Mekong River Commission

PRIOR CONSULTATION PROCESS FOR THE

PAK LAY HYDROPOWER PROJECT

SUMMARY OF
SECOND DRAFT TECHNICAL REVIEW REPORT

20 December 2018

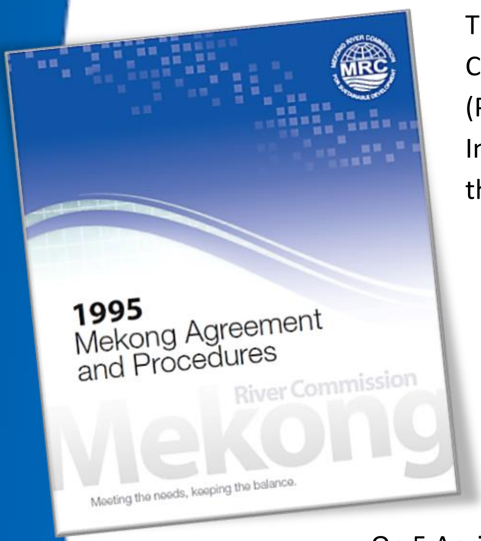
ACRONYMS AND GLOSSARY

Acronyms

HPP	*Hydropower project*
JC	*Joint Committee*
JCWG	*Joint Committee Working Group – established to guide the technical review process*
LBHPP	*Luang Prabang Hydropower Project*
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*
PLHPP	*Pak Lay Hydropower Project*
PC	*Prior Consultation*
PDG2009	*Preliminary Design Guidance of 2009 - approved*
DG2018	*Design Guidance of 2018 – not yet approved*
PNPCA	*Procedures for Notification Prior Consultation and Agreement*
PPA	*Power Purchase Agreement*
TRR	*Technical Review Report*

INTRODUCTION

Background



The Lao National Mekong Committee (LNMC) notified the Mekong River Commission (MRC) of their intention to submit the Pak Lay Hydropower Project (PLHPP) for prior consultation on 13 June 2018. The Secretariat then prepared an Internal Scoping Assessment Report, which formed the basis for the discussions in the first meeting of the Joint Committee Working Group (JCWG).

After checking for completeness, the documentation provided by the Lao NMC was sent to the MRC Member Countries*. The JCWG met on 8 August 2018 and agreed that the meeting would mark the formal start of the prior consultation process. The prior consultation process will run until 29 March 2019, which is just over six months.

The 1995 Mekong Agreement and Prior Consultation

On 5 April 1995, 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 re-affirmed the Member Countries' desire to develop, *inter alia*, hydro-power in the Mekong River Basin in a sustainable and cooperative manner and promotes cooperation in a constructive and mutually beneficial manner. Recognising that development could result in adverse impacts, the Member Countries agreed to a framework of principles and objectives to guide their use of the Mekong River System.

Through this framework, the Member Countries agreed to, (*inter alia*);

> *The Prior Consultation process is governed by the 1995 Mekong Agreement, and the MRC Procedures.*

- 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 Countries, 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.

*All the documentation provided by the LNMC has been made available on the MRC Website at: http://www.mrcmekong.org/topics/pnpca-prior-consultation/pak-lay-hydropower-project/

