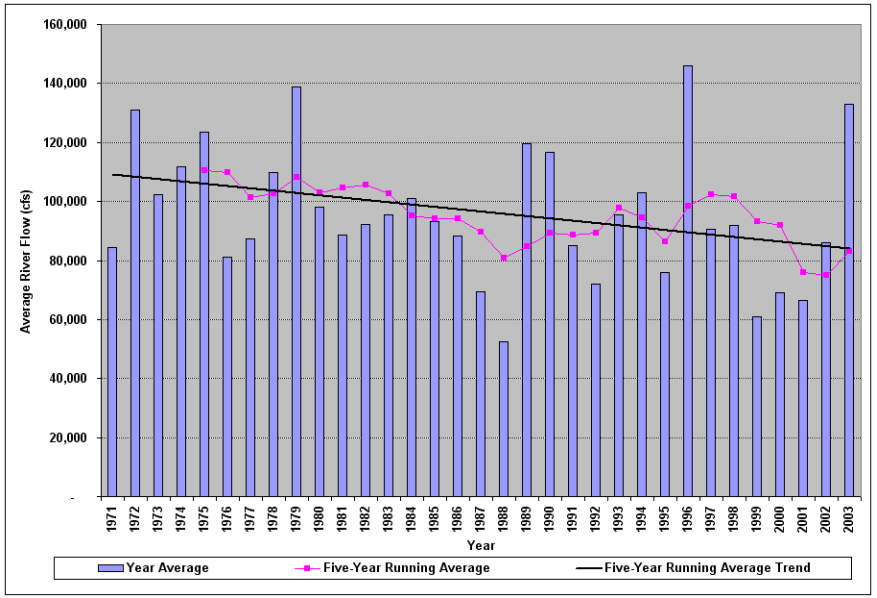
BUILDING A BETTER WORLD

# Agenda

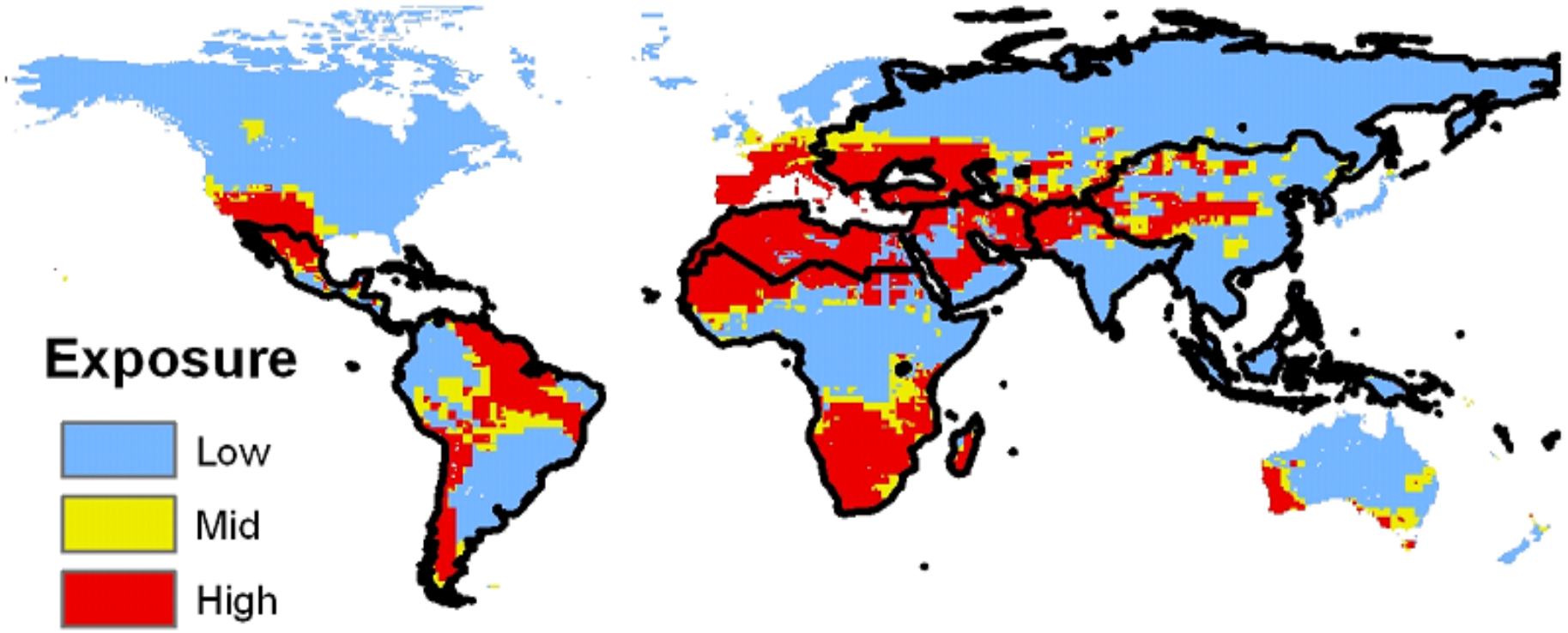
- Introduction
- Dam and Reservoir Vulnerabilities
- Decision Process
- Risk Review
- Case Study Candidates
- Lesotho Highlands Project
- Preliminary Observations
- Next Steps



# Likely Scenarios if CC Continues


Graphic adapted from the National Geographic Society web-site accessed Feb 12, 2009.

