Mekong River Commission

PRIOR CONSULTATION PROCESS FOR THE

SANAKHAM HYDROPOWER PROJECT

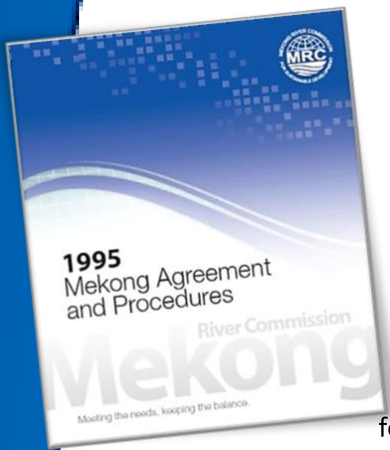
SUMMARY OF THE
FIRST DRAFT OF THE TECHNICAL REVIEW REPORT

ACRONYMS AND GLOSSARY

CIA	*Cumulative Impact Assessment*
DSMS	*Dam Safety Management System*
EAP	*Emergency Action Plan – required for Dam Safety*
EIA	*Environmental Impact Assessment*
FS	*Feasibility Study*
GoL	*Government of the Lao PDR*
HPP	*Hydropower project*
JAP	*Joint Action Plan – a post prior consultation process*
JC	*Joint Committee*
JCWG	*Joint Committee Working Group – established to guide the technical review process*
JEM	*Joint Environmental Monitoring – a monitoring programme being piloted at the Xayaburi and Don Sahong HPPs to evaluate the efficacy of the measures applied.*
Joint Platform	*A body created by the MRC to help improve the implementation of the Procedures in linked and cooperative manner*
LEPTS 2018	*Lao Electric Power Technical Standards 2018. A legal requirement*
LMB	*Lower Mekong Basin - The Mekong River Basin falling in the territories of its Member States*
LNMC	*Lao National Mekong Committee*
MC	*Member Country, one of the four parties to the 1995 Mekong Agreement; viz. Cambodia, Lao PDR, Thailand, and Viet Nam*
MRC	*Mekong River Commission – established by the MC to support their efforts towards collaboration*
MRCS	*Mekong River Commission Secretariat*
PC	*Prior Consultation*
PDG2009	*Preliminary Design Guidance of 2009 - approved*
PDG2020	*Preliminary Design Guidance of 2020 – not yet approved*
PDIES	*Procedures for Data and Information Exchange and Sharing*
PMFM	*Procedures for the Maintenance of Flows on the Mainstream*
PNPCA	*Procedures for Notification, Prior Consultation and Agreement*
PPA	*Power Purchase Agreement*
Pressure flushing	*Use of low-Level outlets to scour sand deposited near the dam wall and turbines, primarily to project the infrastructure and power production.*
PWQ	*Procedures for Water Quality*
PWUM	*Procedures for Water Use Monitoring*
RAP	*Resettlement Action Plan*

RIS	*River Information System – a system that may be introduced to facilitate navigation on the Mekong mainstream*
SEE	*Safety Evaluation Earthquake – a seismic standard applied to possible ground motion.*
Sediment flushing	*Drawing down water levels to periodically induce channel erosion and discharge large volumes of deposited sediment.*
SIA	*Social Impact Assessment*
SMMP	*Social Monitoring and Management Plan – a process initiated with construction to evaluate and adapt to impacts due to construction and operations of the HPP*
SNHPP	*Sanakham Hydropower Project*
Sediment routing	Drawing down water level during periods of high inflow to maximise sediment throughput
TbIA	*Transboundary Impact Analysis*
TRR	*Technical Review Report*

INTRODUCTION



Background

The National Mekong Committee of the Lao PDR submitted the Sanakham Hydropower Project (SNHPP) for prior consultation on 9 September 2019. This was one month after the submission of the Luang Prabang HPP. The MRC Joint Committee therefore agreed to delay the prior consultation process for the SNHPP until the Luang Prabang process was completed. The Sanakham process started from 30 July 2020.

Given the challenges posed by the COVID 19 pandemic, a flexible timeframe has been agreed, with a step-wise approach implementation to have dates for key milestones to be agreed at each meeting of the Joint Committee Working Group.

The proposed SNHPP is the sixth proposed use submitted for prior consultation. The five earlier processes were for the Xayaburi (XHPP), Don Sahong, Pak Beng (PBHPP), Pak Lay (PLHPP) and Luang Prabang (LPHPP) hydropower projects.

The 1995 Mekong Agreement

The Governments of Cambodia, Lao PDR, Thailand, and Viet Nam signed an Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin, “The 1995 Mekong Agreement”. The Agreement established the Mekong River Commission and re-affirmed the Member Countries’ desire to develop the Mekong River Basin in a sustainable and cooperative manner. However, recognising that development could result in adverse impacts on the Mekong River System, Chapter III of the Agreement includes commitments by the Member Countries to:

- Protect the ecological balance of the Mekong River Basin.
- The reasonable and equitable use of the waters of the Mekong River System.
- Discuss and aim to agree (in the Joint Committee) on significant water uses on the mainstream in the dry season (prior consultation).
- Maintain flows in the Mekong mainstream.
- Make every effort to avoid, minimise and mitigate harmful effects on the river system.
- Take responsibility where harmful effects result in substantial damage to the other Member States, and to cease these activities when notified with valid evidence.
- Incorporate navigational uses in mainstream projects so as not to permanently impair navigation, and
- Warn other Member Countries of water quality and quantity emergencies.

> *The 1995 Mekong Agreement is primarily developmental in nature but establishes a framework of objectives and principles through which the Member States agree to the fair and sustainable development of the Mekong River System for mutual benefit.*

The Member Countries aim to achieve these objectives and principles through the unique spirit of cooperation that has underpinned cooperation between the Member Countries since 1957, and which has been reaffirmed on many subsequent occasions.

The 1995 Mekong Agreement also establishes the Mekong River Commission (MRC), and its institutional structures as an international body and gives certain powers and functions to these bodies.

> *The MRC Member Countries established the Commission and its structures and gave certain powers and functions to these bodies. The MRC can **only** function within these given mandates.*

- ***The Council*** is empowered to establish the 'Rules for Water Utilization and Inter-Basin Diversions' (now the five MRC Procedures). The Council agreed the Procedures for Notification, Prior Consultation and Agreement (PNPCA) in 2003.
- ***The Joint Committee (JC)*** is empowered by Article 5 of the Agreement and the PNPCA to undertake the prior consultation process, and Technical Guidelines to support the PNPCA were agreed by the Joint Committee on 31 August 2005.
- ***The Secretariat (MRCS)*** provides technical and administrative support to the prior consultation process, can take a pro-active role in assisting the Joint Committee in this regard.

The MRC can *only* work within this framework. The Agreement also indicates that prior consultation is neither a veto right, nor a unilateral right to proceed without taking the other Member Countries' concerns into account. Prior consultation and all the other Procedures are, therefore, not regulatory mechanisms, but rather establish a framework for cooperation and discussion.

The PNPCA and the Prior Consultation process

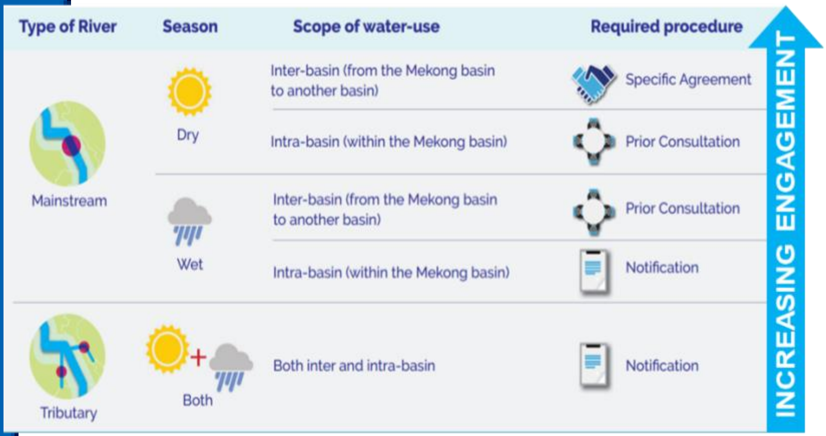
Prior consultation is based on Article 5 of the Agreement where the Member Countries agree to the reasonable and equitable use of the Mekong River System. However, prior consultation takes a broader perspective, considering all the objectives and principles agreed in Chapter 3 of the Agreement.

Together these objectives and principles promote the fair and just development of the Mekong River System, while minimising the potential for transboundary harmful effects and impacts on the ecological balance of the System.

The Procedures for Notification, Prior Consultation and Agreement (PNPCA) specify three processes: i) **N**otification, ii) **P**rior **C**onsultation and iii) specific **A**greement.

Notification is applied to water uses on the tributaries of the Mekong System, and for 'wet season' use on the mainstream. ***Prior consultation*** is required for water use on the mainstream in the 'dry season', and for inter-basin diversions in the 'wet season'. ***Specific Agreement*** is required for inter-basin diversions in the dry season.

The MRC is not empowered to instruct the Member Countries to take any action. It is, in practice, primarily an advisory body.



These increasing levels of interaction reflect a balance between the likelihood of adverse transboundary impacts, and the principle of sovereign decision making.

They are also, to some extent, a hangover from a time when the primary concern of the Member States was sharing water. The idea being that in the wet season there was so much water available there was less concern about the sharing of water, and that provided flows on the mainstream were maintained within agreed limits, tributary uses would have limited transboundary impacts.

However, the impacts of development of the basin on sediment transport, fisheries and ecological processes are also central to the reasonable use of the Mekong River System. We now know that significant impacts to fisheries and sediment transport can also occur due to tributary developments while the large storage hydropower reservoirs in China and on the tributaries disrupt flow regimes affecting the timing and volume of the reverse flow into the Tonle Sap Great Lake and other wetland systems. This in turn affects the fisheries. The 2018 State of the Basin Report has also highlighted other impacts on the ecological balance of the system including, *inter alia*, overfishing, pollution, sand mining and large numbers of irrigation diversion weirs.

> *The Prior Consultation process is governed by the 1995 Mekong Agreement, and underpinned by all the MRC Procedures. It aims to promote the just and fair use of the benefits that derive from the Mekong River System.*

Growing concerns over the cumulative impacts of the rapid development in the Basin is prompting a shift towards a more proactive role for the MRC. This will see the MRCs regular monitoring of the river system forming the basis for recommendations for management measures that will address the impacts of droughts, floods and improved sediment transport.

Some Things to Keep in Mind

> *The Prior Consultation process aims to reach consensus on a Statement calling on the notifying country to make every effort to implement identified measures that further avoid, minimize and mitigate potential transboundary impacts.*

It is important to keep the following in mind:

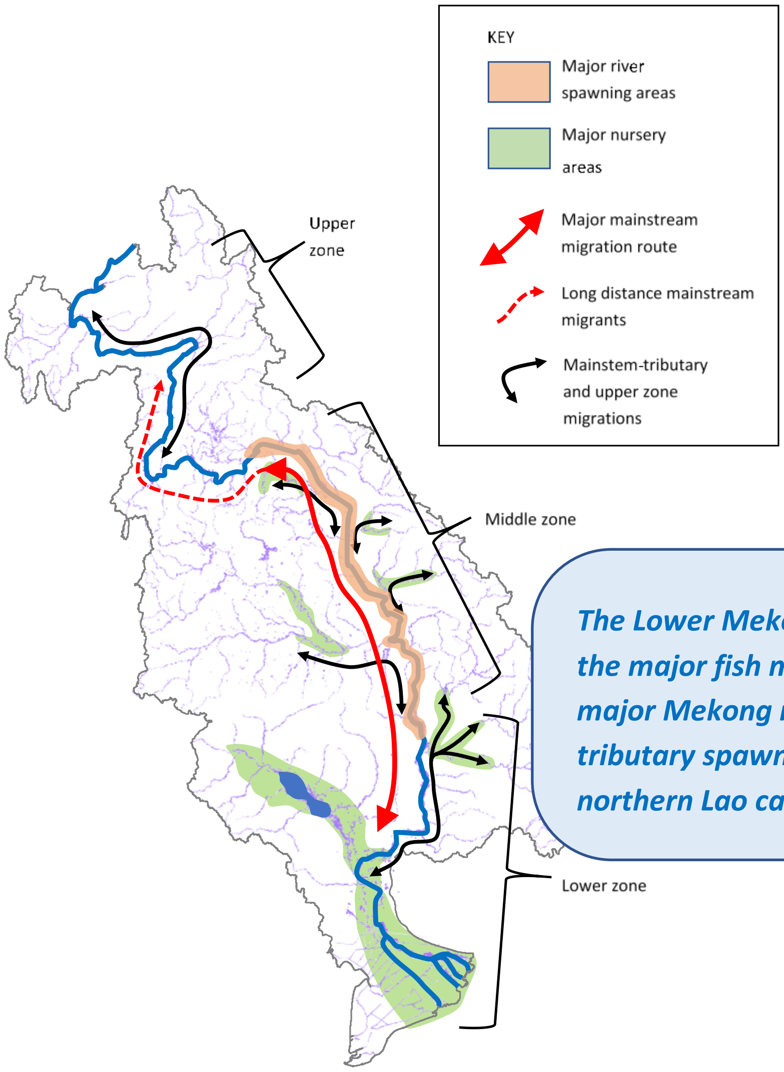
- The assessment of whether any proposed use is *reasonable and equitable* is beyond the scope of the technical review process.
- The Member Countries have committed to making *every effort to avoid, minimise and mitigate possible harmful effects* on the Mekong River System. The review process aims to identify design and operational measures that do this.
- The Joint Committee will agree a ***"Statement"*** at the conclusion of the prior consultation process that will urge the notifying country to make every effort to implement measures that eliminate or reduce the risk of transboundary harm.