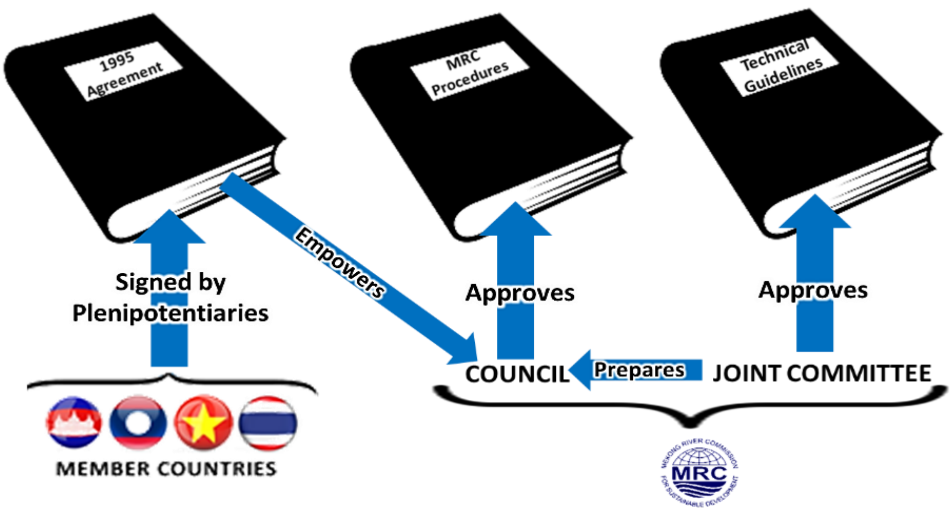
The Agreement provides for the achievement of these objectives and principles through the unique spirit of cooperation that has inspired cooperation between the Countries since 1957, and which has been reaffirmed on many subsequent occasions, including at the outset of this current process.

The Member Countries have also, through the 1995 Mekong Agreement, established the Mekong River Commission (MRC), and its sub-structures as a *separate* international body*. They conferred certain powers and functions on the MRC's structures. With respect to the prior consultation process;

> *The MRC Member Countries established the Commission and its organs, and conferred powers and functions to these bodies in the 1995 Mekong Agreement.*
>
> *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 Procedures). The Council agreed the Procedures for Notification, Prior Consultation and Agreement (PNPCA) in 2003.
- ***The Joint Committee (JC)*** is empowered by the Procedures for Notification, Prior Consultation and Agreement (PNPCA) to undertake the PC process, and Technical Guidelines to support the PNPCA were agreed 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 JC in this regard.

The MRC can only work within the framework and powers conferred by the Member Countries through the 1995 Mekong Agreement and Procedures. 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 indeed all the Procedures are, therefore, not regulatory mechanisms, but rather establish a basis for cooperation for information sharing, discussion and negotiation, and to work together in avoiding, minimising and mitigating potential risks and transboundary impacts.



* This means that while the Council and Joint Committee are made up of delegations from the Member Countries, These bodies function as a separate international organisation when a quorum is formed by all 4 Member Countries. The Technical Review Report reflects the consensus view of the Joint Committee and is an MRC product.

The PNPCA and PC process

The PNPCA derive from Article 5 of the 1995 Mekong Agreement where the Parties agree to the reasonable and equitable use of the Mekong River system and is ultimately intended to promote the fair and just use of the Mekong River System. The PNPCA specify three distinct forms of inter-State communication; i) Notification, ii) Prior Consultation and iii) specific Agreement.

Notification is applicable to water use on the tributaries of the Mekong mainstream, 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.

Type of River	Season	Scope of water-use	Required procedure
Mainstream	Dry	Inter-basin (from the Mekong basin to another basin)	Specific Agreement
		Intra-basin (within the Mekong basin)	Prior Consultation
	Wet	Inter-basin (from the Mekong basin to another basin)	Prior Consultation
		Intra-basin (within the Mekong basin)	Notification
Tributary	Both	Both inter and intra-basin	Notification

These increasing levels of interaction reflect a balance between the likelihood of adverse transboundary impacts, and the principle of sovereignty. They are also, to some extent, a hangover from a time when the primary issue was sharing water in a reasonable and equitable manner – the principle being that in the wet season there was so much water available there was less concern about the fair apportionment of water.

However, our current understanding has highlighted that the impacts of mainstream developments on sediment transport, fisheries and ecological processes are also very important. Significant impacts to fisheries and sediment transport can also occur due to tributary developments while the large storage hydropower reservoirs in China can disrupt flow regimes affecting the timing and volume of the reverse flow into the Tonle Sap Great Lake, and hence its fisheries potential.

