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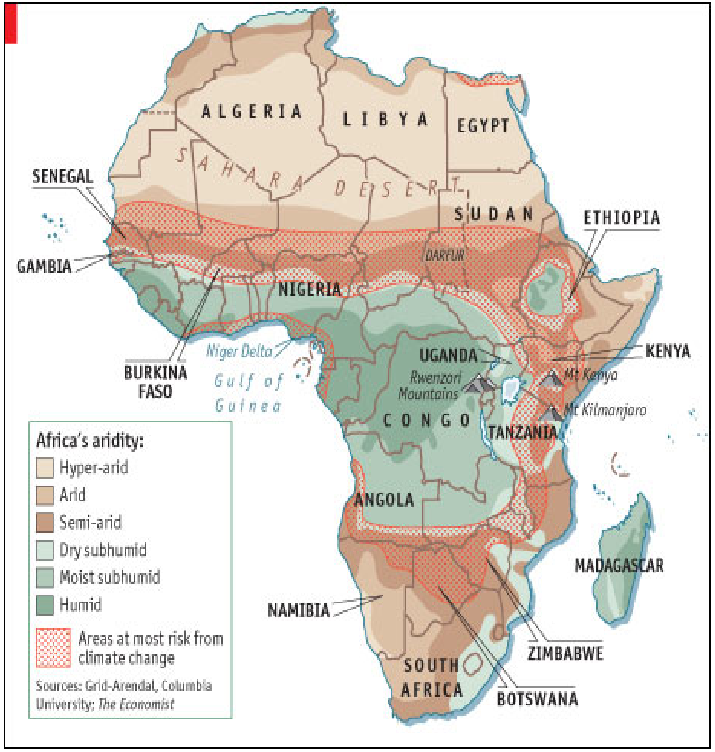
Application of Climate Risk Assessment Protocol: Case Study the Borenga Dam

The Problem

- The climate is changing
- Climate change threatens the ability of engineers to safely and effectively design resilient infrastructure
- Design, operation and maintenance practices must adapt considering the life-cycle of the infrastructure
- Climate change engineering vulnerability assessment can help with adaptation process



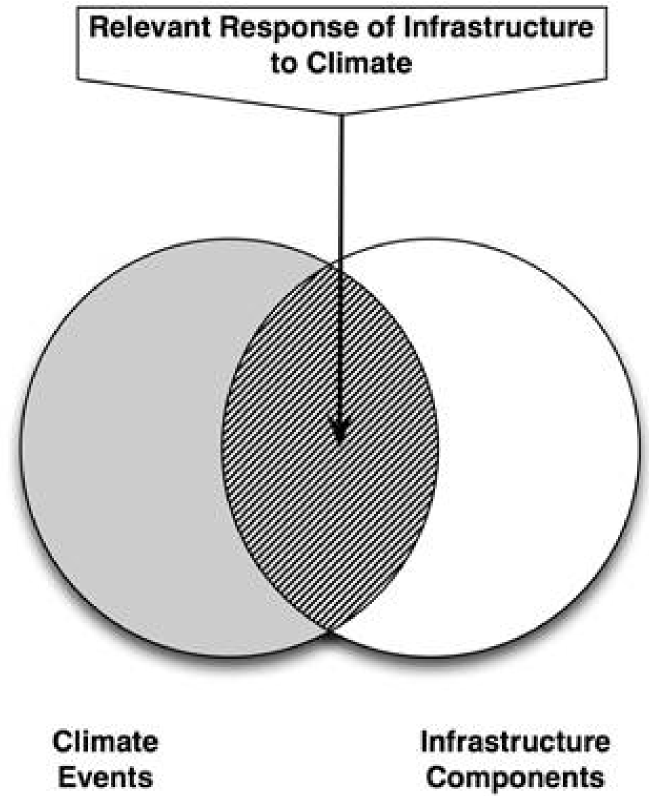
https://www.economist.com/middle-east-and-africa/2007/05/10/drying-up-and-flooding-out