# Projected Exposure to Change in Runoff




Graphic adapted from Strzepek and Yates, 1997

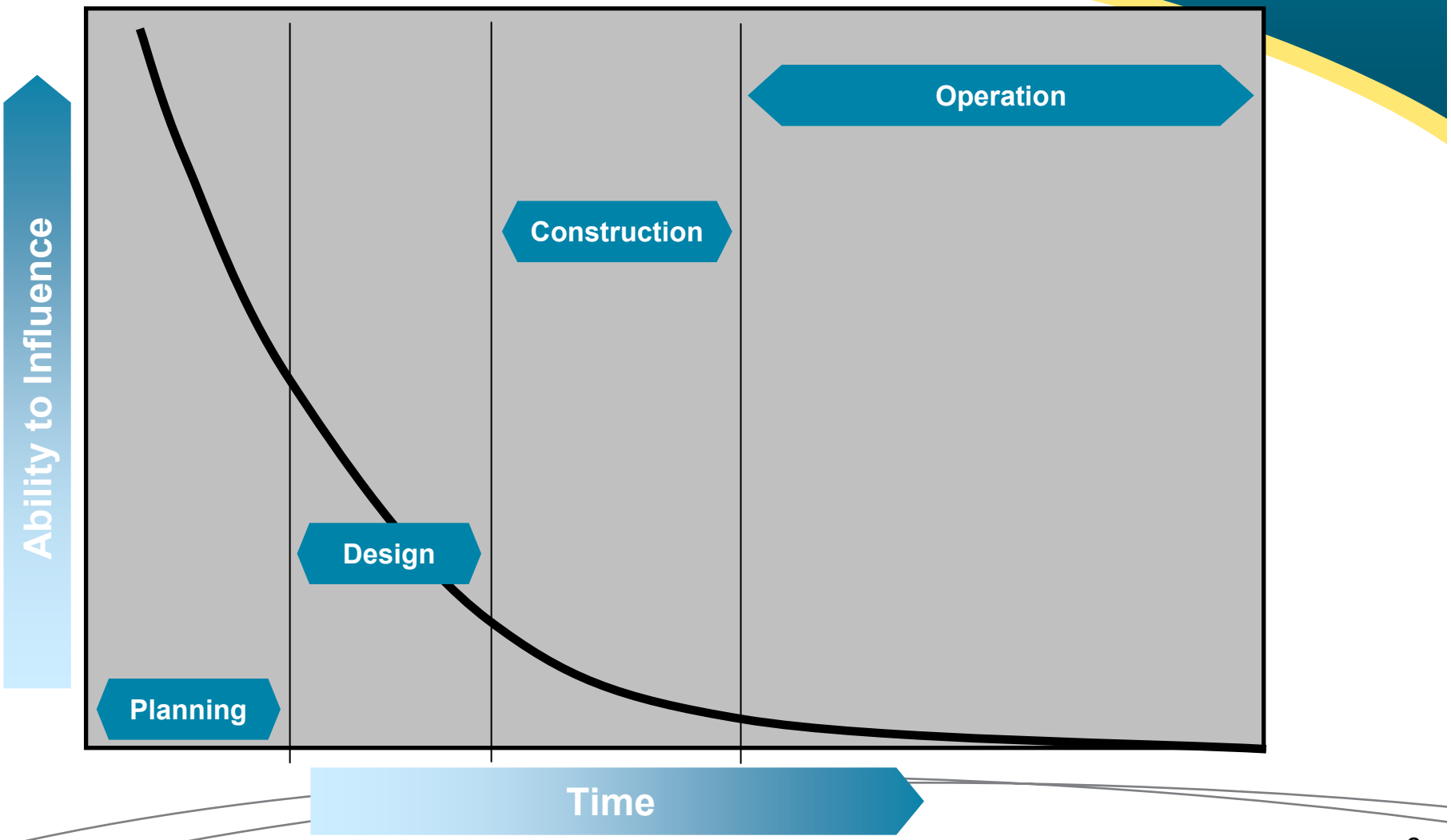
# Dam and Reservoir Vulnerabilities

**DAM AND RESERVOIR COMPONENTS**

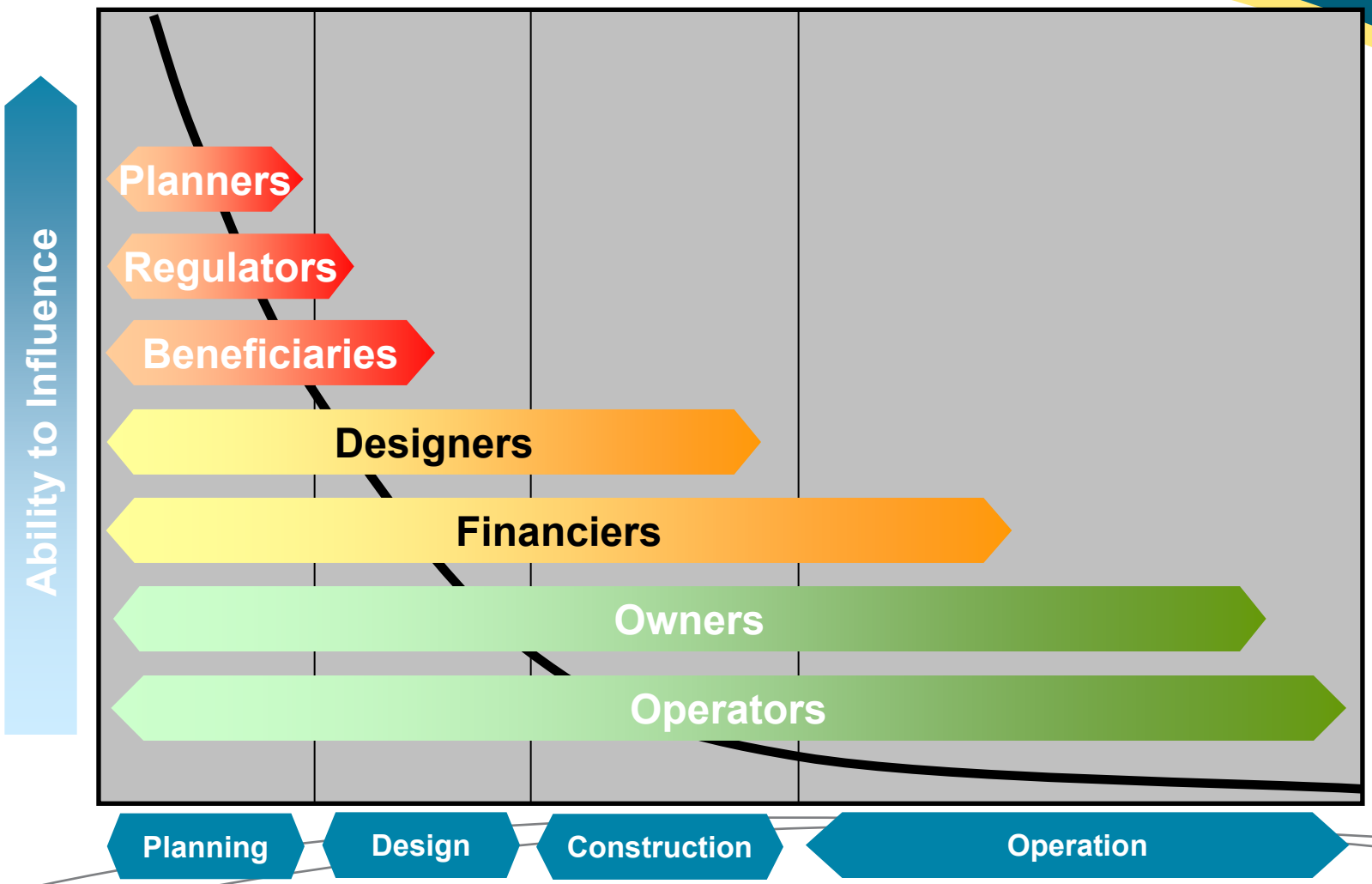
**HYDROLOGICAL DRIVERS**

| | Basin Yield | Reservoir Size | Hydro Power Output | Irrigation or Water Supply | Water Quality | Spillway Design Discharge | Outlet Works | River Diversion |
|---|---|---|---|---|---|---|---|---|
| Average Annual Precipitation (AP) | ● | ● | ● | ● | ● | | ● | |
| Precipitation Extremes (EP) | | ● | | | | ● | ● | ● |
| Glaciers and Snow (GS) | ● | ● | ● | ● | ● | ● | ● | ● |
| Sea Level (SL) | | | ● | | | | | |
| Evapo-transpitation (ET) | ● | ● | ● | ● | ● | | ● | |
| Soil Moisture (SM) | ● | ● | ● | ● | ● | | ● | |
| Runoff and River Discharge (RR) | ● | ● | ● | ● | ● | | ● | |