- These measures can refer to either the Final Design, Construction or Operational phases.
- The measures need to be technically and financially viable. They would otherwise amount to a *de facto* veto of the development.
- The notified use is just one of a series of planned developments. It is important to consider the cumulative impacts of all the notified and planned projects.

The main purpose of the technical review is, therefore, to highlight what *additional and viable* efforts could be made to avoid, minimise and mitigate any harmful effects.

Improvements to the Prior Consultation Process

The MRC strives to continually improve the prior consultation process. In the previous processes the concept of ***"Statement"*** and ***"Joint Action Plan"*** or post prior consultation process were introduced to promote ongoing engagements throughout the design, construction operations phases of the HPP. In the Sanakham process greater effort has gone into delivering a more comprehensive first draft of the TRR, allowing more time discussion and agreement of measures to include in the ***"Statement"***.



The Lower Mekong Basin, showing the major fish migration routes, the major Mekong mainstream and tributary spawning areas, and the northern Lao cascade of HPPs.

THE SNHPP PRIOR CONSULTATION PROCESS

More frequent and transparent engagement with stakeholders is key to improving the outcomes of the prior consultation process.

The Prior Consultation Process Timeline

Due to the challenges of restricted mobility because of the COVID pandemic, the MRC has agreed that the prior consultation process for Sanakham would be implemented with a flexible timeline and with a step-wise approach in which each meeting of the Joint Committee Working Group will determine dates to carry out subsequent key activities. This is to allow meaningful participation from all stakeholders during the review process.

This process can be extended by agreement in the Joint Committee. Following international practice, this would typically only be considered if the MRCS experiences special difficulty in undertaking the technical review, or if critical new information comes available late in the initial process.

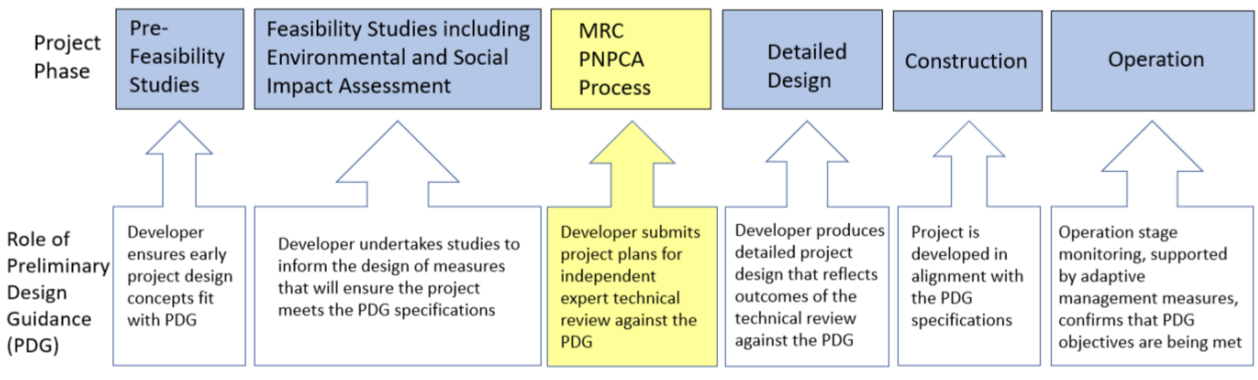
Under guidance from the JC Working Group (JCWG) on the PNPCA, the MRC Secretariat has appointed several expert groups, made up of national and international experts, to provide independent specialist evaluations of the documentation submitted.

Important Milestones for Stakeholders

- This Summary of the Technical Review Report is based on the first draft dated **21 September 2020**.
- The 1st round of national stakeholder consultations takes place in **October-December 2020**, and the 2nd round will be in **January-February 2021**, after the 2nd draft TRR has been completed. A 3rd round is planned for **March 2021.**
- The 1st regional stakeholder consultation is scheduled for **24 November 2020** and the 2nd one **in March-April 2021**.

Notification at the Feasibility Stage

Large infrastructure projects go through several phases. This allows the developer to incrementally assess the viability of the proposed project before committing additional resources and allows them to identify specific design requirements before finalising the design. The MRC's Design Guidance requires submission for prior consultation at the feasibility stage. At this point the development of the project is ongoing, and some changes may already be planned by the developer.

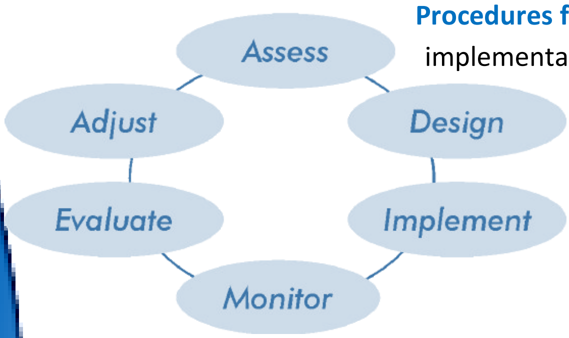


There are both advantages and disadvantages to this. It means that the prior consultation process can influence the final design and operation of the SNHPP. The Lao PDR and the developer can also make an earlier decision on the financial viability of the project based on the inputs from the MRC. However, notification at the feasibility stage may mean that there is insufficient information available to undertake a comprehensive technical review, and an unnecessarily negative impression of the proposed project may arise.

The Post-Prior Consultation Process

To address some of these shortcomings a post prior consultation phase is planned. This aims at continual engagements between the Lao PDR, the developer and the MRC and notified Member Countries during the final design, construction and operational phases. The intention is to refine the measures to avoid, minimise and mitigate any harmful effects by considering their engineering and financial viability.

Ultimately, it is hoped, that a set of operational measures, for example regular sediment flushing operations, can be agreed which will become part of the **Procedures for Water Use Monitoring (PWUM)** and their implementation will be reported on at the regular MRC JC meetings. This is critical in the light of the conjunctive operations of all the mainstream HPPs in the cascade. This together with the **Joint Environmental Monitoring (JEM)** programme may place the MRC in a better position to recommend adaptive management operations.



THE MAIN FEATURES OF THE SNHPP

Location

The Sanakham hydropower project is the most downstream of the cascade of 5 HPPs and is only some 1.5 - 2 km from the Lao PDR – Thailand border. This is important for the potential for transboundary impacts.

It is situated about 155 km upstream of Vientiane and 1,737 km from the sea. It lies some 20 km upstream of Chiang Khan, a large population centre in Thailand. Both the Lao PDR and Thai sides of the river are well populated for some 50 km downstream.

The project developer is the Datang (Lao) Sanakham Hydropower Company Limited. The construction was originally planned to commence in 2020. The power station was expected to start operations in 2028, but that will be delayed given that construction has not yet started.

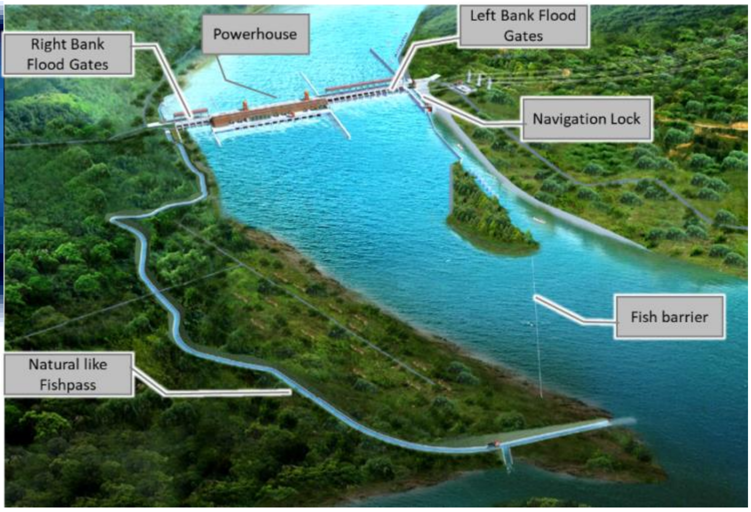
The power plant will have an installed capacity of 684 MW, with 12 turbines (generators), each producing 57 MW. The project is mainly intended for power generation for export and local consumption.

> *The SNHPP is only about 1,500 meters upstream of the point where the Mekong forms the border between Laos and Thailand*

Main engineering structures

Proposed Dam Sites

The developer considered several dam sites. The first was at Km 1772, but after an optimisation study done by the Lao PDR, it was moved about 35 km downstream. A site, about 3.1 km upstream of the present site, was considered but abandoned. Finally, an alignment some 280 m upstream of the current site was considered but found to be less suitable. The position and alignment of the SNHPP was therefore refined based on the hydropower potential of the full northern Lao cascade, and local impacts on villages that would be inundated.



A Run-of-River Project?

There is some uncertainty around whether the SNHPP will be operated as a run-of-river project. This is important to clarify as it will have a significant influence on the impacts in the Mekong immediately downstream of the project.

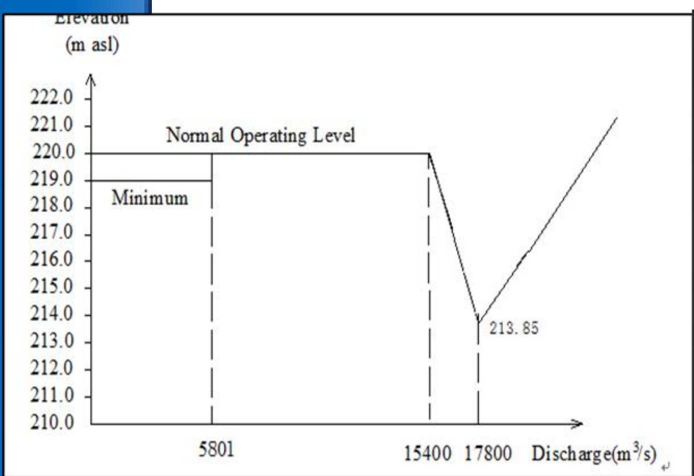
Operating Rules

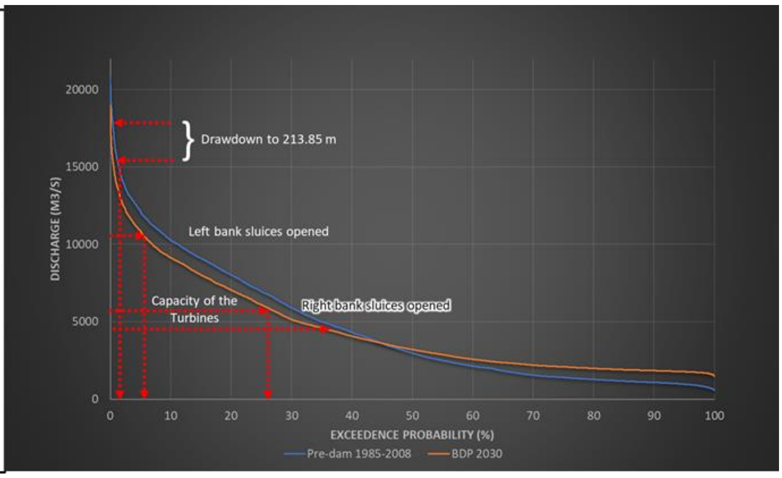
The normal pool level of the SNHPP will be between 220 – 219 masl. When the reservoir inflow is greater than the capacity of the turbines (5,801 m³/s), the sluices will be progressively opened to release the surplus water, this occur for about 23% of the time, probably on an annual basis.