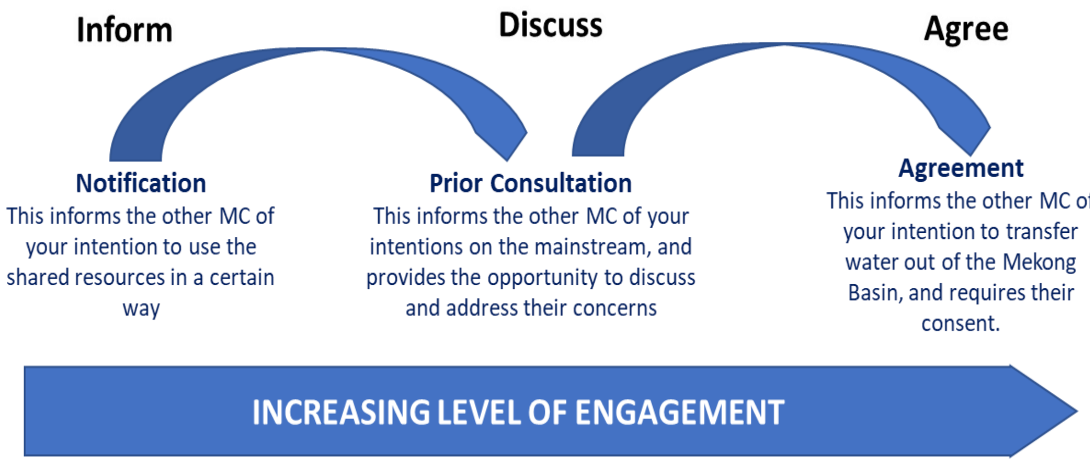
Prior consultation is therefore not necessarily the ideal tool to determine whether a proposed use is reasonable and equitable as this would require a more comprehensive and balanced view of ***all*** the impacts on the shared Mekong River System, including some that are not typically subject to prior consultation, such as those on tributaries, increasing levels of pollution and increased fisheries pressure. Nonetheless, even if a proposed use does not require prior consultation, the expectation is still that the Member Countries will still apply the principles and objectives outlined in the Agreement.

The experiences in the first three PC processes have highlighted that it is very difficult to reach consensus on whether a proposed use is reasonable and equitable in such a complex and interconnected system. However, the PC process for the Pak Beng HPP has shown that, while the JC must consider the whole of the 1995 Mekong Agreement, a focus on Article 7 and what additional efforts can be made to avoid minimise and mitigate any potential impacts, particularly where they may be transboundary in nature, does allow progress to be made.

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

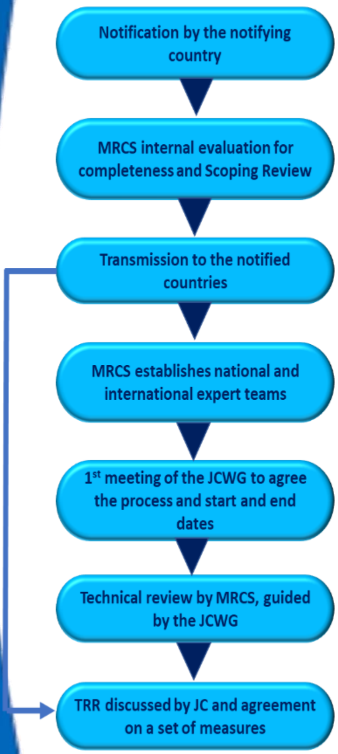
Because PC is neither a veto right, nor a right to unilaterally proceed without taking the concerns of the notified Countries into account, it need not end with a 'yes' or 'no' decision. Rather a Statement calling on the notifying Country to consider a set of measures (or conditions*) in the ongoing development of the proposed project can be agreed by the JC. This Statement calls on the notifying country to implement measures that would result in a better project with fewer impacts.

While this statement does not imply approval of the project, its implementation does help build confidence in the notified MC that their concerns are being considered and implemented as much as is possible. Further confidence in the process can be built through a post-prior consultation process which provides for ongoing interaction with a view to further improving the proposed project throughout its development, and on an adaptive management approach that maintains the project's financial viability while minimising its impacts.