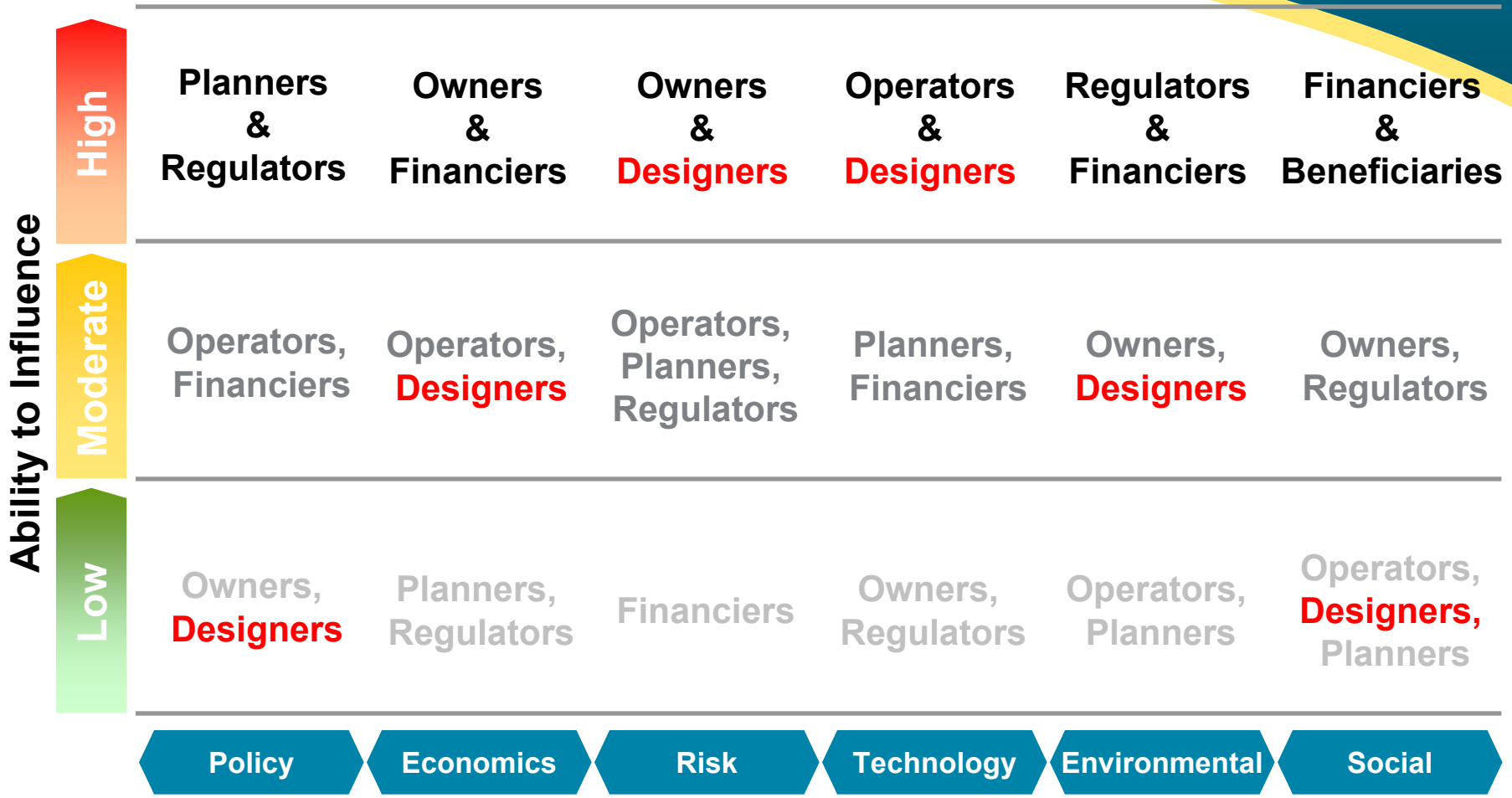
# Typical Dam & Reservoir Project Life Cycle



