WORKSHOP ON CLIMATE CHANGE AND DISASTER RISK MANAGEMENT IN PLANNING AND INVESTMENT PROJECTS

Climate Risk and Vulnerability Assessment: The Case of the Nam Ngiep 1 Hydropower Project (Lao PDR)

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Adaptation Solutions

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Outline of Presentation

1. Nam Ngiep 1 – Background
2. Climate change risks to Nam Ngiep 1
3. Methodological approach
4. Selected results
5. Adaptation recommendations
6. Lessons learned

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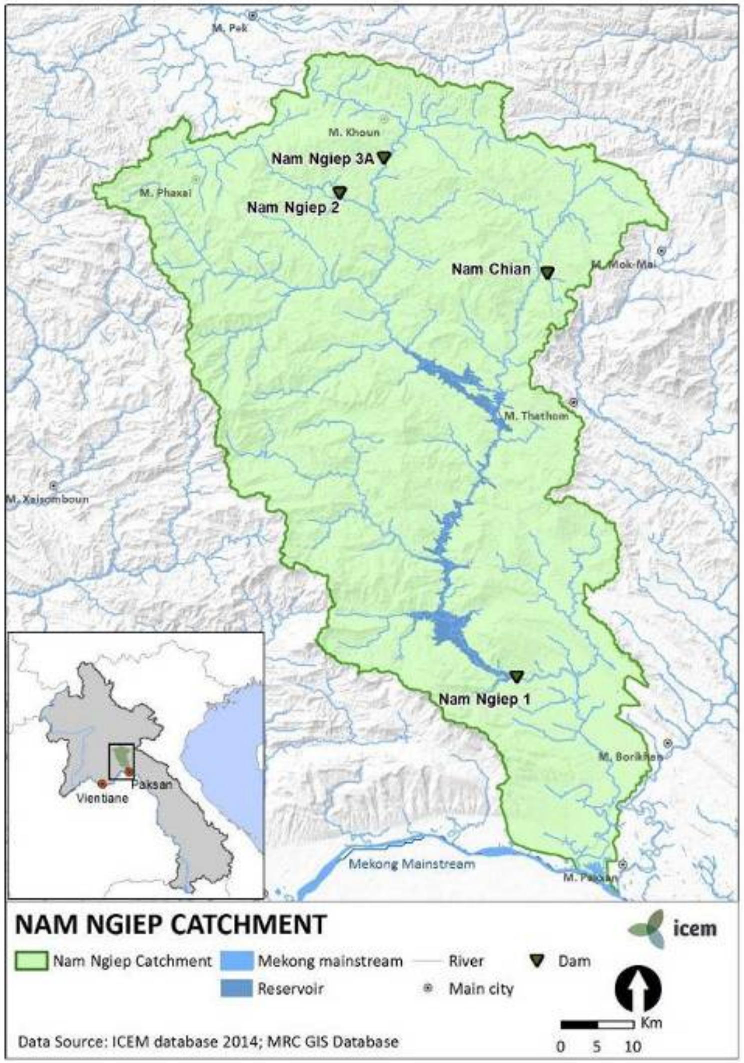
Nam Ngiep 1 - Background

- NNP1 catchment area = 3,700km^2
- 157 – 2,800 masl
- Rainfall: 1,870mm/yr
- Reservoir mean annual flow – 148.8m^3/s
- Catchment land cover: large tracts of remaining forest cover, but significant areas of degraded vegetation and deforestation including on steep sloped lateritic soils