At inflows less than 11,000 m³/s, the 5 flood sluices on the right bank will be opened first – i.e. for ≈ 6% of the time. These are at a lower level better suited for sediment flushing. The left bank sluices will be brought into operation as needed, starting at 15,400 m³/s – i.e. ≈ 1% of the time and probably not every year.

At inflows over 17,800 m³/s (i.e. a 3-year flood or < 1% of the time) all 10 sluices will be opened, and the pool level lowered. This will start when the flood is detected upstream to make room for the expected high inflow, and water levels. When the water head is below 4 m, all turbine units shall be shut down, and all gates will be opened for flood releases and sand flushing. Reservoir drawdown with all the sluice gates full opened will therefore occur for only 1% of the time in the long term. However, the operator will undertake sediment flushing operations for 5 to 7 days every year in early September. These rules should be re-examined as part of the joint cascade operating rules to enhance sediment flushing.

Ship lock operations will be suspended when the inflow is greater than the 3-year flood peak discharge of 17,800 m³/s, which will occur for less than 1% of the time.





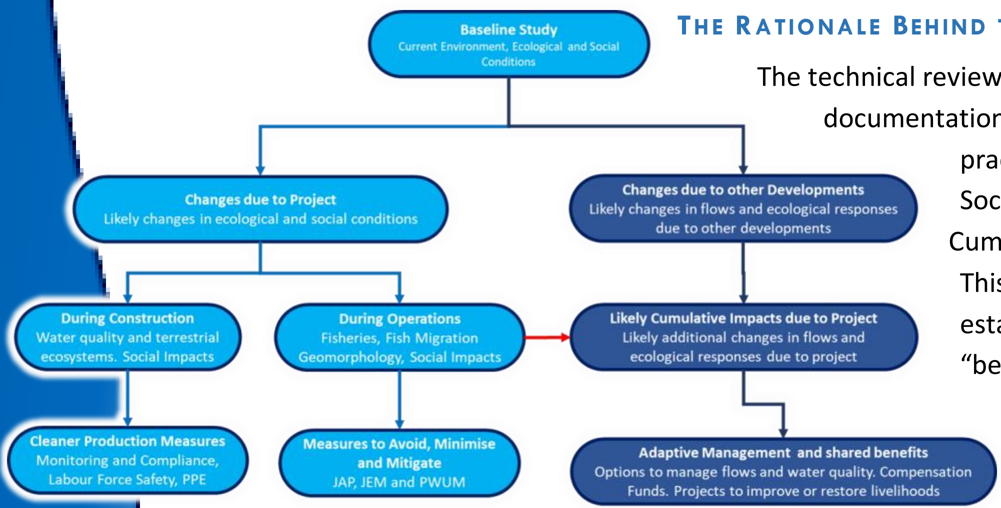
A SUMMARY OF THE TECHNICAL REVIEW REPORT

BACKGROUND

THE REVIEW PROCESS

The technical review has been undertaken by seven expert teams covering hydrology and hydraulics, sediment transport, water quality and aquatic ecology, fish passage and fisheries, dam safety, navigation and socio-economic issues. These teams as part of the MRCS work under the guidance of a Joint Committee Working Group for the PNPCA, who in turn report to the Joint Committee.

The review is based on the documents submitted by the Lao National Mekong Committee (LNMC).



THE RATIONALE BEHIND THE REVIEW

The technical review process assesses the documentation provided against good practice in Environmental and Social Impact Assessments and Cumulative Impact Assessments. This means the developer should establish a comprehensive "before project" baseline against which changes because of the project can be measured.

They should identify the potential[1] changes that may arise, and then establish well-funded comprehensive monitoring programmes to track any changes during the construction and operations phases. These should be designed to detect impacts in a timely way to support allow adaptive management.

Because impacts may also occur due to other projects, it is to the developer's advantage to identify the cumulative impacts of current and future projects. However, in transboundary systems underpinned by cooperation agreements, developers should also strive for joint operations that realise greater and shared benefits.

The review therefore:

- Supports the Lao PDR in their oversight of the implementation of the project.
- Supports the developer with the design of the project, and
- Provides the MRC Joint Committee with the information they need to agree on the ***"Statement".***

[1] Potential means the impact does not have to be proven in the EIA, but just that it is a possibility.

For the purposes of the technical review:

- ***Avoid*** means the measure, if implemented, would ensure that any residual harmful effects will be negligible.
- ***Minimise*** means the measure, if implemented, would reduce harmful effects, or the risk of harmful effects, considerably, and
- ***Mitigate*** means the measure, if implemented, would reduce the *impact* of any residual harmful effects on other users of the Mekong River System.

General comments

The data used are 10 years old or even older, which affects its usefulness. This leads to a skewed picture of the baseline situation, as well as the forecasts of possible changes during the operational phase.

In most cases, the sampling methodologies, sites, models and QA/QC procedures have not been described, making it difficult to assess the reliability of the data and results. The limited number of sampling occasions, sometimes not covering a full annual cycle will also distort the results. There are also contradictions and inconsistencies between the documents, making the review difficult.

The following sections summarise the main findings of the Technical Review Report.

Hydrology and Hydraulics

Why are the Hydrology and Hydraulics Important?

The future hydrology determines the how much power can be generated and hence the feasibility of measures to limit adverse impacts.

The *hydrology and hydraulics*[2] of the SNHPP determine the most appropriate design for both the generation of power, and the financial and technical viability of measures to avoid, minimise and mitigate any potential harmful effects.

Hydrological Data and Forecasts

The developers have calculated flow records at the SNHPP site using data from Luang Prabang and Vientiane. This has generated a daily flow for 1923 to 2012 at the dam site. The calculated records could be improved by incorporating recorded rainfall and flow from nearby sites. The developers have initiated monitoring at the project site, and these data should be used to update the forecasts of future flows. The effects of tributary hydropower and climate change have not been

[2] "*Hydrology*" is the amount and timing of water (volume) that reaches the project from upstream dams, rainfall and runoff processes, and hence what is available for power production, fish passage, navigation and sediment flushing.
"*Hydraulics*" is the water depths, velocities, turbulence, the transfer of flood waves, and other properties of flow in rivers and reservoirs.

included in the forecasts for future hydrology. The latter is now standard practice, while the MRC's studies have shown that tributary hydropower influences mainstream flows. The higher dry season flows due to upstream tributary hydropower will increase the total potential hydropower output. The MRC's 2030 flow scenario shows that, before the turbine capacity at the SNHPP is reached, for 77% the time flows are higher, and hence generating more power, compared to the pre-dam development (1985-2008) period[3].

The developer has proposed a flow forecasting system to be implemented before construction starts. But this is based partly on the Luang Prabang flow gauge which has now been drowned by the Xayaburi impoundment. It is recommended that the developer links into the Xayaburi and Luang Prabang flow forecasting systems to provide longer lead times. It is nevertheless expected that the northern Lao cascade operating rules, currently being developed, will address these issues.

Flood Frequency and Design Floods

The frequency and size of possible future floods is important to the design of the HPP, as it must be able to survive future floods. The design floods the developer have used are conservative and should be acceptable for design purposes. However, in the interim the Lao PDR has promulgated its LEPTS 2018 standards. These impose a more stringent design standard which must now be adopted for the design.

Modelling Tools for Impact Assessments

The use of computer and physical models helps the design process and improve the operating rules.

Several modelling tools have been used to support the feasibility level designs. Limited information on the models and their calibration has been provided at this stage.

A physical model for the SNHPP has been used to support the design, although it is recommended that further computer and physical models are used to improve the understanding of the hydraulics near the sluice gates. The SNHPP is situated on a bend in the river, and this will affect the way water flows toward and through the sluices.

Sediment Transport and River Morphology

Why is Sediment Transport Important?

The downstream transport of both fine and course grained sediment in the Mekong River is important to maintain the structure and functioning of downstream ecosystems, and to carry nutrients onto the floodplain areas.

[3] These calculations include the Lancang HPP, tributary HPP and climate change impacts.

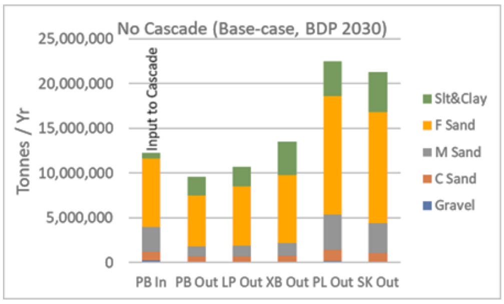
SEDIMENT TRANSPORT DATA AND IMPACTS

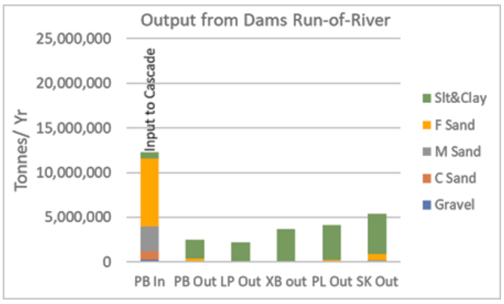
The documentation presents a wide range of sediment data which was used to model sediment transport through the impounded reach and the dam. The developer's sediment loads are based on very old data and are about 3 x higher than those determined by the MRC. The differences reflect the operation of the Chinese dams. More recent changes would also be expected due to the operation of the Xayaburi HPP.

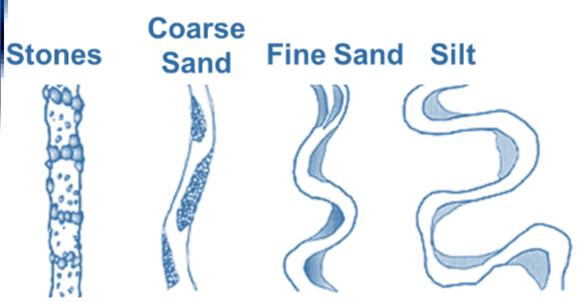
It is therefore recommended that sediment monitoring is initiated at the site as soon as possible, and that this is supplemented by the recent data from the MRC. This should be used to improve the sediment modelling at the site to provide a more reliable assessment of the impacts of the SNHPP on sediment transport. The MRC's modelling suggests that the impacts are likely to be considerably larger than suggested by the documentation.

The MRC's modelling shows that significant differences in total sediment loads, and grain size distributions are likely after completion of the whole northern Lao cascade:

- Pre-dam sediment loads are ~21 Mt/yr at the Sanakham dam site under the 'no cascade' scenario.
- Under pre-cascade conditions, most the sediment load passing through the Sanakham dam site is composed of fine sand.
- After the cascade, virtually all of the sand (fine, medium and course) and gravel is captured, with only silt and clay and little fine-sand discharged downstream, with a total about 5 Mt/year.







The transport of coarse and fine sand and silt affects the downstream habitats in the river

The "sediment hungry" water discharged from the SNHPP will have a significant impact on the river habitats (geomorphology) downstream and into the Lao – Thai border reach of the Mekong. Sediment will be scoured from the bed of the river and erosion and deposition patterns will change which will affect the ecology of this reach. This will be even more significant if hydropeaking operations are adopted.

These potential impacts are noted in the TbSEIA, but the measures to mitigate these impacts must be more clearly described and based on updated modelling with improved input data.