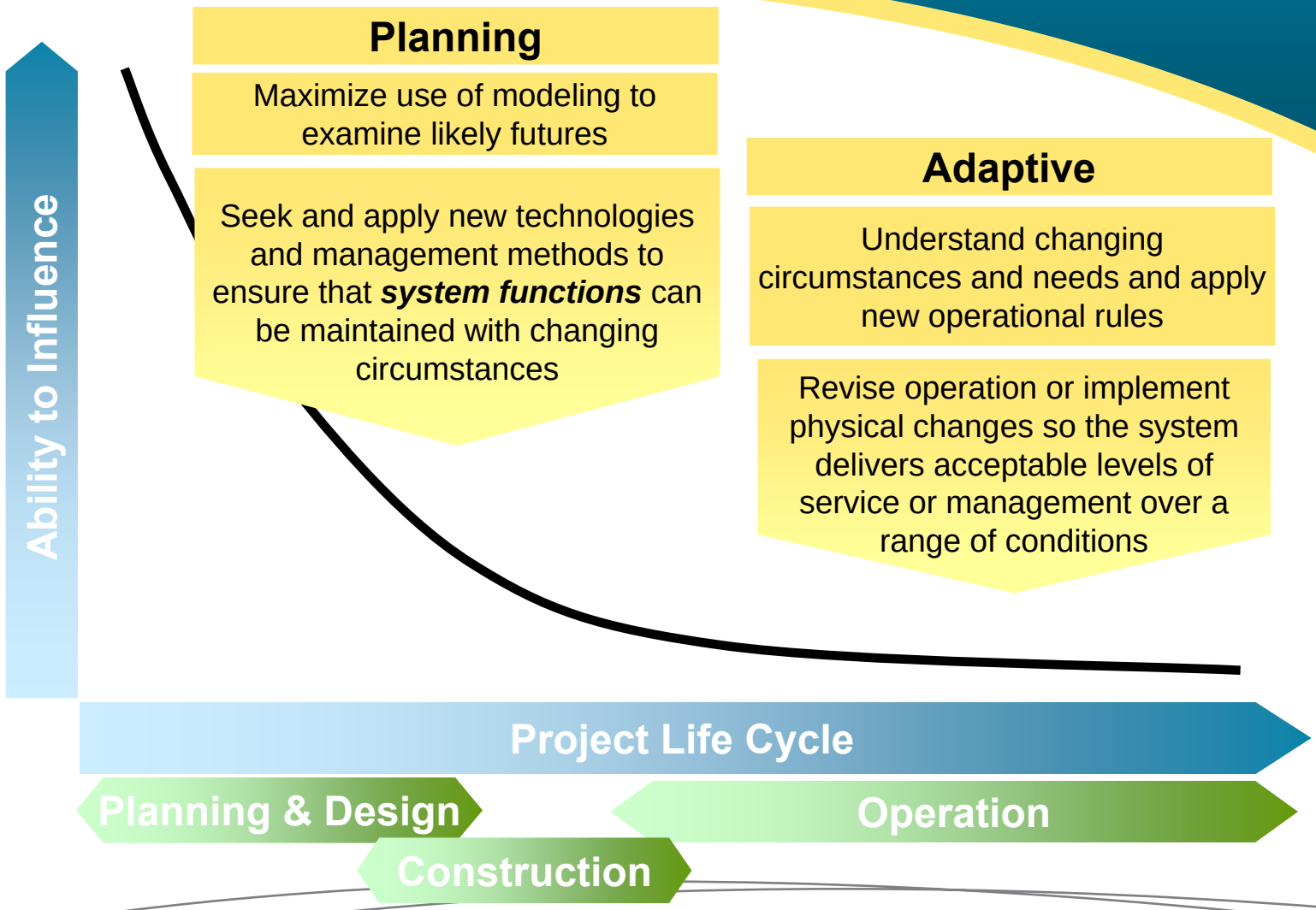
# Stakeholder Influence



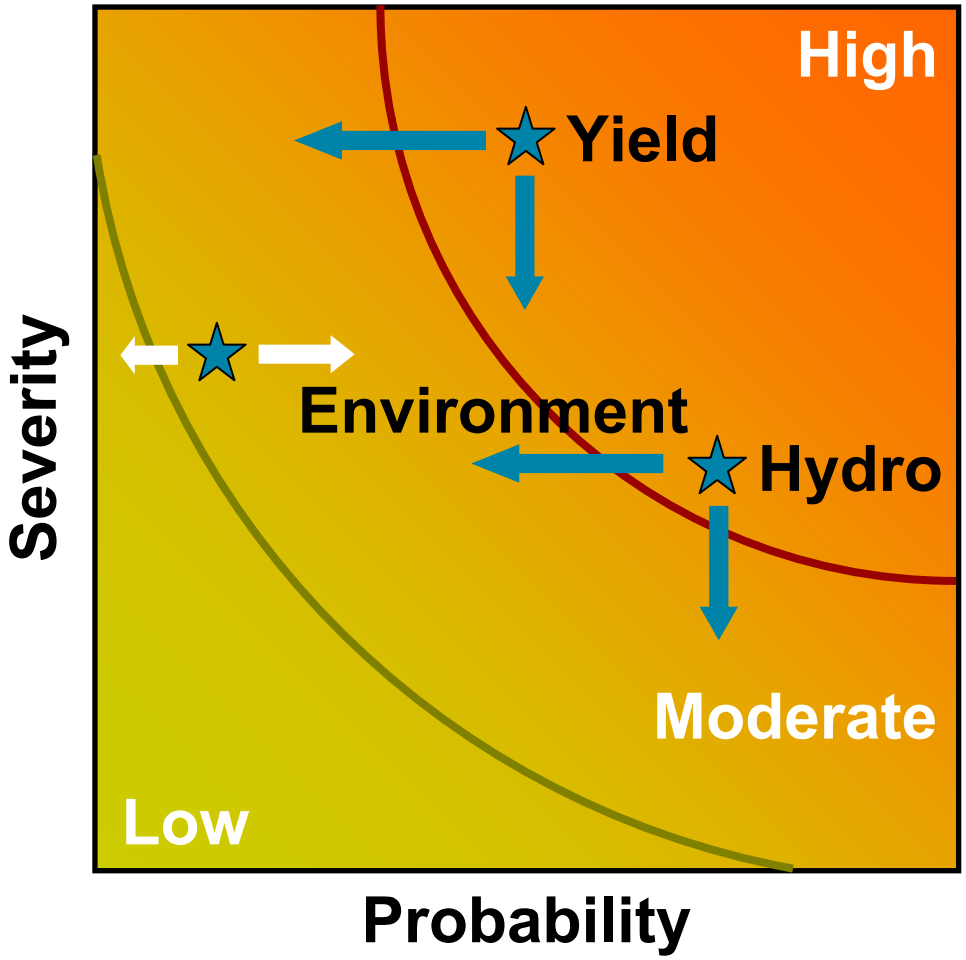
# Decision Process



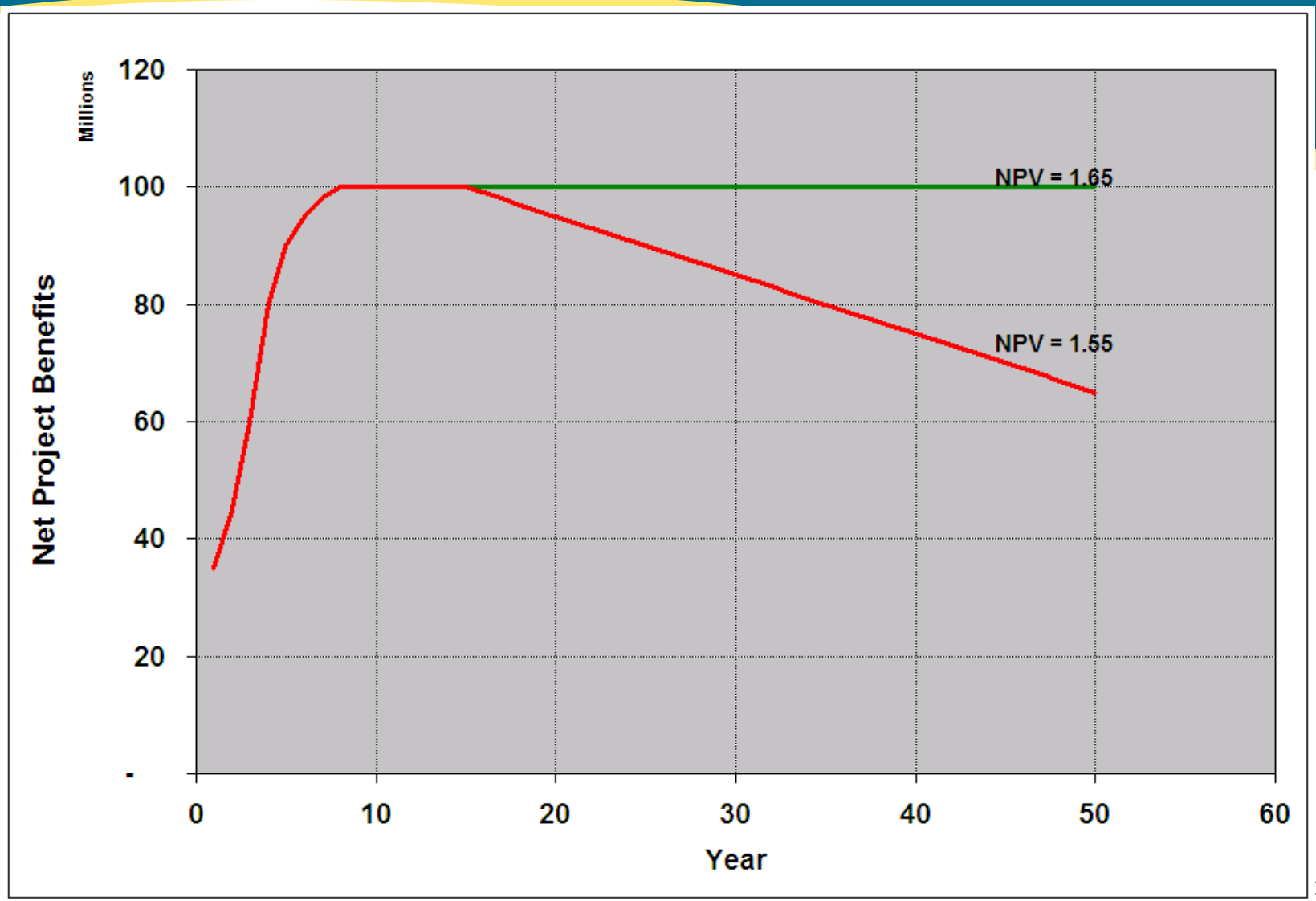
# Risk Management Strategy



# Risk Profile



# Economic Impacts of CC on a Dam Project



# Case Study Candidate Projects

| Case Study Projects | Dam and Reservoir Project Components | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Basin Yield | Reservoir Size | Hydro Power Output | Irrigation or Water Supply | Water Quality | Spillway Design Discharge | Outlet Works | River Diversion |
| Lesotho Highlands | AP, ET, SM, RR | AP, ET, SM, RR | AP, ET, SM, RR | AP, ET, SM, RR | AP, ET, SM, RR | EP | EP | EP |
| Siberian River Reversal | Possible case study | | | | | | | |
| Salt River Project | Possible case study | | | | | | | |
| Hidrovia Navigation | Possible case study | | | | | | | |
| Kafue Gorge Lower Hydro | Possible case study | | | | | | | |
| Nam Theun 2 Hydro | Possible case study | | | | | | | |
| Yacyretá | Possible case study | | | | | | | |
| Kárahnjúkar Hydro | Possible case study | | | | | | | |