Nam Ngiep 1 - Background

Technical Feature of the Project

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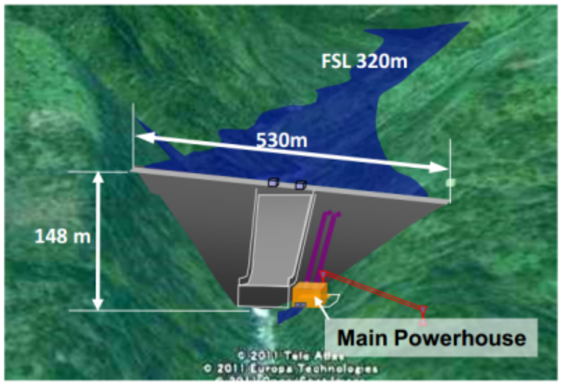
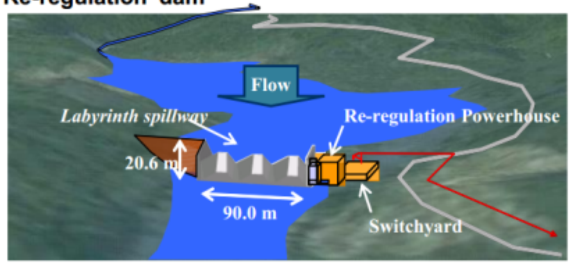
Main dam (RCC dam)



Re-regulation dam

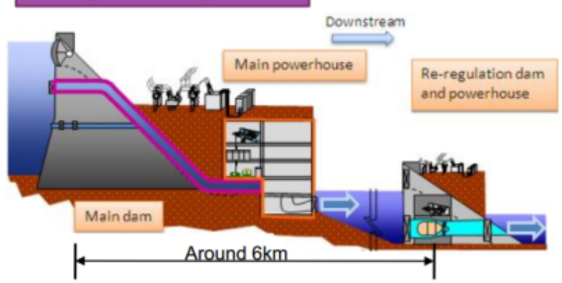


NAM NGIEP 1 POWER COMPANY

Project features

	Main P/S	Re-regulation P/S
Generation type	Dam type	
Catchment area	3700km²	–
Reservoir	66.9km2	1.27km2
Storage capacity	1.2 billion m^3	4.6 million m^3
Output	272MW	18MW
Dam type	Concrete gravity dam	
Dam height	148.0m	20.6m
Access Road	58.2 km (27.8km newly constructed)	

Longitudinal profile



- Main dam positioned between a steep natural canyon.
- Designed for peaking operations (16hrs on, 6 days/wk)
- Peaking ops require a re-regulating reservoir built in the floodplain.
- Re-reg reservoir requires a saddle-dam to contain the reservoir within the low points in floodplain topography.

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Climate change risks to Nam Ngiep 1

Types of impact of CC on infrastructure

- Affect performance of the power station
- Damage or reduce integrity of NNP1 assets

Climate change risks to Nam Ngiep 1

- Loss of reservoir active storage (operating life)
- Flood risk & uncontrolled releases
- Landslides & hillslope failure

Key issues

- How will climate change risks accrue over time?
- What timescales are relevant for each asset?

Climate change risks to Nam Ngiep 1

Impact pathways **establish causal relationships between changing threats and changing performance/damage of plant assets, based on underlying biophysical processes.**

THREATS		NNP1 SYSTEM ASSETS
Variability in the water cycle 1. Air temperature 2. Precipitation (intensity & magnitude) 3. Flood event **Cascade management** 4. Normal cascade operations 5. Cascade emergency flood management	❯❯❯	**Infrastructure and physical assets** 1. Reservoir (main dam and re-regulation dam) 2. Dam wall (main dam, re-regulation dam & saddle dam) 3. Spillway structures (main dam and re-regulation dam) 4. Intake & penstock (main dam and re-regulation dam) 5. power house (main dam and re-regulation dam) 6. turbine and generators (main dam and re-regulation dam) 7. Watershed condition and productivity 8. Resettlement area productivity **Processes** 9. Energy production 10. safeguards and regulatory compliance