The SNHPP will also result in the loss of habitat drowned under the reservoir area. The documentation presents information on the geomorphology of this area and the EIA Report includes detailed maps of the potential area of inundation showing the distribution of different habitats that will be drowned, although details are not visible due to the scale of the maps.

It is noted that water level changes in the impoundment may cause slumping of the banks, and it is planned to strengthen the banks of the impoundment where necessary.

Sediment Management Infrastructure and Operations

> *The SNHPP includes plans for infrastructural and operational sediment management operations. However, the modelling and data need to be updated for a post Xayaburi condition. Further attention needs to be paid to sediment transport up to and through the dam using 2D modelling.*

The design and operations of the SNHPP include limited provisions for sediment management. As the inflow exceeds the capcity of the turbines the low level sluice gates on the right bank will be opened to transport sediment through the infrastructure. However, the 2D hydraulic modelling shows that flows in front of these gates is low. There are sediment sluices between every second turbine to manage accummulation. But sediment would need to accummulate for some time before these can discharge sediments. These issues raise questions about the sediment passing efficiency of the structure.

The developer intends to open the right bank gates when flows reach 5,801 m^3/s. This will promote the transport of sediment deposited near the dam, but will not flush sediments within the impoundment. When flows exceed 17,800 m^3/s approximately once every 3 years, gates will be gradually opened and the water level will be reduced, which will mobilise some sediments in the impoundment. Flushing will also be implemented to manage the deposition of sediment at the upstream extent of the impoundment with frequency guided by monitoring results.

It is recommended that regular sediment management operations are included in the joint cascade operating rules. The developer proposes managing sediment in concert with the Pak Lay HPP.

Sediment Monitoring During Operations

The developer needs to update the sediment monitoring programme for a post Xayaburi situation.

The bathymetry of the impoundment will be monitored along one longitudinal control line, and 90 cross-sections. This will provide an indication of sedimentation in the impounded reach which can be used for adaptive management.

Shoreline monitoring in the impoundment and riverbank downstream of the SNHPP will be done annually after each flood season, and riverbank strengthening will be done where needed. The developer notes that river bank strengthening has already been undertaken on the Thailand bank of the river in the Chiang Khan area. Any further work must be done with the consent and involvement of the Thai Authorities.

Water Quality and Aquatic Ecology

Why are Water Quality and Aquatic Ecology Important?

Construction activities and the storage of water can lead to changes in water quality, which can affect other users of water. Aquatic ecosystems form the basis for the fisheries and other services that so many in the Lower Mekong Basin depend on.

Baseline monitoring – Water Quality

This reach of the Mekong mainstream is mostly in the "Excellent or Good" class, and suitable for protection of aquatic life, human health and for agricultural use.

Water quality sampling was conducted on one occasion in both the dry and wet seasons (2010 and 2011 respectively). A range of water quality parameters were collected and analysed using standard methodologies, but no quality control details have been reported. Only the dry season results are presented. This monitoring is not sufficient to establish a reliable baseline against which to monitor changes.

The potential for algal growth in the impoundment is not considered a problem because of the short retention time of the water. However, the dominance of the toxic algae, *Microcystis aeruginosa,* in the samples is a potential cause for concern. The developer intends to limit the impact of algal growth by clear cutting the vegetation in the impounded area, which reduces the release of nutrients from decaying vegetation. However, some hardwood trees should be left to provide habitat and feeding areas for fish.

Baseline Monitoring – Aquatic Ecology

The aquatic ecological baseline monitoring is similarly limited. The numbers and diversity of aquatic organisms reported is much lower than what have been found by during the MRC's monitoring. This may be a result of the monitoring methodology.

This is also insufficient up to date data to establish a reliable post-Xayaburi baseline. It is therefore recommended that more comprehensive monitoring is undertaken before construction starts.

> *Baseline monitoring has been limited, and the proposed monitoring programs need to be expanded and implemented for at least two years before construction starts.*

Construction and Operational Monitoring

Water quality monitoring during construction has been outlined, but this is not linked to potential pollution risks. Continuous monitoring, linked to emergency response protocols, is needed to identify and control pollution incidents.

Operational monitoring should similarly be based on the potential changes that may result because of the SNHPP. The programme described is not consistent with international standards, and it is recommended that the MRC's **Joint Environmental Monitoring** protocols are adopted. More relevantly, the budget provided for ongoing monitoring is very small and will not sustain a comprehensive programme for either water quality or aquatic ecosystem monitoring during operations.

Potential Impacts During Construction

The river reaches upstream and downstream of the SNHPP will be subject to considerable impacts during the construction phase, which will impact water and habitat quality, and hence aquatic ecosystem functioning. Activities such as excavation, earthworks and transport of construction materials can lead to increases of suspended solids, oils and chemical spills. Improper disposal of organic and domestic wastes can cause environmental damage resulting in degraded soil, water and air quality. The proximity of the Thai border makes these, even local pollution incidents, potentially transboundary impacts.

These can be managed if strict criteria, and well-established management protocols and good environmental practices are established and adhered to. It is assumed that the Lao PDR's environmental compliance monitoring during construction will ensure adequate supervision.

Potential Impacts During Operations

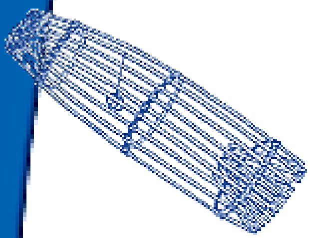
Water quality problems may arise during the operational phase, some of which are outlined by the developer. The risks are mostly associated with an increase in pollution due a higher population surrounding the impoundment, and changes in the downstream habitats. Sediment flushing from the reservoir may also smother downstream habitats causing loss of invertebrate fauna and lost spawning areas, in the immediate downstream reach.

Fish spawning and macro-invertebrate habitats will be lost in the immediate downstream reach

The SNHPP will inundate the last free-flowing section for some 600 km upstream. This will threaten aquatic ecosystem functioning in the northern Lao section of the Mekong mainstream. Consequently, the reach immediately downstream of the SNHPP down to Vientiane, becomes more critical as the last refuge for species requiring flowing water to complete their life cycles (assuming the Pha Mong HPP does not proceed).

This will in turn require a robust long-term biodiversity monitoring and evaluation programme for this reach.

Fisheries



The Importance of Fisheries

The Mekong River System has the world's largest inland fishery with a value of some $7 billion. Fisheries are vital to sustaining the livelihoods and food security of many of the rural poor in the basin. However, many of the targeted Mekong fish species are migratory. The inclusion of fishpass facilities at mainstream HPPs is therefore standard practice.

While most of the fisheries productivity is in the reaches below Vientiane, considerable fishing activity takes place in the SNHPP area and further upstream, mainly based on migratory fish species. It has been estimated that some 40,000-60,000 tonnes/yr of fish are caught the upper migration zone. Fishing generally occurs during the period of upstream migration and is associated with increasing water levels. It has been estimated that a 40% reduction in the catch of whitefish species in this area may occur if the full cascade of HPPs is developed.

The Baseline Survey

The SNHPP documentation includes:

- A review of the fisheries literature for the Mekong focusing on the Sanakham reach.
- Surveys carried out at six sites near the proposed SNHPP in November 2010 and July 2011, and
- Supplementary information on fishing activities in the area, collected in Chaiyaburi Province on 3 December 2011.

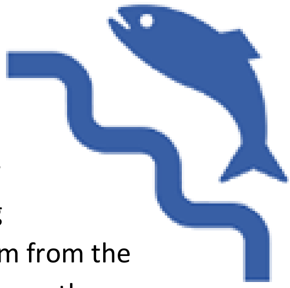
The developer lists the fish species found and their threatened status. However, the fish sampling strategy was not in line with international protocols or consistent with the **JEM** protocols.

A total of 57 fish species were found, which is consistent with the number of fish species reported by some other Mekong mainstream hydropower projects. However, this is considerably lower than to 200-300 species indicated by the MRC Fish Abundance and Diversity Monitoring studies, or the 160 species reported in the Luang Prabang HPP EIA.

Much of the catch reported was juveniles suggesting the area is an important nursery area. However, the lack of large individuals highlights the weaknesses in the sampling strategy as larger individuals should be represented in the catch data. Similarly, little attention is paid to other aquatic animals and useful aquatic plants. The baseline monitoring does not address the importance of fisheries to the local communities and does not highlight any threats to livelihoods or food security.

The baseline monitoring is therefore not adequate to establish a reliable baseline and it is recommended that additional monitoring using the **JEM** protocols is initiated as soon as possible and before construction starts.

Fish Migration

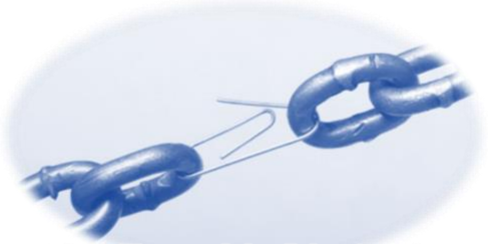


Why is Fish Migration Important?

Many of the fish species that form most of the catch are migratory and must move up and down stream to complete their lifecycles. There are three main migration systems in the Mekong mainstream, the lower zone below Khone Falls, the zone upstream from the falls to Vientiane and the third zone upstream of Vientiane. However, there are also many species that migrate between these zones, and some species (possibly as many as 30 and mostly commercially valuable white fishes) that migrate over longer distances between zones.

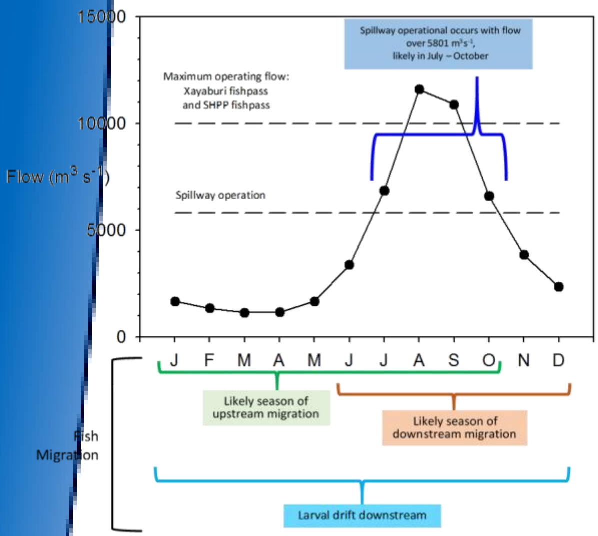
The SNHPP is in Zone 1 and the dam will obstruct both upstream and downstream migration. This will lead to a reduction in the number and biomass of migratory species and potentially a proliferation of non-native species, particularly common carp and Nile tilapia, which will benefit from the changed environment. The dam will also likely inundate many deep pools that act as refuge areas for fish during the dry season.

Principles of Fish Passage Design



The efficacy of the fish migration facilities is determined by the weakest link in the chain of factors required.

Fish passage infrastructure at a site requires consideration of several interlinked factors all of which must function well to allow fish to pass the dam in both an upstream and downstream direction. The weakest link in this chain of factors will determine the efficacy of the complete fish passage. Similarly, if fish can pass upstream but if their spawning habitat is not available, or if the juvenile and larval stages cannot pass back downstream, their numbers will decline rapidly. The same principle of *the weakest link* also applies to fish passage at multiple dams.



Fish passage facilities must function for the periods when upstream and downstream fish migration is occurring, with entrances located where fish will find and use them.