AP - Average Annual Precipitation

EP - Precipitation Extremes

GS - Glaciers and Snow

SL - Sea Level

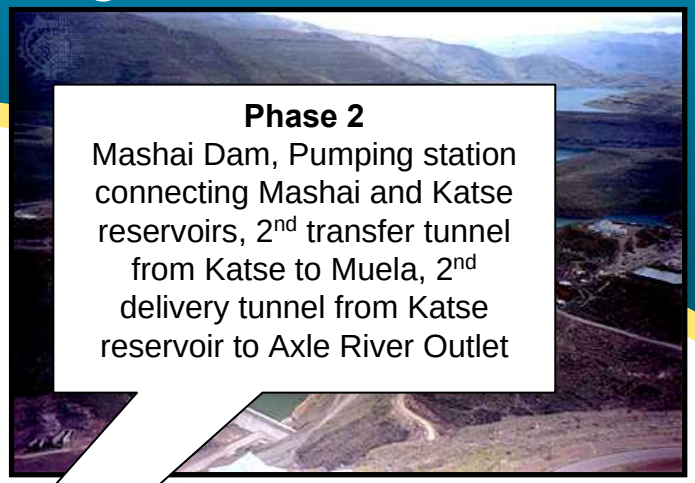
ET - Evapo-transpitation

SM - Soil Moisture

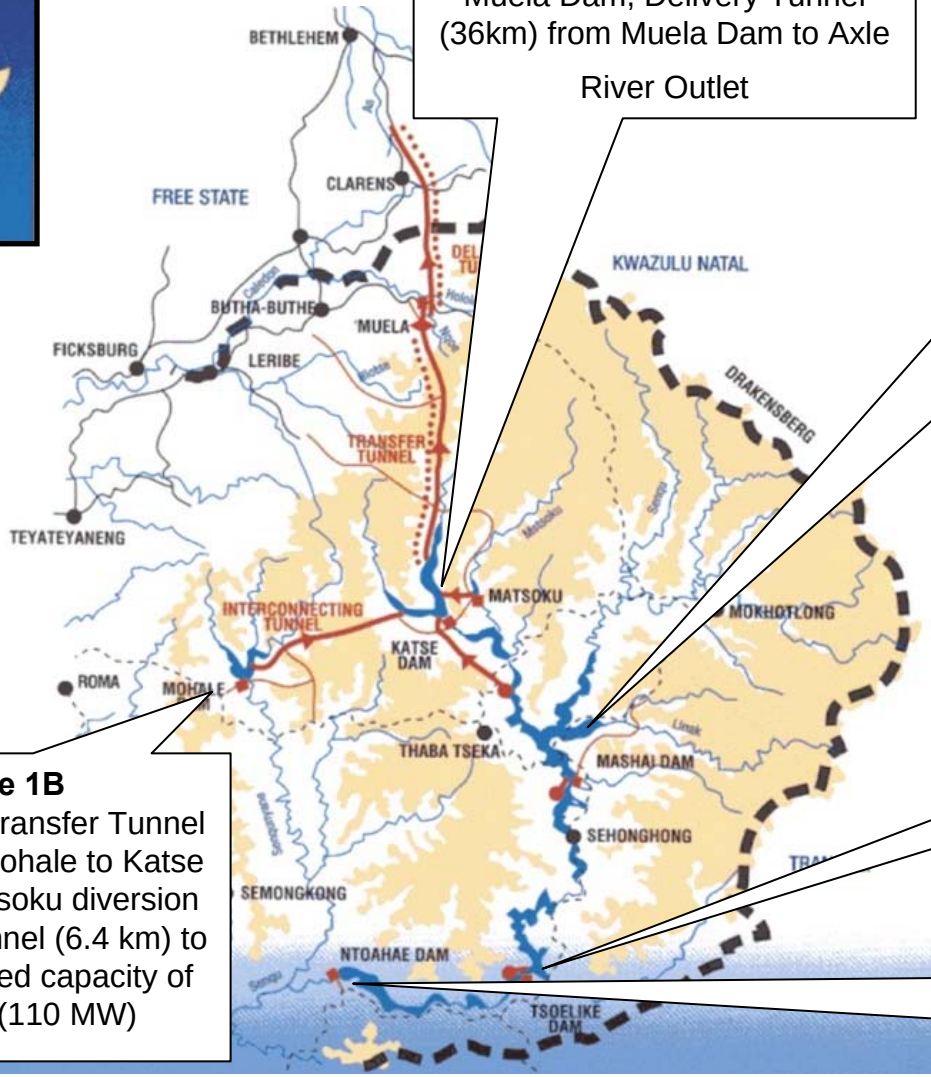
RR - Runoff and River Discharge

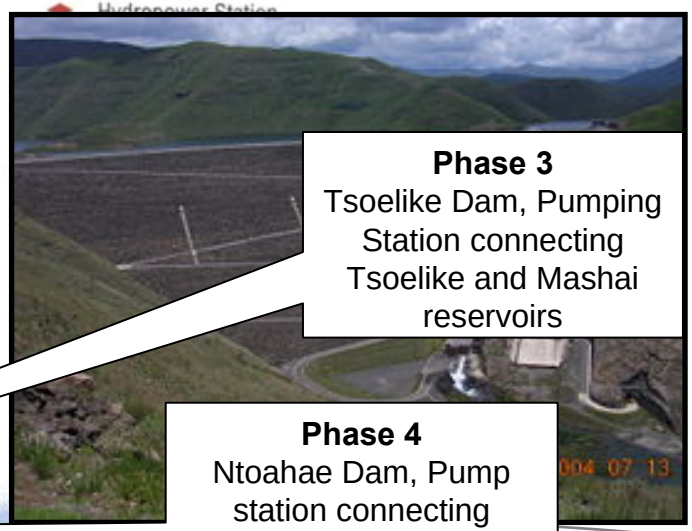
# Lesotho Highlands Water Project

**Phase 1A**
Katse Dam, Muela Powerstation (72 MW), Transfer Tunnel (45km) from Katse to Muela PS, Muela Dam, Delivery Tunnel (36km) from Muela Dam to Axle River Outlet



**Phase 2**
Mashai Dam, Pumping station connecting Mashai and Katse reservoirs, 2nd transfer tunnel from Katse to Muela, 2nd delivery tunnel from Katse reservoir to Axle River Outlet