The PIEVC Protocol… a risk screening tool

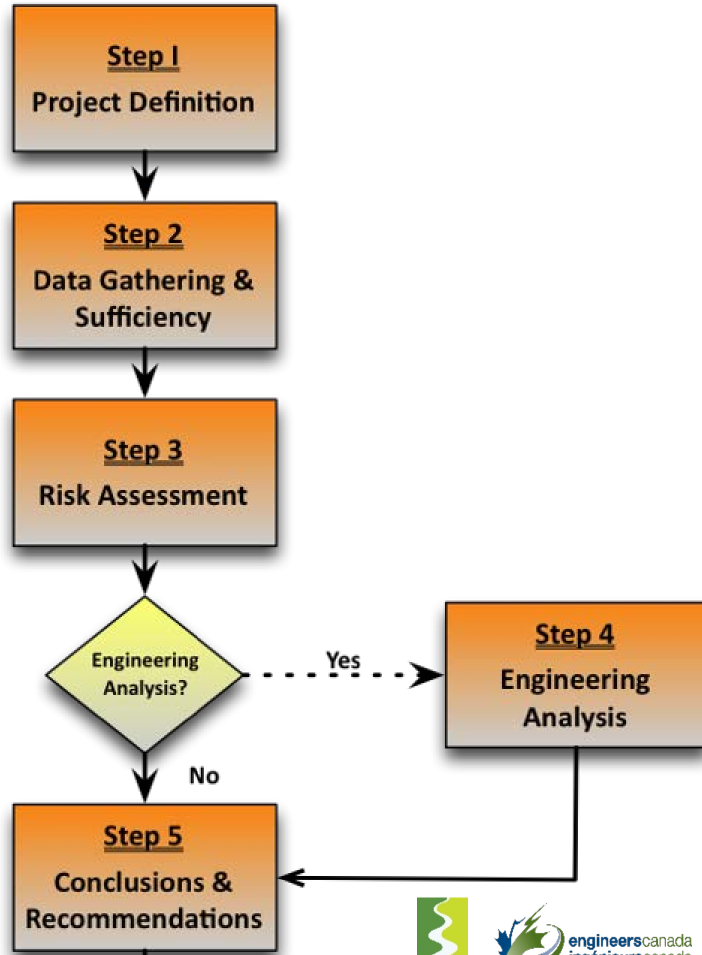
Building infrastructure today without considering future climate impacts is incorporating vulnerabilities that will later cause service disruptions and failures thus increasing costs to government, the private sector and users.

The PIEVC Protocol… a risk screening tool

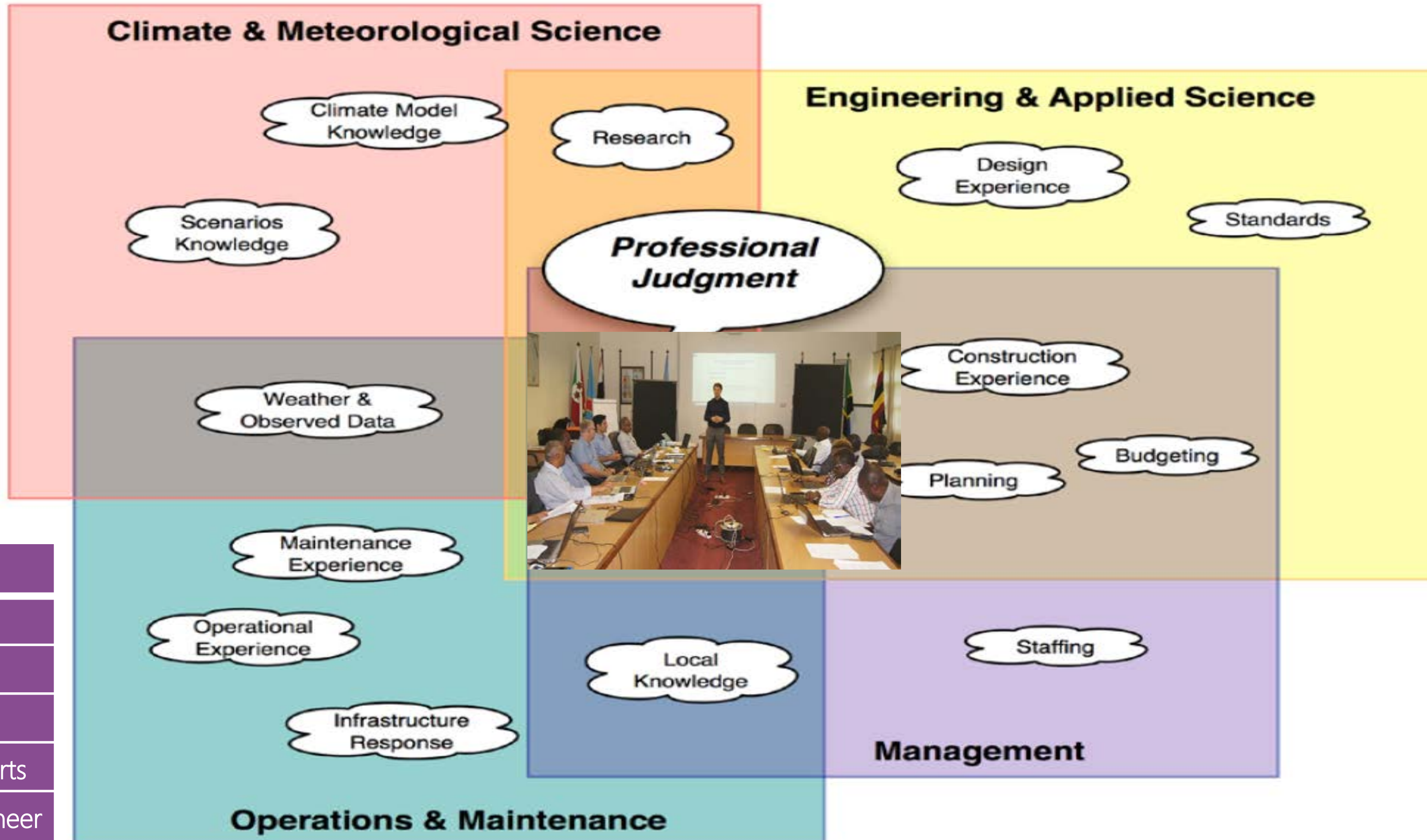
- A tool derived from standard risk management methodologies
- PIEVC established in 2005, the PIEVC Protocol was first applied to an infrastructure project in 2007
- Applied to 50+ vulnerability assessments of infrastructure case studies in Canada, Costa Rica, Brazil, Vietnam, Honduras … and now for the NBI countries.
- Intended for use by qualified professionals
- Requires contributions from those with pertinent local knowledge and experience