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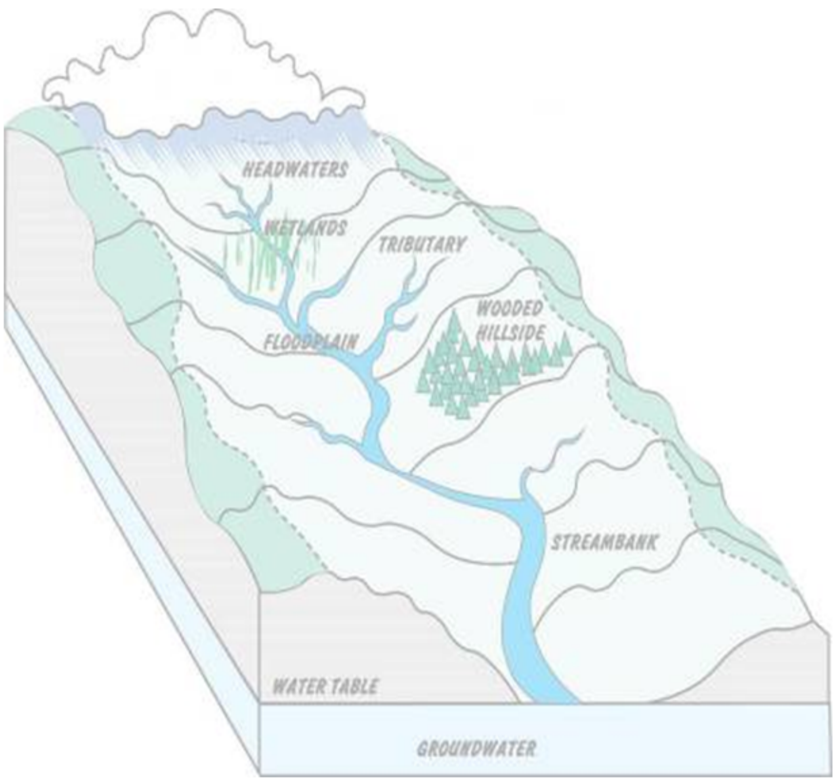
Climate change risks to Nam Ngiep 1



THREATS	IMPACT PATHWAY
$[CO_2]$	
AIR TEMPERATURE	IP1: WATER QUALITY - DOWNSTREAM AQUATIC ECOSYSTEM
	IP2: TRANSMISSION LINES - ENERGY LOSSES
PRECIPITATION	IP3: RESERVOIR SEDIMENTATION - STORAGE CAPACITY
	IP4: RESERVOIR SEDIMENTATION – REGULATION CAPACITY
	IP5: SEASONAL WATER AVAILABILITY - INCREASE ENERGY PRODUCTION
	IP6: INCREASED SPILLAGE – DAMAGE TO SPILLWAY
PROBABLE MAXIMUM FLOOD	IP7: OVERTOPPING MAIN DAM- INUNDATION OF POWERHOUSE
	IP8: ELEVATED REREGULATION WATER LEVELS - FLOODING OF POWERHOUSE FROM BACKWATER
	IP9: OVERTOPPING MAIN DAM - SADDLE DAM BREACH
	IP10: REDUCED OR DAMAGED AGRICULTURE PRODUCTION AT RESETTLEMENT AREA
HYDROPOWER PLANTS CASCADE	IP11: DAM BREAK SCENARIO OF NAM NGIEP 2 HYDROPOWER PROJECT
	IP12: OPERATION OF ALL THE UPSTREAM HYDROPOWER PROJECTS IN THE CATCHMENT

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Climate change risks to Nam Ngiep 1

Threat	Increased hillslope erosion and sediment transport
Impact pathways	Increased precipitation intensity could lead to increased erosion and sediment mobilisation. Increased river flows will also enhance sediment transport capacity of the Nam Ngiep River. Both factors will exacerbate sediment inflows to the reservoir, reduce active storage capacity, and adversely impact energy production and regulation capacity.

Climate change risks to Nam Ngiep 1

Threat	Increase in the size of the probable max flood
Impact pathways	An increase in the PMF flood event will increase the volume of flood waters that need to be stored and passed through the spillway of the main dam. Lacking such capacity, the dam may over-top. On the other hand, if the dam is able to contain the PMF without over-topping, then water levels in the reservoir would rise increasing the discharge flows through the spillway.