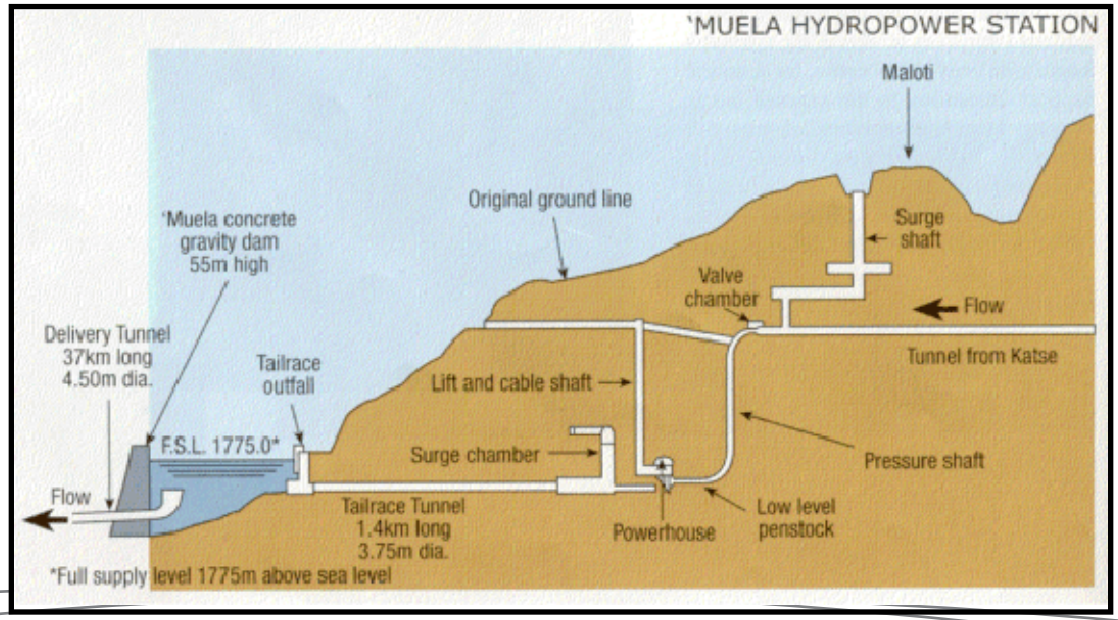
**Phase 3**
Tsoelike Dam, Pumping Station connecting Tsoelike and Mashai reservoirs

**Phase 4**
Ntoahae Dam, Pump station connecting Ntoahae and Tsoelike reservoirs

**Phase 1B**
Mohale Dam, Transfer Tunnel (30 km) from Mohale to Katse Reservoir, Matsoku diversion and transfer tunnel (6.4 km) to Katse, increased capacity of Muela PS (110 MW)

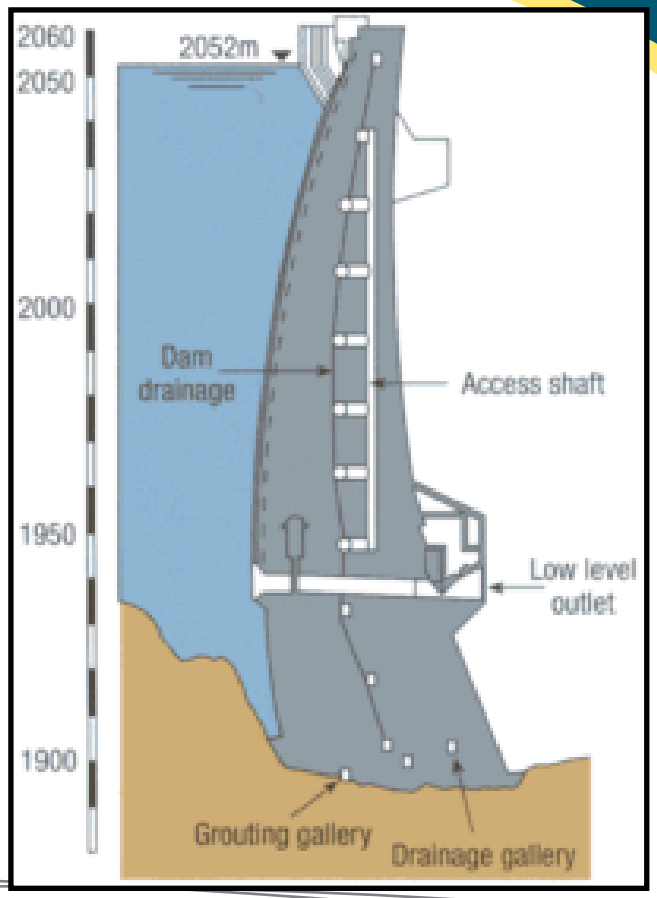
# Areas of Vulnerability Related to Purpose

- Yield at Katse Dam to support water deliveries
- Hydropower production from water deliveries
  - A secondary function
- Sizes of intermediate storage reservoirs
  - Vaal and Muela reservoirs
- Demands
  - Larger or lower than expected growth



# Candidate mitigating strategies to prepare for a declining yield trend – project planning phase

- Plan for future off-stream storage
  - A staged approach
- Plan for dam raising
  - Dam design and reservoir planning
- Consider options for conjunctive ground surface water storage and operation
- River basin management to discourage practices reducing runoff



# Areas of Vulnerability Related to Safety or Other Factors

- Spillway discharge capability
- Reservoir freeboard
- Outlet works design
- Construction diversion facilities
- Environmental flows

# Candidate mitigating strategies to prepare for extreme events - project planning phase

- Plan for supplemental spillway capacity - overflow section or emergency spillway (future action)
- Increase flood storage capability using parapet wall (future action)
- Plan for future parallel outlet tunnel (future action)
- Diversion arrangement and dam type selection (near-term action)
- Use of more conservative design parameters (near-term action)

# Preliminary Observations

- Issues: (1) Project Safety and (2) Performance
- Planning and design standards and procedures
- Flexibility; not foreclosing future options
- Economics – is it worthwhile to invest?
- Avoid over-reliance on one source or technology

# Next Steps

- Continued project review / case study analysis
- Requirements for guide specifications in Bank lending TORs

# Thank you for your attention