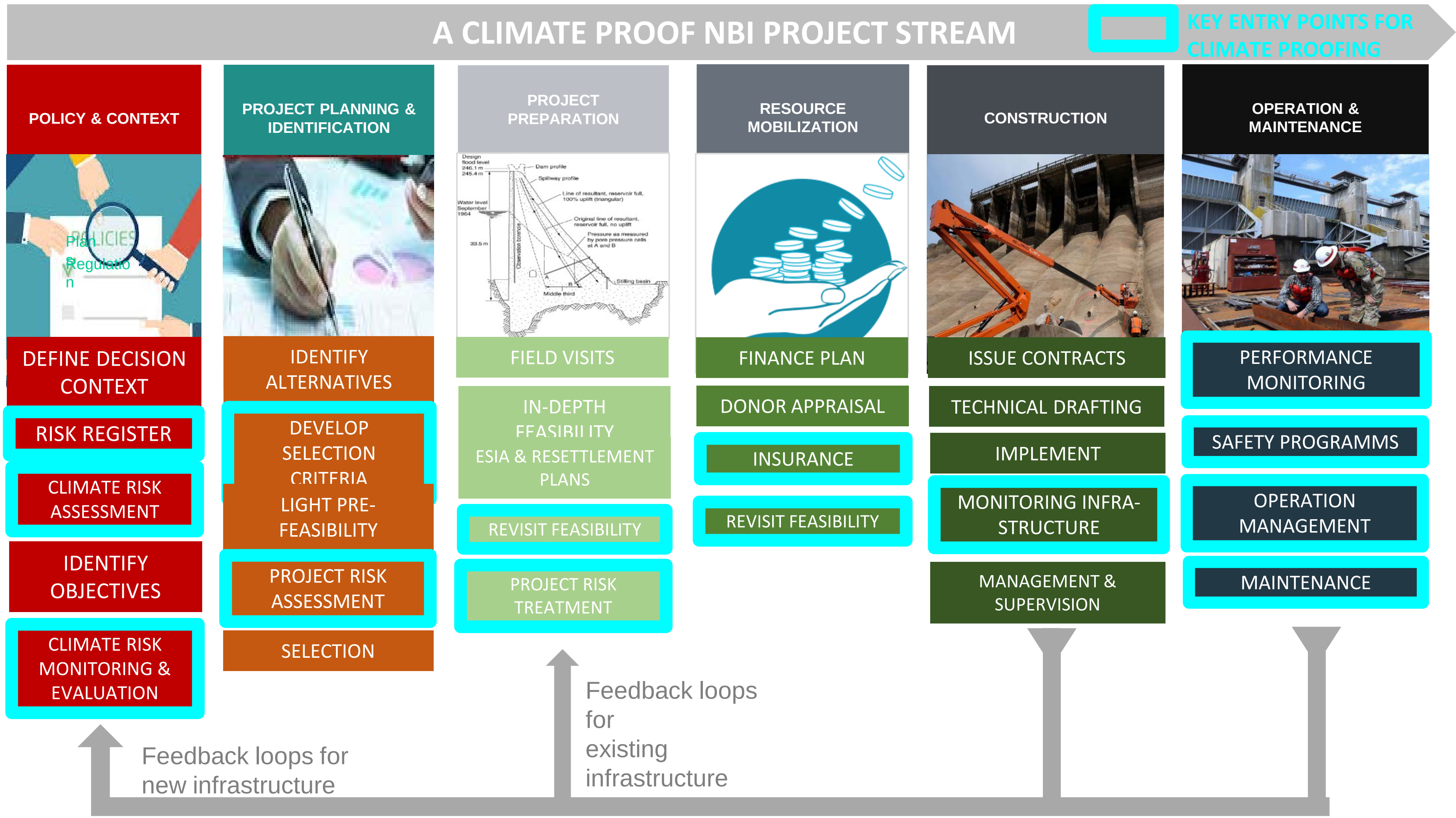
The PIEVC Protocol



The PIEVC Assessment Team & Assessment Approach



Institution
NILESEC
NELSAP
ENTRO
National experts
GIZ and Engineer Canada, WOOD



A CLIMATE PROOF NBI PROJECT STREAM
KEY ENTRY POINTS FOR CLIMATE PROOFING
POLICY & CONTEXT
DEFINE DECISION CONTEXT
RISK REGISTER
CLIMATE RISK ASSESSMENT
IDENTIFY OBJECTIVES
CLIMATE RISK MONITORING & EVALUATION
PROJECT PLANNING & IDENTIFICATION
IDENTIFY ALTERNATIVES
DEVELOP SELECTION CRITERIA
LIGHT PRE-FEASIBILITY
PROJECT RISK ASSESSMENT
SELECTION
PROJECT PREPARATION
FIELD VISITS
IN-DEPTH FEASIBILITY