Overview of Assessment of Submitted Design

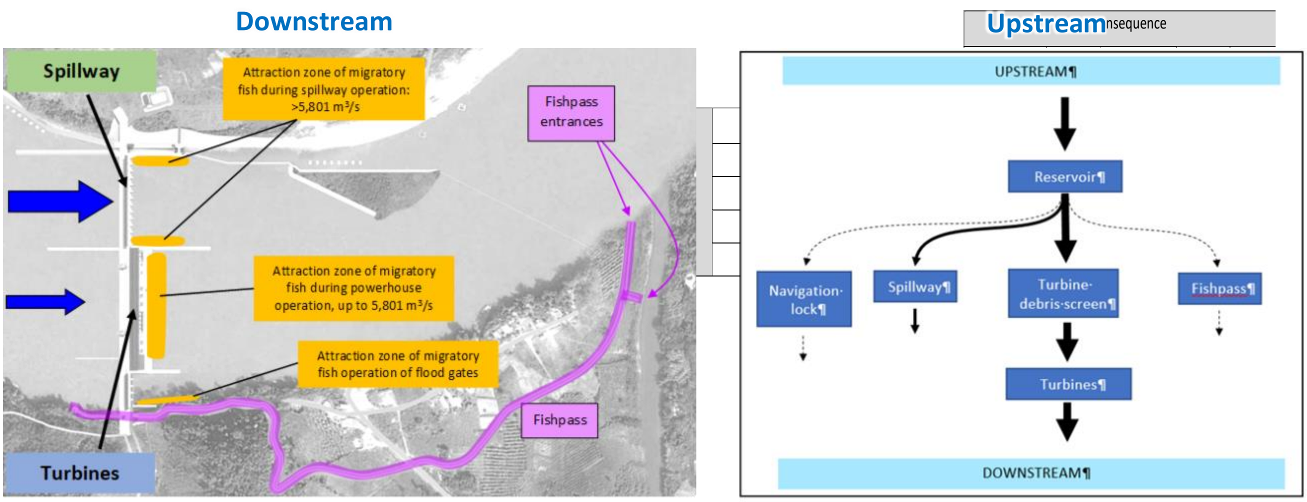
The developer has proposed a “nature-like” fishpass for upstream migration and turbines as the main passage for downstream migration. The “nature-like” concept has potential, but the overall design for upstream and downstream fish passage, as submitted, will not provide sufficient migration to sustain migratory fish populations.

Key Recommendations for Fish Passage

Upstream fish passage needs: i) multiple entrances at the dam and spillway where migratory fish are attracted to (not 1 km downstream, as submitted); and ii) to use 336 m^3/s to attract and pass fish (not 6.6 m^3/s, as submitted); and iii) be designed for fish up to 300 cm (not a maximum of 60 cm, as submitted).

Downstream migration occurs through the impoundment, turbine debris screens, turbines, spillways and, to a much lesser extent, the upstream fishpass and navigation lock. To provide safe downstream fish passage the TRR recommends: : i) maintaining 0.3 m/s water velocity in the impoundment for drifting larvae; ii) installing a collection and bypass facility at the turbine debris screens to divert large fish; and iii) designing turbines with no net pressure changes for fish, minimal shear, and blade strike. Details are provided in the TRR.

Key:	Low	Moderate	High	Very High



Potential migration routes and attraction zones

Risk assessment

The MRC Fisheries and Environment Expert Group have evaluated the risks to fish migration by assessing the likelihood of impaired fish passage, and the consequences of that on the migratory fish populations. Those risks that are *Very High* or *High* are the highest priorities to address in any revised design. The risks before and after the measures outlined above are outlined on the following page.

Risks Before Additional Measures

	Upstream Migration			Downstream Migration			
	Limited attraction and entry into fish passage facilities	Limited ascent of fishpass	Ineffective exit – risk of fallback	Limited passage through impoundment	Limited attraction and entry into fish passage facilities	Mortality passing Sanakham site – including debris screens, turbines and spillway	Poor exit; risk of predation downstream
Life Stage							
Larvae & fry	N/A	N/A	N/A	Very High	Very High	High	Moderate
Small-bodied species (5 -30 cm)	Very High	Moderate	Low	Moderate	Very High	High	Moderate
Medium-bodied (30-150 cm)	Very High	Moderate	Low	Low	Very High	Very High	Moderate
Large-bodied (150-300 cm)	Very High	Very high	Low	Low	Very High	Very High	Low
Behaviour							
Surface	Very High	High	Low	Low	Very High	High	Moderate
Mid-water	Very High	High	Low	Low	Very High	Very High	Moderate
Benthic (including thalweg)	Very High	High	Low	Low	Very High	Very High	Moderate
Migration Flow							
Low (dry season)	Very High	Moderate	Low	Very High	Very High	Very High	Moderate
Moderate (early wet, late wet)	Very High	Moderate	Low	Moderate	High	High	Moderate
High (wet season)	Very High	Moderate	Low	Low	Low	Low	Low
High Biomass	Very High	High	Low	Low	Very High	Very High	High

Key: Low Moderate High Very High

Risks After Recommended Measures Are Applied

	Upstream Migration			Downstream Migration			
	Limited attraction and entry into fish passage facilities	Limited ascent of fishpass	Ineffective exit – risk of fallback	Limited passage through impoundment	Limited attraction and entry into fish passage facilities	Mortality passing Sanakham site – including dam turbines	Poor exit; risk of predation downstream
Life Stage							
Larvae & fry	N/A	N/A	N/A	Moderate	Moderate	High	Moderate
Small-bodied species (5 -30 cm)	Moderate	Moderate	Low	Low	Moderate	High	Low
Medium-bodied (30-150 cm)	Moderate	Moderate	Low	Low	Moderate	Moderate	Low
Large-bodied (150-300 cm)	High	High	Low	Low	Moderate	Moderate	Low
Behaviour							
Surface	Moderate	Moderate	Low	Low	Moderate	Moderate	Low
Mid-water	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate
Benthic (including thalweg)	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate
Migration Flow							
Low (dry season)	Moderate	Moderate	Low	Low	Moderate	High	Moderate
Moderate (early wet, late wet)	Moderate	Low	Low	Low	Moderate	Moderate	Low
High (wet season)	Low	Low	Low	Low	Low	Low	Low
High Biomass	High	High	Low	Low	Moderate	Moderate	Moderate

The expert's risk assessment clearly shows that there are likely to be considerable benefits to implementing the recommendations made in the TRR. However, such large fishpass facilities are, as yet, unproven for large tropical rivers like the Mekong, and until data emerges from the monitoring at Xayaburi, many uncertainties will remain.

Dam Safety

Why is Dam Safety Important?

Large dams pose significant risks to downstream communities if they fail, causing both economic damage and loss of life. Dams must therefore be built to agreed design standards. This is particularly important in the SNHPP case given the proximity to the Lao-Thai border and the large population on both sides of the river just downstream.

Geology and Seismic Studies

The underlying geology is permeable in places and the developer confirms that consolidation and curtain grouting of the foundation will be undertaken. The SNHPP is located at a sharp left-hand bend in the river. The processes of erosion and deposition on this bend will be reduced upstream once the HPP is operational but will continue downstream. The sharp bend at this location will have implications for the approach and exit flow conditions from the spillway and erosion control measures must be considered. The developer notes that liquefaction is possible under the coffer dams, and special provisions will be required during construction.

The regional earthquake risks have been assessed. While there are some faults within 30 km of the site, the developer concludes that these faults have little effect and the project site is in a zone of regional stability. Historic earthquakes in the Sanakham area have been assessed using the records covering 553 years prepared by the Thai Department of Mineral Resources. Based on these data earthquake activity in the project area is considered to be low. There has been no assessment of the November 2019 earthquake. This should be undertaken.

The MRC's latest guidelines suggest that much more extreme earthquake events, than the developer provides for, should be considered. These also suggest that ICOLD[4] Bulletins 120 and 148 should be followed. There is no reference to either of these Bulletins in the Engineering Status Report. Because the SNHPP lies in the Moderate Seismic Zone in Lao PDR, the LEPTS 2018 suggests an estimated seismic coefficient of 0.1g for the Maximum Credible Earthquake but requires that a site specific study is undertaken.

Flood Design Standards

The developer proposes that the infrastructure should be designed for a 1:2,000-year flood event, with the check flood based on a 1:10,000 year event[5]. However, the LEPTS 2018 places the Sanakham dam in the "Extreme Risk" category. This requires that the Inflow Design Flood is the Probable Maximum Flood (PMF) with no damage to the structure. The LEPTS also require that the discharge capacity at

[4] **I**nternational **C**ommittee **O**n **L**arge **D**ams

[5] The Design flood is the flood that will safely pass the structure without any damage. The PMF will safely pass but may cause minor damage.

the upstream dams also be considered in the design. As the feasibility level design was done before the LEPTS 2018 were promulgated, these have not been considered in the design.

Spillway Discharge Capacity


The physical model of the SNHPP

The capacity of the spillway gates has been determined through standard formulae. However, whilst this approach is suitable as a first approximation it is not adequate for design purposes. Approach flow conditions could be complex and interaction between gates may have a substantial influence on overall capacity.

A physical model investigation, covering the entire powerhouse and spillway structures has been undertaken. Given the approach flow conditions, this model should be used to assess the operations of the gates, and the MRC and LEPTS design flow conditions (PMF) tested with one gate not in operation. Further model studies are therefore required.

While the documentation does not refer to freeboard requirements, during the check flood conditions with all gates operational, a 6.2 m freeboard will occur. However, the LEPTS 2018 provides more detailed freeboard requirements based on several different combinations of conditions. The developer should demonstrate that the proposed freeboard complies with these requirements, also using the PMF as the Inflow Design Flood, and with one gate out of operation.

Gate Type and Reliability

Vertical wheeled gates raised by a cable winch are proposed for all spillway openings. This self-closing characteristic offers no advantage to spillway gates where reliable opening is the prime objective. The gates must be raised in one segment resulting in a winch structure rising approximately 34 m above dam crest level. This places the winches in a highly inaccessible location where maintenance and replacement will be difficult.

This suggests that radial gates might be a better solution, as are in place at Xayaburi, and proposed for the Luang Prabang mainstream cascade HPP. Radial gates provide smoother flow discharge performance at all stages of opening and the hydraulic pumping sets for the hoists are located at crest level for easier maintenance.

Reliable gate operation is key for dam safety, and some authorities require the Design Flood to be safely discharged with one gate out of operation (n-1). The Engineering Status report mentions that the dam is safe under the 10,000 year flood with two gates out of action. This is a prudent concept and is a requirement of LEPTS 2018 but a re-examination of freeboard under the revised PMF Inflow Design Flood is still required.

A broader consideration of gate reliability is also required to cover extreme conditions. It is not clear how long the vertical lift gates would take to respond, *The developer needs to engage the Lao Government with respect to compliance to the LEPTS 2018.*

particularly if the primary source of power were not available. The possibility of providing a rapid response facility in the spillway arrangements for forced grid outages should consequently be examined. Solutions that have been adopted on other projects include an ungated overflow section, an air regulated siphon or bottom hinge fish belly gates. At least one of these options needs to be studied in conjunction with an increase in total spillway capacity required to achieve compliance with LEPTS 2018 in the final design stage.

Energy Dissipation and Erosion

The developer proposes the 50-year flood as the design basis for energy dissipation and erosion protection. The physical model indicated scouring depths of up to 5 m and velocities were reported to return to normal conditions within 1 km of the dam. The developer concludes that the proposed energy dissipation and scour protection arrangements will be adequate to avoid any risk to the structures provided the gates are operated in an appropriate sequence.

However, the LEPTS requires that "*plunge pools and other areas near the dam toe shall be designed such that no significant damage occurs under design flood conditions".* A much higher return period design condition should therefore be adopted to ensure that regressive erosion does not occur that could place the spillway structure at risk.

Flood Management

Effective flood management requires an early warning of inflow flood conditions. A system has been proposed, but this should tie into the early warning systems at the Xayaburi and other planned upstream HPPs. However, a cascade flood management plan should be developed with the Government of Lao PDR, which addresses all the HPPs in the cascade, and which makes provision for warning downstream communities. The latter must include input from the Thai authorities.

A cascade flood management system should be developed that includes sediment management fish larval drift considerations, and flood management.

Design Standards

The stability of the infrastructure must comply to the LEPTS. Given the proximity of the Lao – Thai border, and the relatively large Thai population that could be affected by a dam break, the Government of Thailand (GoT) may also wish to compare the design standards applied to their standards. It is therefore recommended that the developer sources and includes the relevant Thai Design Standards for comparison purposes.

Panel of Experts

> *A Panel of Experts should be established as soon as possible, as is recommended by the PDG 2009, ICOLD and World Bank Guidelines.*

The Engineering Status report refers to an Expert Consultation Team. It is understood that this team comprises experts from within the developer's organisation and their advisors and is therefore not an independent panel. The documentation does not refer to the appointment of a Dam Safety Review Panel (DSRP), which is required under World Bank Operational Policy 4-37 and the PDG 2020.