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Methodological approach

Key steps

1. Projections of future emissions
2. Projections of future atmospheric and ocean dynamics
3. Downscaling projections to the Mekong Basin
4. Predicting future changes in the basin hydrological regime
5. Predicting future changes in flooding and hydrodynamic processes (e.g. hillslope erosion, reservoir sedimentation)

Methodological approach

Projection of future emission and global GHG concentration
IPCC EMISSION SCENARIOS

A1B

Projection of future atmospheric & ocean dynamic
GCMs – GLOBAL CIRCULATION MODELS

ncar_ccsm3_0	micro3_2_hires	giss_aom
cnrm_cm3	inv_echam4	cccma_cgcm3_1

Downscaled projections of future climate at basin & catchment level
CLIMATE DOWNSCALING

STATISTICAL

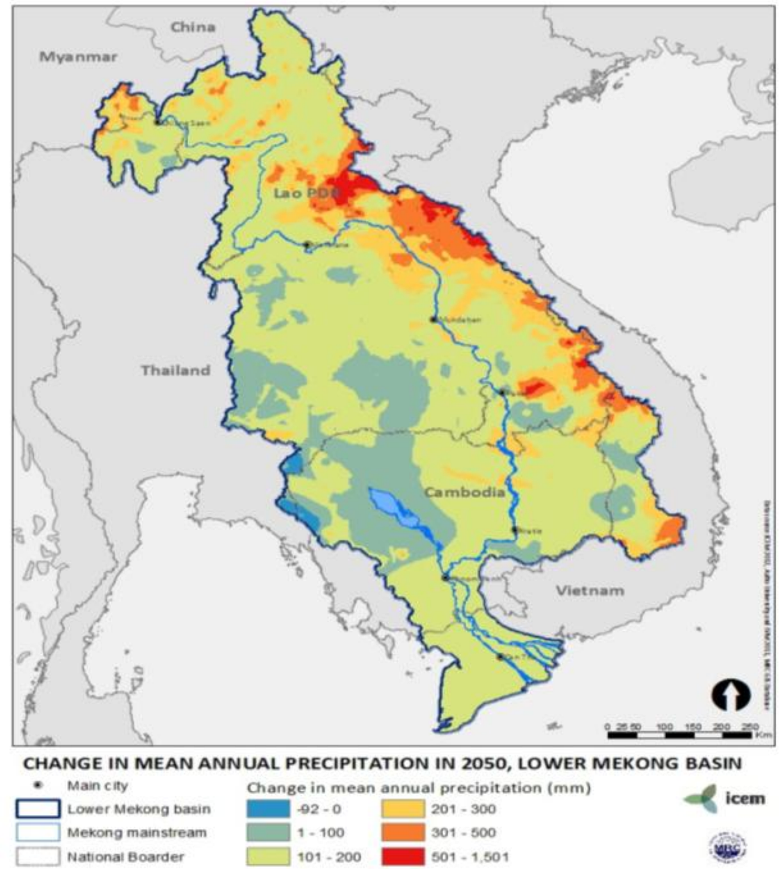
Prediction of future hydrological regime
HYDROLOGICAL MODELING

VMOD

Prediction of future cascade hydrological regime
HYDROPOWER MODELING

MODSIM

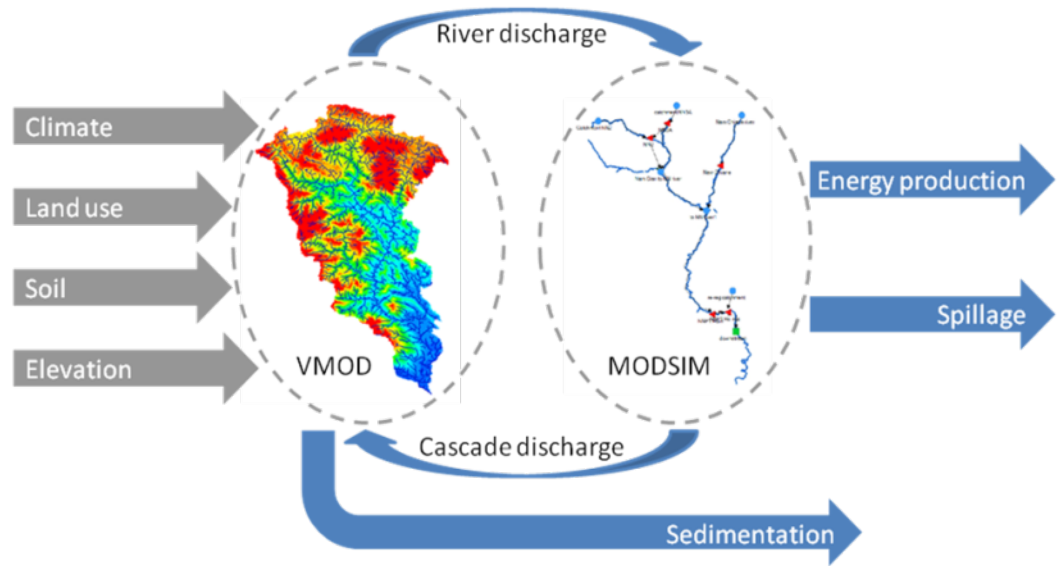
Analysis & interpretation of climate change & hydrological data
DATA ANALYSIS AND INTERPRETATION