ESIA & RESETTLEMENT PLANS
REVISIT FEASIBILITY
PROJECT RISK TREATMENT
RESOURCE MOBILIZATION
FINANCE PLAN
DONOR APPRAISAL
INSURANCE
REVISIT FEASIBILITY
CONSTRUCTION
ISSUE CONTRACTS
TECHNICAL DRAFTING
IMPLEMENT
MONITORING INFRA-STRUCTURE
MANAGEMENT & SUPERVISION
OPERATION & MAINTENANCE
PERFORMANCE MONITORING
SAFETY PROGRAMMS
OPERATION MANAGEMENT
MAINTENANCE
Feedback loops for new infrastructure
Feedback loops for existing infrastructure

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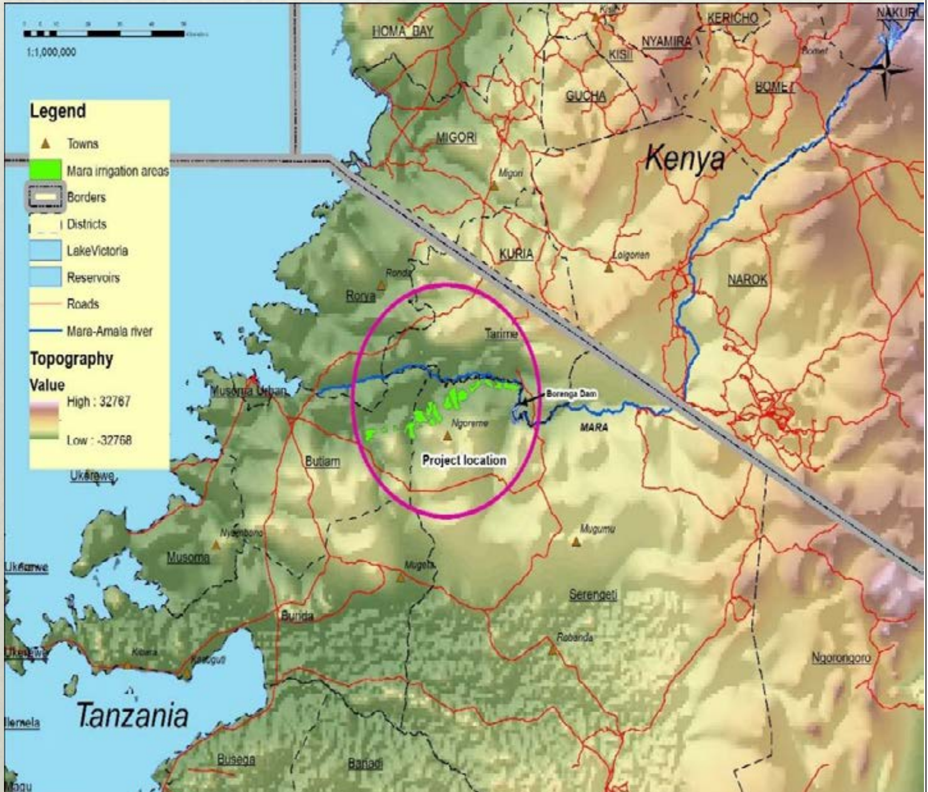
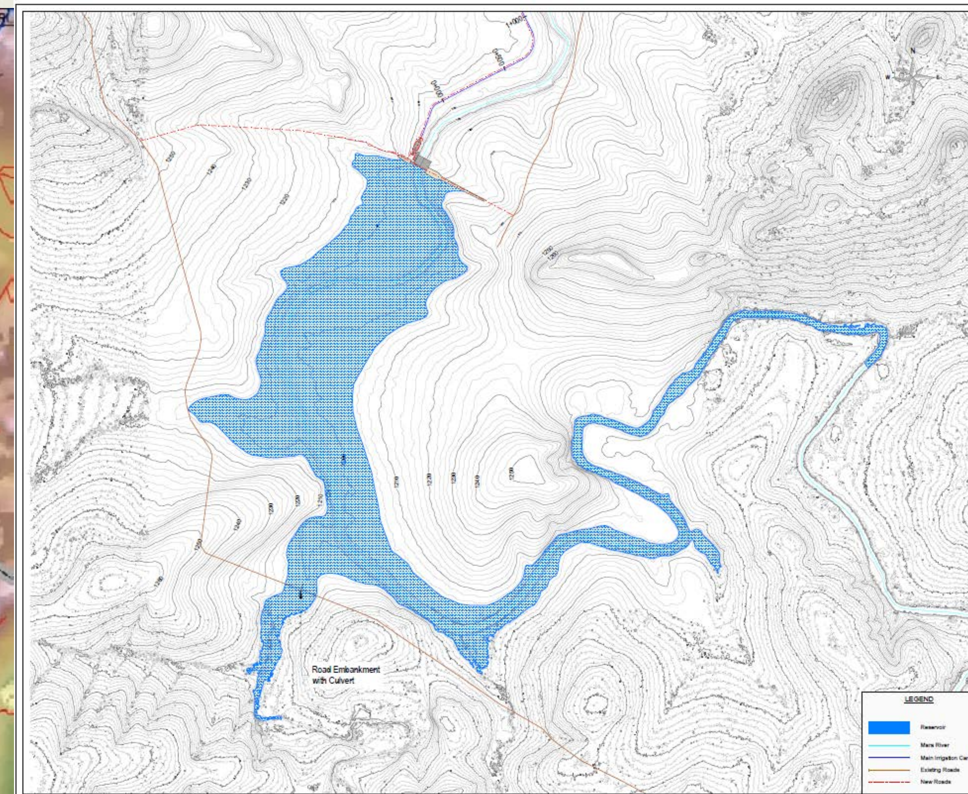
Introducing Borenga Dam Project