The DSRP must be established as early as possible in the project development when investigations are in progress and layout decisions are being made. The Terms of Reference for the Panel are often extended beyond dam safety to cover broader issues of project formulation such as construction procedures, river diversion and power generation facilities. It would be beneficial if similar broader Terms of Reference were adopted for the Sanakham Hydropower Project.

The appointment of a DSRP is a GoL responsibility, although funding is typically provided by the developer.

Emergency Preparedness Planning

The draft PDG 2020 requires the development of an Emergency Preparedness Plan (EPP) for the construction, and operating stages of the project. This should be done for both the river diversion stages. In addition, it would be beneficial for a separate plan to be developed for the first impounding when structures are loaded for the first time and much higher levels of monitoring and rapid response are required.

The Engineering Status report provides a preliminary description of emergency planning and indicates that the EPP will be developed one year before reservoir impoundment. No construction stage EPP is proposed. This is required.

Dam Break Study

The developer has considered a potential dam break for both the second stage coffer dam and the main dam. In both cases there are some impacts on the downstream towns and villages, but not on Vientiane.

However, there is no attempt to assess the people and property at risk on the Lao and Thai banks or to consider the risk that a flood wave might pose to river craft, riverbank users and sand mining operations (8 km downstream). It is critical that a study that identifies what infrastructure and populations could be at risk is undertaken, and that this is shared with the Thai authorities when finalising the emergency preparedness plans.

Instrumentation

The Engineering Status report drawings provide an initial indication of the instrumentation that will be provided. The final requirements can be determined later in the development of the project when foundation conditions have been fully exposed, and a failure modes assessment has been undertaken.

Dam Safety Management System

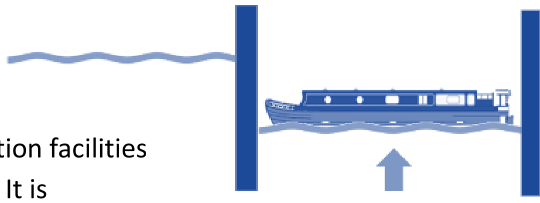
A Dam Safety Management System (DSMS) should be provided. This is a formalisation of procedures that are adopted as part of good practice in dam safety and builds on the issues raised in ICOLD Bulletin - Dam Safety Management. The MRC Design Guidance provides additional recommendations on the structure and content of the DSMS.

Reference should also be made to the Dam Safety Guidelines that are part of LEPTS 2018. The Engineering Status report does refer to several of these issues, but it is too early in the development of the project for the DSMS to have been developed in any detail.

Failure Modes Assessment

The PDG 2020 requires the development of a detailed Potential Failure Modes Assessment (PFMA). The Engineering Status report does not include this assessment. This is reasonable at this stage, but a failure modes assessment should be undertaken at the commencement of the detailed design stage. The output of the assessment will inform the scope of further ground investigation, the development of the DSMS, the Emergency Preparedness Plan and the Instrumentation Plan.

NAVIGATION



WHY IS NAVIGATION IMPORTANT?

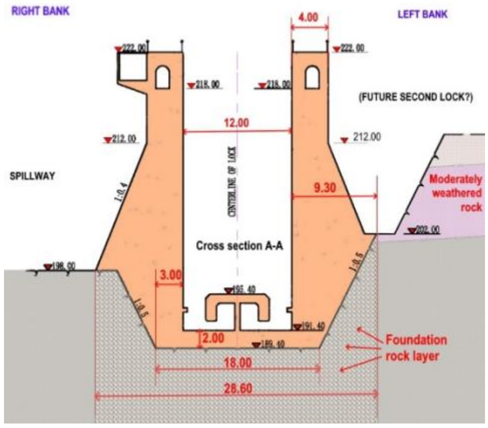
The 1995 Mekong Agreement indicates that navigation facilities must be incorporated into any mainstream project. It is acknowledged that the impounded sections of the river behind hydropower dams can facilitate navigation making it safer if navigation locks are incorporated into the design of the HPP.

MAIN FEATURES

The navigation lock will be located on the left riverbank. This will require considerable excavation of the left bank, leaving a small island. The island and a guiding wall will separate the downstream approach channel from the mainstream and hence from the higher flows from the left bank spillway and powerhouse. The upstream approach will be along the left bank.

A single step lock with a maximum working head of 20.38 m is proposed. The effective length of the lock chamber is 113 m long, 12 m wide and 4 m deep.

The Navigation Lock Chamber



The lock chamber has a floor thickness of only 2 meters. The width at the foundation is 18.00 meters. The wall thickness varies between 3.00 m (at the base), to 9.30 m at the widest level and then narrowing to 4 m at the top. This provides for a much thinner floor slab than have been proposed at the upstream HPPs.

	Luang Prabang	Pak Lay	Pak Beng	Xayaburi	Sanakham
width 1	12.00	12.00	12.00	12.00	12.00
width 2 (min. and max.)	35.00	36.00	42.00	27.00	18.00 a 28.60
total height	39.50	34.00	49.00	53.00	32.60
thickness floor	9.00	7.00	5.62	4.00	**2.00**

The developer is therefore encouraged to re-examine the design in the light of the above and consider a redesign if necessary.

The useful length of the ship lock is less than the 120 m as is required in the PDG2009. The length of the lock chamber should therefore be increased.

Air Clearance

The Mekong mainstream has a minimum air clearance for navigation of at least 10 m. The upstream service bridge has an air clearance of only 8 m. The downstream service bridge has a clearance of only 2.80 m, when the chamber is full. Ships can pass under this bridge only once the lock has been emptied.

The developer should increase the upstream service bridge height from 8 to 10 meters and confirm that the stoppage cable will be installed in front of the downstream service bridge.

The filling and emptying system

The filling and emptying regime may result in high hawser[6] forces. This can be addressed by either changing the design of the filling system or adjusting the program for opening of the tainter valves to avoid a resonance wave in the chamber. The TRR makes some proposals in this regard. The reversed tainter valves are nonetheless suitable for high lift locks and are reasonably resistant to cavitation.

Upstream and downstream approach channels

It appears that lengths of both navigation approach channels are around 250 m in line with the ship lock axis. However, there is uncertainty around the upstream approach which may only have a straight-line channel of 220 m, as the last 30 m included in the developer's design are part of the lock itself.

[6] Hawsers are used to tie the vessel when moored.

The upstream guidance wall provides a comfortable entrance to the ship lock in a straight line with the right bank ship lock wall. The mooring facilities are sufficiently far upstream, but line-hooks should be provided at regular intervals in the guidance wall. There is no information on recessed ladders for this guidance wall and it is not known if the mooring dolphins offer access to the land through interconnected floating walkways which is a good practice.

The downstream approach is in a straight line and sufficiently long (> 250m). But the approach is not wide enough as the mooring area intrudes into the navigation channel. The mooring dolphins should be set back to provide a full width of the navigable water surface of 52 meters.

There is no guidance wall in a straight line with one of the ship lock chamber walls making access for bigger vessels and pushed convoys more difficult. A guidance wall of about 200 m in line with the left bank chamber wall, like that at the upstream approach channel, should be considered.

A clearly readable gauge plate should be provided next to both mitre gates and inside the lock chamber.

Ship Lock Chamber Equipment

There are only 2 x 2 ladders in the entire ship lock chamber. Additional ladders should be included, but do not necessarily have to reach the floor slab. However, they should reach level +198.00, i.e. 2 meters under the low-water line.

There are 2 x 6 floating bitts which is like all previous ship lock chambers for the mainstream HPP-projects. No line hooks have been included in the lock walls. These should be placed adjacent to the ladders. There are no steel slider wall protections or wall armour in the lock walls.

An overhead rolling crane stretching the entire length of the lock chamber is recommended for rescue, lift sunken small boats, lift sunken debris in front of the gate-sills, lift bulkheads, to lift and replace the bulkheads etc.

Operation, safety and maintenance

Navigation conditions will be improved over approximately 600 km through impounded backwaters of the whole northern Lao cascade. This will enable navigation with larger vessels and improve the transport of goods along the river. However, a River Information System (RIS) should be designed and integrated with any joint reservoir operating rules. The RIS will, amongst others, advise skippers of the navigation conditions and the estimated waiting times at each lock system.

The safety of lock operations at the SNHPP must be addressed through both preventive measures and quick reaction and intervention in case of accidents. Ship locks with high lifts are a danger for small vessels. Lock chambers are filled up through bottom orifices that often produce heavy turbulence and mushroom shaped vertical upsurges. These can be problematic for small boats, and it is recommended that a special filling program is developed for small boats.

Emergency stoppage of the locking operation must be possible not only by the lock master but also by the skippers and the supervising staff if needed. A two-way communication system between skipper and lock master should be provided.

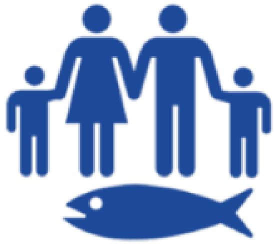
It is important that spare parts for running repairs are immediately available.

Navigation during construction

The first phase will include the construction of the navigation lock, approach channels and the spillway behind a cofferdam. Continuation of navigation during this period is possible through the right bank gap which is the deepest part of the river. The developer has indicated that the navigation lock system will be operational during the 2nd phase of construction. No special provisions for the small fisher / family boats has been made. At the other HPP these smaller boats have been put on a trailer and transported around the construction site.

Design of the second lock system

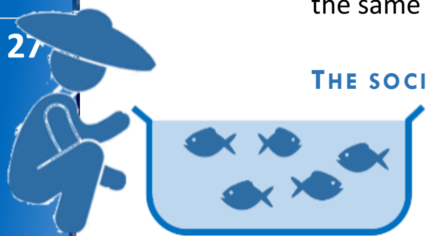
The design of the 2nd lock is recommended under the PDG 2009 and it is recommended to be in parallel with the first one and use the same approach channels. The SNHPP design calls for a bypass channel through a hill on the left bank. However, in line with the PDG2009, the TRR has made an alternative recommendation for a parallel lock on the left bank.



Socio-Economic Issues

Why are Socio-Economic Issues Important?

The generally accepted practice, and Lao PDR legislation requires that all livelihoods that may be affected by the project be restored the same or better level than before the project.



The socio-economic baseline

The baseline was determined through desk studies, field surveys including household census, and village interviews and meetings.

The land that will be inundated comprises 4,425 ha of bamboo and other forest types, rice paddies, ray (shifting cultivation), residential and other lands. Three villages would be inundated, requiring resettlement, and 10 villages would be partially affected (i.e. not totally inundated), requiring some relocation to higher ground. The total number of directly affected people is estimated at 62,530.

Surveys along both downstream banks, for about 100 km downstream were undertaken in 2010 / 2011. These provide general descriptions of the demography, infrastructure and livelihoods of villages in Lao PDR and Thailand. The TbESIA/CIA provides some general information on populations further downstream in 4 zones, with a focus on residents within a 5 km corridor from the Mekong:

- **Zone 1:** Thai-Laos – Pak Heuang (KM 1736, confluence with the Heuang River ~ 1km downstream of dam) to Ban Woenbuk (KM 904)
- **Zone 2:** Southern Laos – Ban Woenbuk (KM 904) to Cambodian border (KM 723)
- **Zone 3:** Cambodia – Cambodia border (KM 723) to Vietnam Border (KM218)
- **Zone 4**: Southern Vietnam – Vietnam border (KM 218) to Mekong Delta (KM 0)

Zones	*Degree of Dependence*	
	Left Bank	*Right Bank*
Zone 1	3.1	2.7
Zone 2	3.3	3.2
Zone 3	4.1	4.0
Zone 4	4.1	4.2

There are more than 24 million people potentially affected by transboundary impacts. However, only those within 100 km downstream of the SNHPP have been formally considered as affected people.

Expected Impacts and Mitigation Measures

Direct social mitigation measures are described in the SIA package. Most of these are formulated as options, recommendations, principles or statements of intent, instead of firm commitments. The most comprehensive package of mitigation and compensation measures is formulated in the RAP, covering just the resettled populations. The packages for other groups with similar impacts (such as people relocated within their village, people losing part of their assets, people losing their livelihoods but not their homes) are less clearly described.