Methodological approach

Model set-up

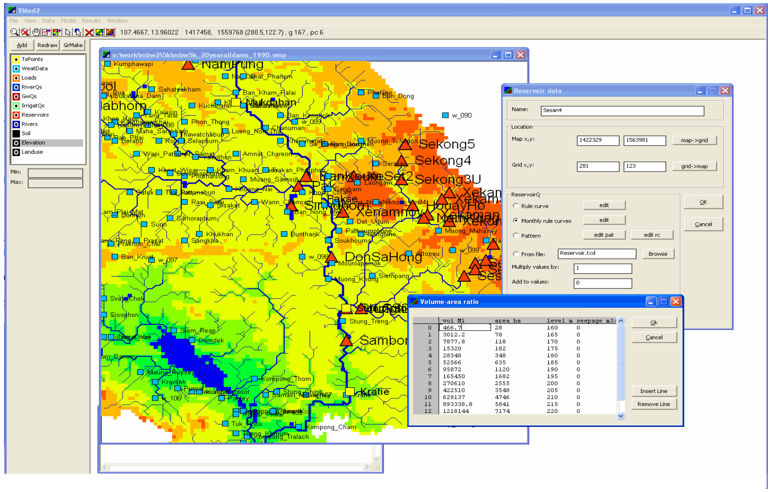
- **VMOD: distributed hydrological model that resolves hydro-climate in 1km x 1km grid cells**
- **MODSIM: network water allocation model to simulate impacts of cascade management on NNP1**

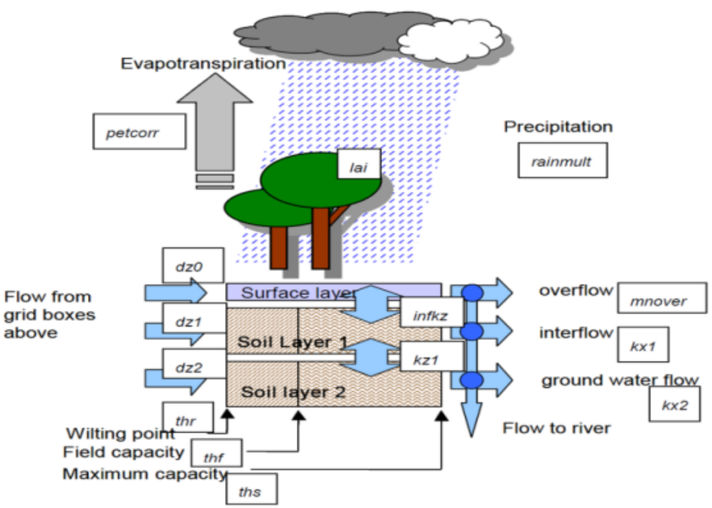


Methodological approach

Hydrological modeling

- VMod model
- 15 years of custom development for the Mekong
- area-based distribution of hydro-meteorological impacts of climate change
- Computes water balance for grid cells (5x5km)
- Baseline:1981 – 2005
- Future CC: 2045 - 2069
- Can predict changes in:
  - *Rainfall*
  - *Runoff*
  - *Flows*
  - *Infiltration*
  - *evapotranspiration*