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MARA VALLEY PROJECT POTENTIAL

IRRIGATION IN SERENGETI DISTRICT	IRRIGATION IN BUTIAMA DISTRICT	HYDROPOWER	RURAL WATER SUPPLY
5,540 hectares all gravity fed	3,400 hectares of which 1,885 gravity and 1,515 pumped	Installed capacity of 2.8 MW	Villages in the Districts of Tarime, Serengeti and Butiama

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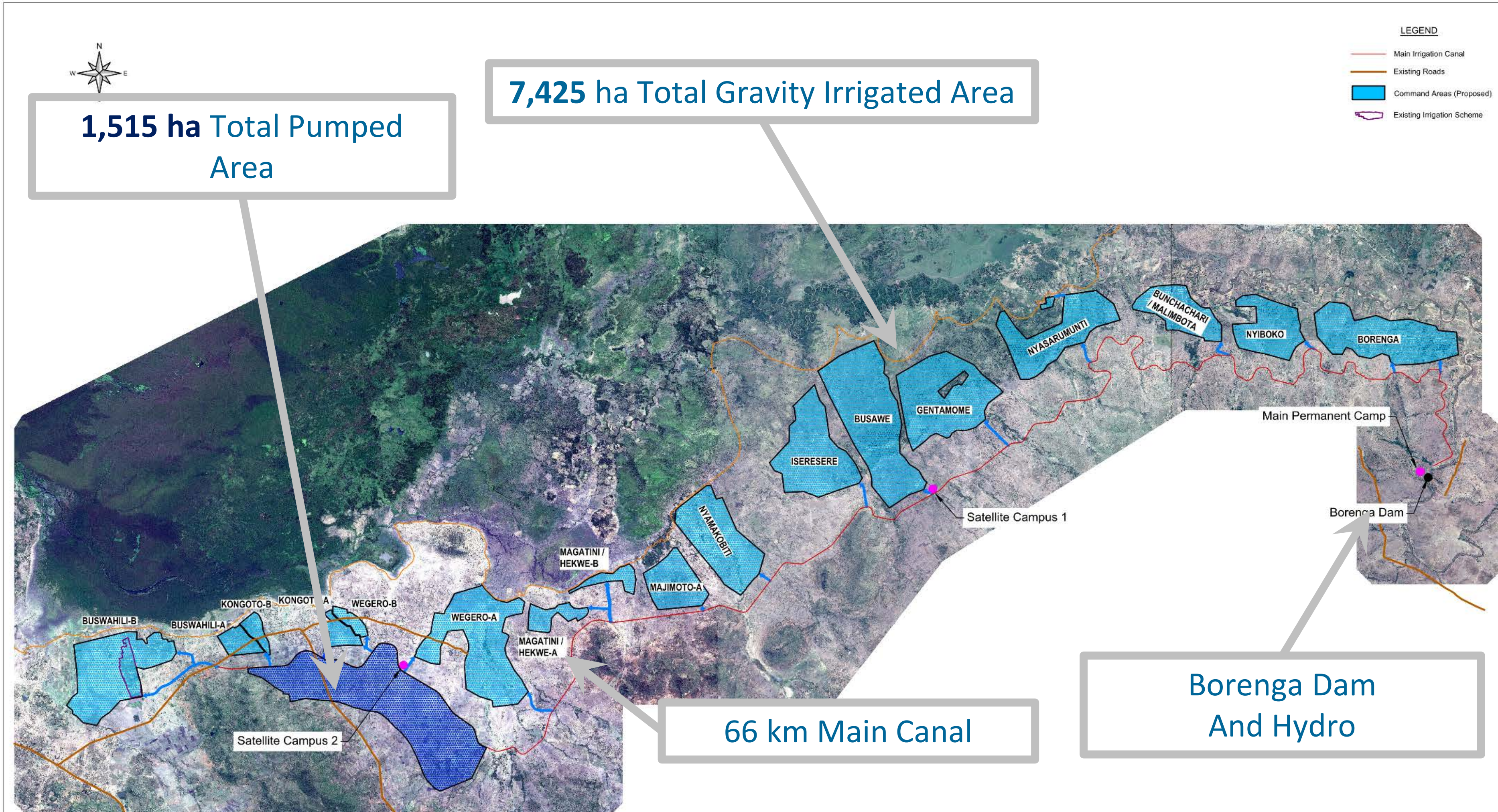
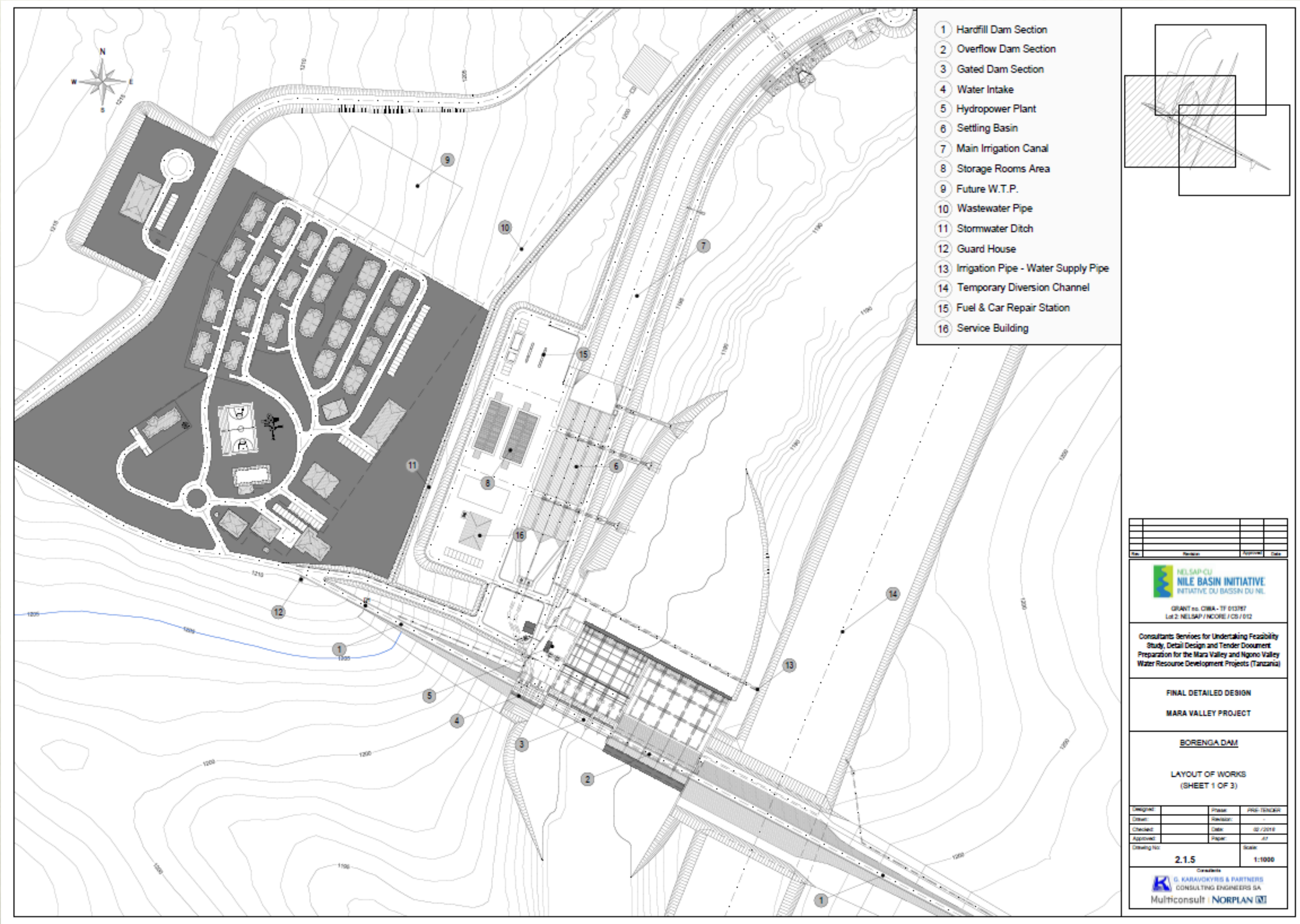
Project Components Layout



BORENGA DAM LAYOUT



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Borenga Dam – Salient Features

Embankment (Crest) length	632m
Dam Height	22m from the original river bed
Storage Capacity	16 MCM
Maximum power output at design head	2.80 MW
Turbine	S - type Kaplan
Annual production	12.6 GWh

System	Component	
Physical structure	Gated spillway	Main canal
	Intake for irrigation	Free overflow spillway
	Weir	Powerhouse
	Turbine	Dam crest
	Downstream face of the dam	Water treatment plant
	Upstream face of the dam	Intake for hydropower
	Access road	Power supply facilities
Functional services	Water supply	Drought mitigation
	Irrigation	Fisheries
	Hydropower	Transportation service
	Flood mitigation	
Operation	Monitoring of water levels	Flushing sediments during low flows
	Releasing flood during high flows	
Construction components	Coffer dam	Diversion channel
	Spillway	Embankments

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We applied the Risk assessment in all the infrastructure components by using the below equation:

R = P x S

Where: R = Risk

P = Probability of the interaction

S = Severity of the interaction

THE RISK MATRIX

Consequence							
7	7	14	21	28	35	42	49
6	6	12	18	24	30	36	42
5	5	10	15	20	25	30	35
4	4	8	12	16	20	24	28
3	3	6	9	12	15	18	21
2	2	4	6	8	10	12	14
1	1	2	3	4	5	6	7
	1	2	3	4	5	6	7

Probability of Occurrence

- *Risk Tolerance Thresholds*

Risk Range	Threshold	Response
< 9	Low Risk	No immediate action necessary
12 – 35	Medium Risk	Action may be required , Engineering analysis may be required
> 36	High Risk	Immediate action required

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Probability scale factors

Scale	Probability		
	Method A	Method B	Method C
0	Negligible or not applicable	< 0.1% or < 0.1/20	Negligible or not applicable
1	Improbable / Highly Unlikely	5% or 1/20	Improbable 1:1 000 000
2	Remote	20% or 4/20	Remote 1:100 000
3	Occasional	35% or 7/20	Occasional 1: 10 000
4	Moderate / Possible	50% or 10/20	Moderate 1:1 000
5	Often	65% or 13/20	Probable 1:100
6	Probable	80% or 16/20	Frequent 1:10
7	Certain/Highly Probable	> 95% or >19/20	Continuous 1:1

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Data Analysis and Process:

DSS + CHIRPS + Years

Climate Variable	Observed Days / year	Projected Days / year	Projected Days / year
	1973 - 2008	2036 - 2065	2066 - 2095
High temperature :			
Number of days with a maximum temperature > 38°C	0	0	0
Number of days with a maximum temperature > 29°C	0,18		
Number of days with a maximum temperature > 25°C	0,71		
Low temperature:			
Number of days with a minimum temperature < 10°C	0,02	0	0
Number of days with a minimum temperature < 5°C	0		
Number of days with a minimum temperature < 18°C during 2036-2065		0,07	0,01
Heavy Annual Rainfall:			
Number of days with annual rainfall > 900 mm at Keekorouk	0,65	0,89	0,95
Hydrological parameters:			
Extreme flood (Probable Maximum Flood, Flow of 8,000 m3/sec)	0	0	0
Safety check flood (10,000 year flood, Flow of 3,000 m3/sec)			
Design flood (Flow of 2,000 m3/sec)			
5 year flood (Flow of 550 m3/sec)			
Dead storage availability (less than 11 mt/year sediment load in Boregna's reservoir)			

Climate Variable	Component
High temperature :	Gate Hoist Mechanism, Power Supply Facilities, Backup Power Supply, Generators, SCADA System, Switch Yard, High Tension Cables, Transmission Towers, Access Roads, supplies delivery, operations (Personnel),
Number of days with a maximum temperature > 38°C	
Number of days with a maximum temperature > 29°C	
Number of days with a maximum temperature > 25°C	
Low temperature:	
Number of days with a minimum temperature < 10°C	Radial Gate Bearings, Monitoring Water Levels (auto and manual), Maintenance Systems & Procedures, Dam Inspections, Personnel, Telephone, Telemetry, Control/Monitoring Systems
Number of days with a minimum temperature < 5°C	
Number of days with a minimum temperature < 18°C during 2036-2065	
Heavy Annual Rainfall:	
Number of days with annual rainfall > 900 mm at Keekorouk	Personnel, Telephone, Telemetry, Control/Monitoring Systems
Hydrological parameters:	
Extreme flood (Probable Maximum Flood, Flow of 8,000 m3/sec)All	All Dam infrastructure components
Safety check flood (10,000 year flood, Flow of 3,000 m3/sec)	
Design flood (Flow of 2,000 m3/sec)	
5 year flood (Flow of 550 m3/sec)	Dam Infrastructure during the Construction Period (Coffer Dam, Diversion Channel, Spillway, etc.)
Dead storage availability (less than 11 mt/year sediment load in Boregna's reservoir)	

❖ *Severity methods for climate risk assessment*

	Severity	
Scale	Method D	Method E
0	No effect	Negligible or Not Applicable
1	Measurable 0.0125	Very Low / Unlikely / Rare / Measurable Change
2	Minor 0.025	Low / Seldom / Marginal / Change in Serviceability
3	Moderate 0.050	Occasional Loss of Some Capability
4	Major 0.100	Moderate Loss of Some Capacity
5	Serious 0.200	Likely Regular / Loss of Capacity and Loss of Some Function
6	Hazardous 0.400	Major / Likely / Critical / Loss of Function
7	Catastrophic 0.800	Extreme / Frequent / Continuous / Loss of Asset

Infrastructure Component	Climate or Hydrological Parameter	Probability (up to 2080)	Severity	Risk
Infrastructure				
Dam				
Weir	PMF	1	5	5
Gated Spillway	PMF	1	6	6
Dam Crest	PMF	1	7	7
Radial Gates	PMF	1	6	6
	10,000 year flood	2	6	12
Stilling Basin	PMF	1	6	6
	10,000 year flood	2	6	12
	Dead Storage Availability - Sediment	3	6	18
Reservoir	PMF	1	5	5
	10,000 year flood	2	5	10
	Dead Storage Availability - Sediment	3	5	15
Power Supply Facilities	PMF	1	6	6
	Dead Storage Availability - Sediment	3	3	9
	High Temperature	2	4	8
Water Treatment Plant				
Water Treatment Plant	PMF	1	6	6
	10,000 year flood	2	6	12
	Dead Storage Availability - Sediment	3	3	9