The total budget for the SMMP is given as USD 274,120. This is extremely low, for example the SMMP for the Pak Lay project has a budget of USD 90.6 million. This may be a result of arithmetical errors, or that some of the activities are not included e.g. it may exclude the resettlement budget. The total budget for the RAP is given as USD 23.3 million, which is less than USD 8,000 for each person to be resettled or relocated. This appears to be low by international standards and compared to the other mainstream hydropower projects. The management plans and their budgets must in any event be updated to align with the new regulatory frameworks and based on reassessments of the number of people and assets affected, and their unit costs and values.

Comments on the socio-economic aspects

The information presented is generally 10 years old or even older. This predates new Lao legislation and significant development over the last decade. Economic growth in Laos over the last 10 years ranged from 8.5% to 4.6%,[7] approximately doubling national income within a decade, while population growth averaged 1.5%. This has changed the socio-economic baseline situation, impacts and required mitigation significantly.

The documentation covers the population within a 5-km corridor and is thus not directly comparable to the MRC's 15-km corridor data. In each downstream zone,

[7] https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=LA

some villages and districts have been surveyed or are described, but no information is provided how these were selected and how representative they are. The index for 'degree of dependence' could be useful for highlighting areas of concern, but the figures are based only on expert opinion and not substantiated.

Impacts are generally not differentiated by gender, ethnicity, income or other categories. There is a superficial analysis of gender and vulnerability issues, which does not include specific mitigation measures for all vulnerable groups.

Potential impacts on populations within 100 km downstream of the SNHPP are mentioned, but they are not comprehensively analysed with a view to maximizing the positive impacts and minimizing the negative impacts. Several villages and townships such as Sanakham in Lao PDR and Chiang Khan in Thailand are within 20 km of the dam, and some of them will be nearby work camps, access roads, transmission lines, quarries and other project components.

These components are not clearly indicated on maps, and hence it is unclear who will be affected and how those impacts could be mitigated through siting of components. With a large workforce, several nearby communities in Thailand, and limited border controls, there are risks of conflicts, communicable diseases, and social problems. Such impacts depend strongly on the siting and management of camps and the proportion of local workers, which are not described. There are also no clear predictions on the likely impact on local river-related activities such as tourism (including the downstream rapids), fish cages in the river, local navigation, sand mining, or riverbank gardens and fish farms.

Mitigation / Compensation

Mitigation measures related to the physical displacement of people in the immediate project area are relatively well defined. But the mitigation measures for villages which are not directly displaced are less well defined. Notably, it is unclear which mitigation measures identified will cover these communities.

Large infrastructure projects can provide many opportunities for local economic development, but this requires conscious and active management. Local employment can be enhanced by skills development and local preferences and access roads can be built to also improve transport for local communities. Such mitigation measures are not outlined.

CUMULATIVE AND TRANSBOUNDARY IMPACTS

BACKGROUND

The focus of the prior consultation process is on the notified project, and recommendations are made after reflecting on the impacts the proposed use will have over and above the existing projects, and those that have been notified. However, the SNHPP is the 5th HPP in the upper Lao Cascade to undergo prior consultation. It will inundate or affect most of the last remnants of flowing water habitat in the Mekong mainstream in northern Laos. This makes the cumulative impacts of the cascade an increasingly important consideration. Critically, the Lao – Thai border is within 2 km of the HPP. Transboundary impacts would therefore be immediate, inevitable and potentially significant.

WHAT IS A CUMULATIVE IMPACT ASSESSMENT (CIA)?

The CIA recognises that there are multiple sources of impacts on the Mekong River System. The proposed new water use has impacts that occur on top of all the impacts from existing developments (beyond just hydropower). Other future uses are also largely known and should be accommodated when evaluating the reasonable and equitable use of the Mekong River System. At some point, the cumulative impacts from both existing and future developments will rise to the point where transboundary impacts could be unacceptable. In these cases, the Member Countries may have to negotiate which future developments should be considered.

However, any such evaluation must recognise the developmental nature of the 1995 Mekong Agreement, and that there are climate resilient benefits to regional economic growth.

A REVIEW OF CUMULATIVE AND TRANSBOUNDARY IMPACTS

TRANSBOUNDARY HYDROLOGICAL IMPACTS

Sanakham will be operated primarily as a Run-of-River HPP, but short-term hydrological impacts, caused by operations of sluices and turbines will occur. Given that the Lao – Thai border is less than 2 km downstream, these will have transboundary impacts.. Furthermore, should hydropeaking operations be adopted rapid water level changes of up to 1 – 2 m can occur as far downstream as Sanakham town, and hence also on the Thailand side. Fluctuations from peaking, as well as from the flood operations can be noticeable in water levels beyond Vientiane. This will have a range of adverse transboundary impacts including:

- Navigation can be dangerous as the depth may change rapidly.
- Rapid changes in water levels could cause riverbank slumping where the banks are steep. This can affect infrastructure and agriculture close to the banks.

- Increased scouring of the riverbed at high flows will affect habitats resulting in adverse ecological impacts and potential loss of fisheries.
- Conversely, deposition of sediments at lower flows can smother spawning grounds and affect habitats.
- The rapid fluctuations in water level will disrupt fisheries recruitment processes and contribute to the collapse of the fisheries in the region.
- The operations at a sand mining operation 8 – 9 km downstream of the dam site will be affected, potentially causing damage to equipment and reducing the sand available for extraction.

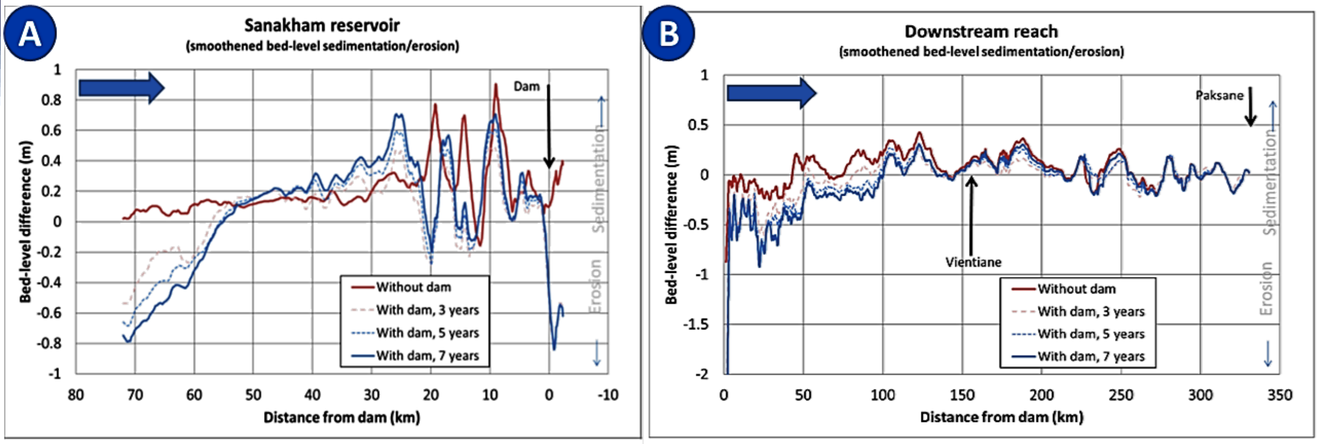
It is consequently strongly recommended that hydropeaking operations are not adopted, and that the operators rather seek to attenuate any rapid changes in inflows due to upstream hydropeaking and by operations of turbines and outlets by slower ramping rates. Considering the size of the project, the expected impacts to environment (notably sediment, ecology), and the location to the Thai border, a detailed Environmental Flow Assessment (EFA) will be required.

SEDIMENT IMPACTS

The EIA suggests that sediment delivery will not be much affected by the project because when the gates are open sediment will flow through and sediment will be mobilised from below the dam. In contrast the TbESIA-CIA indicates two-thirds of the incoming sediment will be trapped in the impoundment and concludes that:

> *"on the balance of probabilities, the dam would likely be responsible for transboundary sediment, morphology and nutrient impacts, leading to consequential environmental impacts that are both measurable and significant to communities, economies, habitats and ecosystems in the Mekong River, as well as its floodplains, wetlands, and delta."*

The trapping of sediment in the dam, and the remobilisation of sediments downstream of the dam has also been demonstrated by the MRC's modelling.



This shows erosion, gradually increasing over time, in the headwaters of the impoundment. Deposition occurs from 20 – 50 km upstream of the HPP. Downstream an erosional wave gradually moves downstream, reaching Vientiane approximately 7 years after the start of operations. In time, the deposition / erosion cycle will stretch downstream to Cambodia and Viet Nam. The EIA acknowledges this, but does not estimate the volume of sediment downstream, and hence the time it would take for the erosional wave to reach the border with Cambodia.

The modelling work cited in the TbESIA-CIA is consistent with recent MRC and regional investigations. This shows that sediment loads will drop from the historical loads of some 80 Mt/yr to 5 Mt/yr with the full cascade in place.

Minimising Sediment Loss through Joint Cascade Operations

The MRC has investigated joint sediment management measures for the northern Lao cascade. This identified a sediment flushing scenario that maximised benefits and minimised the impact on energy production at any one project.

Flushing was initiated at Sanakham through the drawdown of water level and opening of low-level outlets over a period of about 5-6 days (not unlike that proposed by the developer, but more frequently). This transported sand and gravel, as well as silt and clay out of the impoundment. Following flushing, water levels in the impoundment were returned to the Minimum Operating Level (MOL) in 1-2 days and energy production recommenced.

As water levels in Sanakham returned to normal, flushing was initiated in the same way at Pak Lay, and so on up the cascade to Pak Beng. The result is the release of sediment to the river downstream of the cascade over a period of about 5 days, followed by a period of lower sediment discharge (although still higher than typical operations). Within the cascade, the operations promote the downstream movement of coarse sediment in a controlled manner, such that no one impoundment was unduly laden with sediments from the flushing activities.

Model simulations over 7 years showed that the maximum amount of sediment flushed from the cascade was almost 2 Mt/yr. While small in comparison to the historical or pre-cascade sediment load, it still reflects a 40% increase in sediment transport. Running the model for a 16-year period indicated that as more sediment is accumulated larger volumes will be mobilised, suggesting sediment flushing will become more effective over time.

While drawdown of the impoundments reduces the total production of hydropower, the study estimated that the total lost energy production was 2.8% of the total annual generation. The estimated loss of 722 GWh per year across the full cascade is small in terms of the regional energy needs but, unless accommodated by an upward adjustment of energy tariffs, may be a concern to the individual operator–owners.

Aquatic ecology

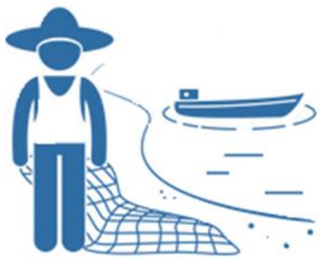
Should the full northern Lao cascade be completed, the free-flowing reach of the Mekong downstream of SNHPP as far as Vientiane will likely become an even more critical spawning habitat for migratory whitefish, as much of the habitat upstream of SNHPP will be lost. Also, it is likely that many fish will be stranded below the dam, even if the fishpass facilities are improved, and these will likely make use of this reach for breeding.

The release of 'sediment hungry' water from SNHPP will affect habitats in this area, and potentially result in an incised river over bedrock, with little sand and gravel substrate which is required for aquatic biota. Considerable effort should therefore be invested in maintaining some form of natural river system in this reach or offsetting investment to areas that can benefit from habitat restoration or rehabilitation actions.

The impoundment of water upstream of SNHPP dam will reduce flows though the reservoir and compromise the drifting of aquatic organisms, especially the egg and larval stages of fish that use flows to disperse downstream to nursery and feeding habitats. This will have serious implications for recruitment of many fish species that rely on drifting of early life stages to maintain their life cycle, as well as many aquatic organisms. It is expected the life cycles of many aquatic insects that depend on drifting to disperse will be disrupted, and the aquatic faunal community will change over time.