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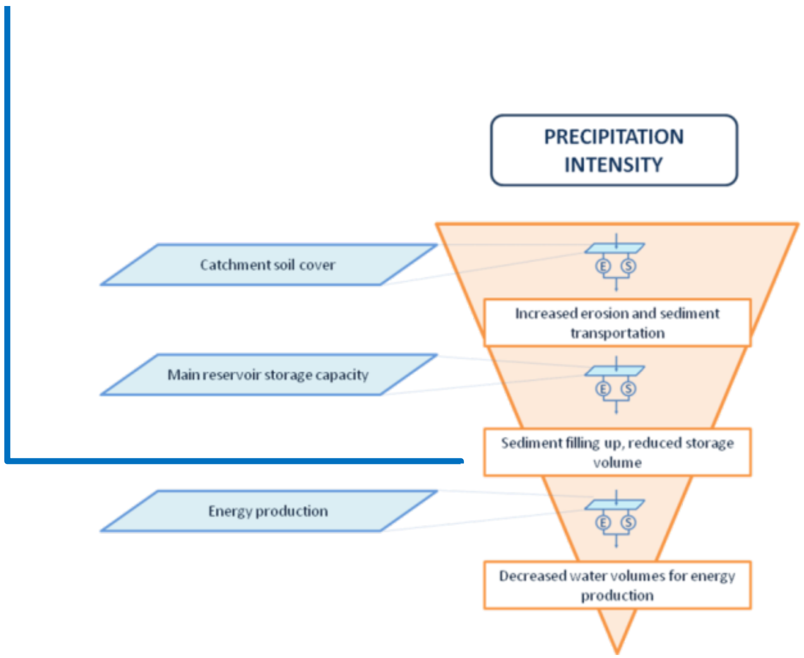
Selected results: Increased erosion

	Upper impoundment			Lower impoundment		
	Total sediment yield (Mt/yr)	*50 years accumulated sediment (MCM)*	*% of storage capacity*	*Total sediment yield (Mt/yr)*	*50 years accumulated sediment (MCM)*	*% of storage capacity*
Baseline	0.381	13.32	3%	0.689	25.29	1%
Climate change	0.965	32.98	8%	1.552	56.48	3%



Impact pathway

⇒ Majority of the catchment will experience increases in erosion of 200-300% (up to 400% in some parts)

⇒ Tripling of sediment inflows into the reservoir over 50yrs form 38.5MT to 89.5Mt

⇒ Reduction in active storage of 5-7.5%

⇒ Rise of wet season reservoir levels of 0.8m

⇒ **More spillage and therefore foregone energy production.**

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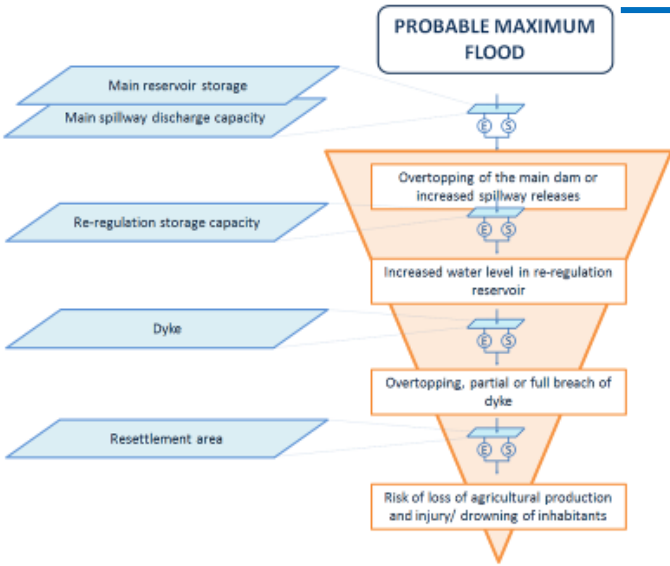
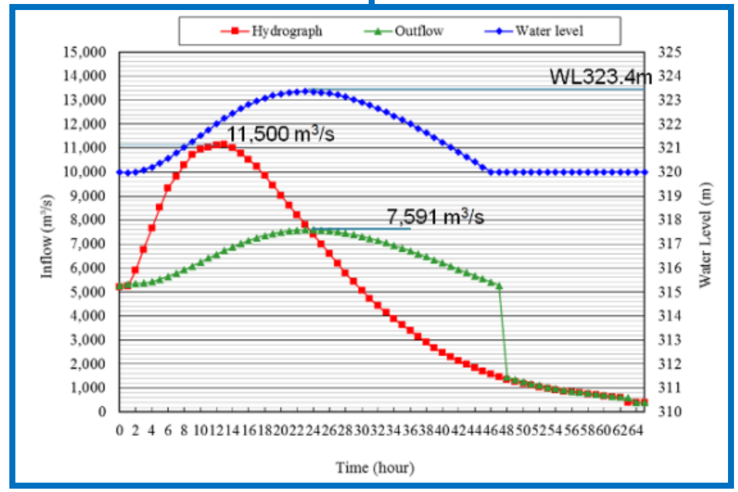
Selected results: Increased PMF