Infrastructure Component	Climate or Hydrological Parameter	Probability	Severity	Risk
Infrastructure				
Powerhouse				
Generators	High Temperature	2	4	8
Tailrace Channel	PMF	1	3	3
	10,000 year flood	2	3	6
Tailrace Rip-Rap Erosion Protection	PMF	1	6	6
	10,000 year flood	2	6	12
External Power Infrastructure				
Switch Yard	PMF	1	4	4
	High Temperature	2	3	6
High Tension Cables	PMF	1	4	4
	High Temperature	2	4	8
Transmission Towers	PMF	1	4	4
	High Temperature	2	3	6
Access Road				
Access Road	PMF	1	5	5
	10,000 year flood	2	5	10
	High Temperature	2	2	4
Supplies Delivery	High Temperature	2	3	6

Infrastructure Component	Climate or Hydrological Parameter	Probab-ility	Severit y	Risk
Operations				
Personnel	PMF	1	6	6
	10,000 year flood	2	6	12
Telephone, Telemetry	PMF	1	6	6
Control/Monitoring Systems	PMF	1	2	2
Control Building	PMF	1	3	3
Functions Services				
Flood Mitigation	PMF	1	6	6
	10,000 year flood	2	6	5
Transportation Service	PMF	1	5	5
	10,000 year flood	2	5	10
Construction Period				
Diversion Channel	5-year flood	6	4	24
Access Roads	5-year flood	6	4	24
Cofferdam	5-year flood	6	7	42
Spillway	5-year flood	6	6	36
Embankments	5-year flood	6	5	30
Irrigation Structures (intake)	5-year flood	6	4	24
Transportation				
Supplies Delivery	PMF	1	6	6
	High Temperature	2	3	6

Summary of risk findings

- A total of 104 climate|hydrology/infrastructure interactions were identified
- Seventy-two (72) interactions as low risk for future conditions
- Thirty (30) interactions as medium risk for future conditions
- Two (2) interaction was identified as high risk for future conditions
- Forty-seven (47) interactions were relevant for further consideration.

Conclustion of risk findings

- Borenga Multipurpose dam has the capacity to withstand the projected future climate (i.e. to the 2080s).
- largest potential impact could be during the construction period and on the spillway structure.
- Due to expected increase in 25 years flood, the increase in flood magnitude can affect the upstream coffer dam and other diversion structures and hamper the construction of the main Dam.
- 25 years flood can affect the Dam during the operation of the dam. This mainly on spillway structures such as gates and stilling basins.

Recommendations

Components of the physical structure	Recommendations
Dam Crest	✓ Incorporate fuse plug ✓ Consider emergency spillway during design ✓ Consider watershed management interventions. This relates to allowing physical space for the river flood along the river course ✓ Prepare emergency action plan ✓ Use climate projections to determine the future PMF to adjust/amend the dam crest design (height)
Dam Instruments	✓ Use instruments that can withstand the max and min temperature.
Spillway	✓ Incorporate fuse plug ✓ Increase resilience of the spillway by increasing the freeboard and making it flexible to adjust to climate change ✓ Plan for emergency spillway ✓ Carry out more investigation during the design planning considering climate change ✓ Check design parameter of the spillway against high floods
Powerhouse	✓ Keep the design as it is ✓ Consider backwater protection (e.g. valve) ✓ Consider enough space for tail water depending on topography

Type of components	Recommendation
Operations	➢ Establish emergency plan to be used in the event of flooding ➢ Create awareness about hazard of flooding and safety measures to be implemented during flooding ➢ As Tams is a big structure, establish wireless communication system which will be used during severe flooding ➢ Consider satellite for hydrological data transmission
Functional Services	➢ Establish an early warning system for flood protection ➢ Establish upstream monitoring system ➢ Evacuation plan should be prepared ➢ Review emergency plan if it is prepared during the reconnaissance study ➢ Consider alternative power sources to be utilized during high flood and disruption of power production from the dam ➢ Try to have robust irrigation infrastructure design considering climate change to avoid damage in the event of high flow ➢ Consider the design parameter for navigation as a social condition

Type of components	Recommendation
Construction Period	• Design coffer dams for longer return period considering climate change • Check it with projected climate • Consider other diversion methods during design of structure for the construction period
Other systems	• Consider alternative power supply for safety purposes • Consider nearby fire extinguishing service • Consider modern satellite power transmission • Consider underground cabling for power transmission • Improve structural capability of transmission lines and substations • Consider air transport in places where there is poor road network although it requires high cost • Widen roads to accommodate appropriated vehicle for the delivery of hydro-mechanical parts for the dam • The delivery of dam supply should be properly planned. For example, avoid rainy season for transportation of heavy hydro-mechanical parts


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THANK YOU!