Avoiding or minimising this problem is difficult, although operations like those outlined for sediment flushing could be considered. However, to be effective this would have to take place over longer periods and on a much more frequent basis, and may be unaffordable. Drifting fish larvae require an average cross-sectional flow of 0.3 m/s to stay in the water column. In the Sanakham impoundment this will require inflows of about 4,000 m^3/s. Flows will only exceed this for about 35% of the time in the SNHPP – this will differ at the other HPPs in the cascade. In reality, therefore, the majority of the reach covered by the upper Lao cascade will be transformed from a free-flowing river to a series of impoundments.

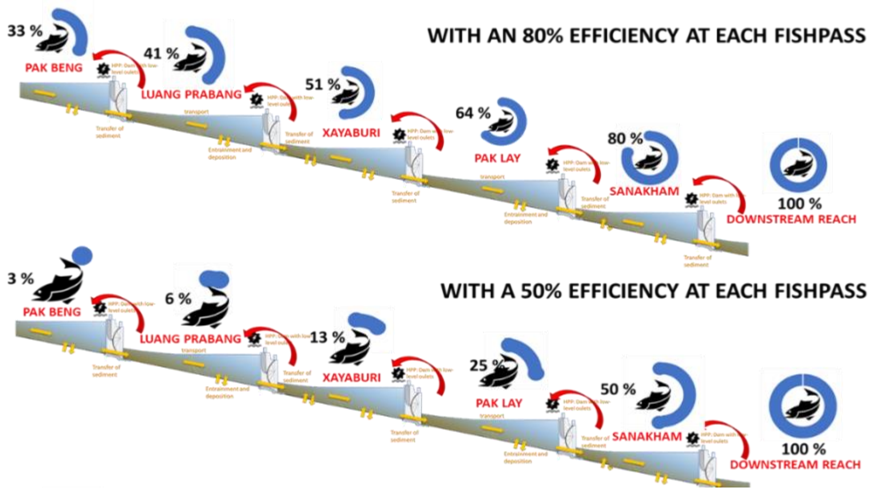
Mitigation measures to address lost fish and other aquatic animal production will need to consider wider options beyond stocking and fish farming in the impoundment, e.g. to explore the use of off-setting and creation of artificial wetlands and lagoons to increase productivity. This could potentially be done through a Mekong Fund.



Fish passage

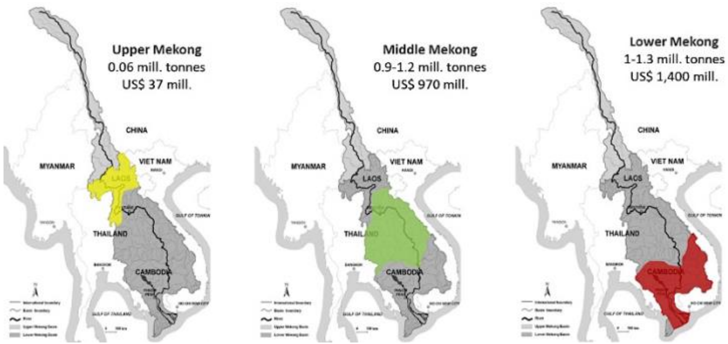
The cumulative impacts on fish migration are likely to be considerable. Each HPP blocks upstream and downstream migration. These impacts can be minimised through effective fish passage facilities. However, fish passes are rarely, if ever, 100% efficient, especially when passing the highly diverse fish species found in tropical rivers. The cumulative effects of reducing migration success at each dam will not be additive but the product of success at each facility. For example, if 80% pass the first HPP, and 80% pass the 2^{nd}, then only 80% of 80% will pass both i.e. 64%. In addition, the probability of bypassing several dams in series decreases with each successive dam, irrespective of the efficiency of each fishpass.

Therefore, with an 80% success rate at each fishpass, only 33% will make it over and through all 5 HPP. With a 50% success rate only 3% will make it over and through all 5 HPP.



A Cost-Benefit Analysis of Fishpass facilities

It should be possible to make a considerable improvement in the efficacy of all the fishpass facilities. But this will require investments of many 100 million US$. The additional flows required for the upgraded facilities will place an additional operational cost on each HPP. All of this comes with uncertainty. The rapid submission of the HPP for prior consultation means that there has not been sufficient time to evaluate the fishpass facilities put in place at Xayaburi both for upstream and downstream migration.



The estimated total fisheries and economic value in the 3 main migration systems in the LMB is 2,407 million U$. A 40% loss of fisheries in the upper system would be a loss of some U$ 14.8 million annually. This is 0.6% of the total value across all three systems, although the completion of the northern Lao cascade will also result in some losses in the middle and lower systems.

Conversely, investing the capital and operational value of the fishpass facilities at all the HPPs in a "Mekong Fund" could yield a substantial return which could be used to support livelihoods improvement projects for those communities in all the Member Countries that have lost fisheries. Ideally, therefore, a Cost – Benefit Analysis should be undertaken to help develop a more strategic overview of the optimum approach to fish migration in northern Lao PDR.

The 40% loss of migratory whitefish species in the upper Zone estimated due to the upper Lao Cascade, makes up less than 1% of the total capture fisheries in the LMB. A smaller proportion of this will be transboundary in nature.

An EFA for the downstream reach

The release of 'sediment hungry' water from SNHPP will likely affect habitats in the immediate downstream reach. Considerable effort should therefore be invested in maintaining some form of natural river system in this reach or offsetting investment to areas that can benefit from habitat restoration or rehabilitation actions. In addition, daily fluctuations in water levels due to hydropeaking will exacerbate these impacts on habitats just downstream of the SNHPP.

The developer considers there can be no minimising of this effect but recognizes that diurnal variations can cause serious problems for river, but has not considered undertaking an Environment Flow Assessment (EFA) in the submitted documents.

It is therefore recommended that an EFA is done for the reach immediately downstream of SNHPP as far as Vientiane and for the lower Mekong basin as a whole. This should assess the potential impacts of regulated flows on spawning and nursery/refuge habitat for key fish species and aquatic biota and seek to minimise these impacts through adjusting the ramping rates of discharges. This will require detailed sediment transport and remobilisation modelling. It is also recommended that the EFA is integrated into the joint operating rules for the northern Lao cascade.

Dam safety

The Sanakham Hydropower Project is located just upstream of the point where the Lao / Thai border joins the Mekong. Transboundary impacts of dam failure or normal operations are therefore critical. This makes it especially important that a study is undertaken of the areas, depth, and velocity of the area that will be inundated for the reach just downstream of the SNHPP. This study will identify the impacts of different dam break scenarios in both Lao PDR and Thailand both for the construction and operational period. All property at risk should be assessed against its vulnerability to damage, and the likely cost of the damage.

Transboundary socio-economic impacts

The developer defines cumulative impacts as those arising from all seven planned mainstream hydropower projects in Lao PDR. The documents note that this would result in the resettlement of 30,000 people and the loss of 18,000 ha of agricultural land. These negative impacts are considered to be of major significance. Beneficial changes such as improvement in basic social infrastructures and facilities, improved revenue base in Lao PDR and local employment are not quantified but are also seen as of medium-major significance.

In most large-scale projects, an explicit objective is to at least retain, or better still improve, the incomes or living standards of all affected parties. This is required by Lao legislation. No such specific objectives are reported in the SIA or SMMP for the SNHPP. Nonetheless, direct compensation for relocation and / or livelihoods projects (fish farming) have been proposed, and this has been the pattern in the last 4 prior consultation processes. However, typically these mitigation measures have been limited to the affected Lao communities.

It is, nevertheless, recognised that cross border compensation is fraught with difficulties related to the quantum of compensation required, and the distribution of funds. This also recommends that the establishment of a Mekong Fund be pursued further.

Conclusions and Recommendations

There are several measures that could be applied to further limit the potential cumulative and transboundary impacts of the upper Lao cascade. However, these measures require balancing the costs of reduced power output with the environmental and social benefits that may accrue. Some of these measures may also compromise the financial viability of the individual HPPs without a commensurate increase in the price of the power or extension of the concession period.

Some of these measures have already been tested by the MRC and show promise but require further optimisation and the exploration of different combinations of sediment flushing and downstream larval drift as well as protection of downstream ecological integrity.

This study can only be driven by the Government of Lao PDR and this is being further explored by CNR. However, the expertise and modelling systems already developed for the Council Study and used in the MRC would facilitate the optimisation of these studies.

COMMENTS, RECOMMENDATIONS AND WAY FORWARD

General Comment

The proximity of the Lao – Thai border means that greater attention needs to be paid to potential impacts due to the SNHPP, even if these are localised.

It is highly recommended that hydropeaking is not considered. In contrast, the possibility of using the SNHPP to smooth out rapid changes in flows from the upstream HPPs should be considered.

Conclusions

Hydrology and Hydraulics

The data available at the MRC and Meteorological Departments in Lao PDR and Thailand would improve the hydrological simulations. The methodologies used to determine the flood peaks appear to have produced results in the same order of magnitude as the other studies, albeit erring on the conservative side. The PMF should be determined as is required by the LEPTS 2018.

More details of the operations at the HPP, and particularly the ramping rates and use of the sluices are needed, particularly in the light of the hydraulics associated with the bend in the river and the downstream transboundary impacts of rapid flow variation. An alternative site to the Luang Prabang gauge will be needed as that site has been drowned by the backwaters from the Xayaburi HPP.

The impacts of Climate Change and the tributary HPPs in Lao PDR should be included in the forecast flows.

The work being undertaken by the Lao PDR to formulate cascade operating rules should consider combining the flow forecasting systems for all the HPP operators. The cascade operating rules should also consider the coordinated flushing of sediments, flood control operations, a RIS to facilitate navigation, and the potential of using the SNHPP to smooth out rapid fluctuations in flows caused by operations at the upstream HPPs.

Sediment

Additional sediment monitoring and should be undertaken to revise the estimates of sediment loads, grain sizes and bed loads. This should be used to improve the modelling studies undertaken, and the assessments of the sediment trapping in the impoundment. Cascade sediment management operations should be explored by the Lao PDR, ideally drawing on the expertise available at the MRC.

Water Quality and Aquatic Ecology

At least 2 years of monitoring should be undertaken to establish a more comprehensive baseline. This should include water quality, aquatic ecology and fisheries assessments, particularly in the reach from the SNHPP to Vientiane.

The water quality monitoring programme for the construction phase should be based on anticipated problems. Continuous real time monitoring should trigger management measures when pollution incidents are noted.

Fisheries and fish passage

The SNHPP developer has indicated that the fishpass facilities will be redesigned. However, the following should be considered in this process:

- The risk assessment of the proposed fish passage facilities suggests that it should be possible to make a considerable improvement in the efficacy of the facilities.
- But as no fishpass is 100% effective, some vulnerabilities will remain at all the HPPs in the cascade.
- Given the costs of improved fishpass facilities, and the cumulative and multiplicative impacts, a cost-benefit analysis could be considered to develop a more strategic approach to either minimising or mitigating the impacts of reduced fisheries.

Dam Safety

The proposed design falls short of the LEPTS 2018, and hence Lao legislation. An independent Dam Safety Review Panel should be established before the final design progresses much further.

Given the immediate and transboundary nature of any dam failure, or even under normal flood operations, it is critical that consequence studies are undertaken for a full range of flows up to the PMF. Any emergency management protocols should be developed with the relevant Thai Authorities.

Navigation

The developer should reconsider the design of the bottom slab of the lock chamber. The length of the lock chamber also needs to be increased to align with the PDG 2009. Similarly, spares for critical parts of the navigation facilities should be kept on site. Additional safety measures in the lock, hooks, ladders, gauge plates etc. are recommended.

The proposed alignment of the 2nd lock is likely to entail significant costs which may fall to the Government of the Lao PDR if it is needed after the concession period. An alternative parallel lock design has been proposed and should be considered.

Socio-economic

The socio-economic assessments should be updated, and the developer should ensure compliance with the updated Lao legislation. Where possible joint mitigation options with other developers and agencies should be considered.

As with the other technical reviews, the socio-economic baseline in not suitable to measure likely changes due to the SNHPP. Similarly, a more rigorous and adequately funded monitoring programme is required for the operational phase.