Impact pathway

⇒ PMF increases from 8,890 to 11,500m3/s

⇒ Max. Water Level in reservoir increases from 321.94masl to 323.4masl

⇒ Below max dam height of 323.5masl **so no overtopping**

⇒ Increased spillway release from ~6,500 m3/s to 7,591 m3/s for 20hrs

⇒ Re-reg. water level rises from 197.7masl to 188.5masl

⇒ Below the max dam height of 189.4masl **so no overtopping**

Selected results: Most significant impacts

1. **The most significant CC-benefit to NNP1 is a projected increased energy production potential,** with future climate change conditions likely to enhance the project's capacity to produce energy by increasing the year-round water availability.

2. **The most significant impact of climate change is a dramatic increase in the frequency of spillway usage which will over the design life accelerate wear-and-tear of the spillway apron and scour of the riverbed as waters exit the spillway structure**:

Selected results: Moderate impacts

1. Reduced active storage capacity of the main dam.
2. Increased risk of reduced productivity of the agricultural lands of the resettled community.
3. Reduced oxygen levels and water quality of dam releases.
4. Impact on electricity production from altered flow regime due to upstream cascade.

Selected results: Low impacts

1. **Over-topping of the main dam**
2. **Over-topping of the re-regulation saddle-dam during the future PMF event routing uncontrolled flows through the agricultural lands of the resettled community**

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Adaptation recommendations: Monitoring

1. **Threshold monitoring: establish critical thresholds for cc-risk parameters and monitor during operating life**
   - **Reservoir & release temperature & DO**
   - **Monthly spillage volumes**
   - **Land zone scour hole development**

Adaptation recommendations: Interventions

1. **Preventative measures for catchment sediment conservation:** site and develop preventative measures such as check dams and constructed wetlands that allow for increased sediment loads to be trapped within the landscape before they reach the headwaters of the reservoir.
2. **Build adaptive capacity for increased wet season electricity production**: inclusion of a blank manifold and provision for an additional penstock should be considered whilst the main dam is still under construction.

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Lessons learned

1. **Draw on multiple scenarios and multiple GCMS:** CC projections cannot predict the future, the more future time series developed the greater the likelihood of characterizing the range of change possible.
2. **Replicate methodologies used during the design process**: findings from the CRVA must be comparable to existing design calculations; where possible use the same calculation approaches used in the original design to build confidence in findings.
3. **Understand critical thresholds for desig**n (e.g. design flood event or minimum quantum of electricity production p.a.) then use the CC projections to characterize how likely these thresholds might be crossed.

Lessons learned

4. **Move beyond temperature and rainfall:** Most climate scientists talk about changes in temperature and rainfall. Typically this isn't speaking the language of design engineers. CRVA should move beyond climate to trace the knock-on effects of changing temperature and rainfall on parameters that are of interest to design engineers (flood return periods, DO levels, drought incidence, landslide potential etc).
5. **Breakdown infrastructure into discrete components:** Typically, large infrastructure investments are complex assemblages of civil, mechanical, and electrical assets. Developing an asset inventory allows the problem of CC vulnerability to be broken down into manageable pieces. Overall vulnerability can then be summed as the cumulative vulnerability of each asset component.
6. **Don't hide uncertainty:** All forms of modelling contain some level of uncertainty, CVRAs need to find a practical way of characterising uncertainty so that it does not impede confidence or uptake of recommendations.

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Acknowledgments

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