* Because 'conditions' implies some form of regulatory force, the prior consultation process for the PLHPP will end in a Statement calling on the Government of the Lao PDR to make every effort to implement measures that will further avoid, minimise and mitigate potential impacts.

Replies from the notified countries



The decision made in the JC is made by consensus. This consensus reflects the view that all the MC delegations can agree to and requires the JC to discuss and arrive at an acceptable compromise position. It does not therefore necessarily reflect the separate opinions of the MC or their stakeholders. For this reason, in addition to the MRC driven prior consultation process, the notified countries will also submit formal replies to the proposed use, which are placed on the record of decision. Similarly, the notifying country may also submit a formal response to the TRR for the record of decision. These formal replies need not align fully with the TRR, they are products of the Member Countries.

All the MC will also undertake their own separate stakeholder engagement processes that will help them establish a position in the JC meeting, as well as to formulate their replies. Member Countries are also not prevented from entering any bilateral or multilateral discussions on the proposed use, outside of the prior consultation process. There are, for example, ongoing discussions between Lao PDR and Thailand on the Pak Beng HPP.

The initial PC process and technical review takes place over six months, and follows the steps as outlined here. This is a very tight timeframe, as a wide range of experts in various fields need to develop a common view of the intentions of the developer, and the implications for the shared Mekong River System. The details and timing of the PLHPP PC process are presented in the following section.

Key principles to keep in mind

Stakeholders need to bear the following in mind regarding the prior consultation process;

- The Member Countries have committed to the *reasonable and equitable* use of the Mekong River System. However, the determination of whether any proposed use is *reasonable and equitable* is difficult and nuanced and is beyond the scope of a 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, even if they are not transboundary in nature.
- The Joint Committee's deliberations are primarily focused on potential transboundary impacts, and agreement on a set of measures to avoid, minimise or mitigate these impacts.
- In the PLHPP case, documentation at a feasibility level has been put forward to support the prior consultation process. Any measures the JC may wish to propose for the ongoing development of the project can refer to either the Final Design, Construction or Operational phases, should the project proceed.

The main purpose of the TRR and the prior consultation process is, therefore, to highlight what *additional and reasonable* efforts should be made to avoid, minimise and mitigate any harmful effects. It also attempts to evaluate the extent of any residual harmful effects, particularly those of a transboundary nature.

THE PLHPP PC PROCESS

Start and end of the PC process

> *The PC process takes place over an initial 6-month period. This may be extended for a reasonable period by agreement in the JC.*

The Mekong River Commission (MRC) Secretariat received notification from the National Mekong Committee of the Lao PDR on 13 June 2018, of their intention to submit the Pak Lay Hydropower Project (PLHPP) for prior consultation. The Secretariat then started preparations for the prior consultation process, through *inter alia* the mobilisation of resources to undertake the process.

Under guidance from the JCWG the MRC Secretariat appointed several expert groups, made up of national and international experts, to provide independent specialist evaluations of the documentation submitted.

The documentation provided by the Lao NMC was sent to the MRC Member Countries on 12 July 2018. The JCWG met on 8 August 2018 and agreed that the meeting would mark the formal start of the prior consultation process. The process will run until 29 March 2019. The process in this case will therefore run for just over 6 months.

The stakeholder process has already been initiated through both national and regional stakeholder events. Ongoing stakeholder events will be supported by this summary of the TRR.

The PLHPP was notified 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 PLHPP is in the feasibility stage, and the development of the project is ongoing. This means that the technical review process has aimed at a moving target, and many of the recommendations are already being addressed. However, the review process can only be based on studies that have been completed by the developer, and where the Lao NMC has formally submitted the reports.

> *The TRR must be based on documents that have been formally submitted by the Lao NMC.*

There are both advantages and disadvantages to this. Because prior consultation took place before the final design was completed it could directly influence the final design and operational plan. In addition, the Lao PDR and the developer can 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 full and final technical review, and an unnecessarily negative impression of the proposed project may arise by identifying issues that are already being addressed, and the MRCS has been informed of several ongoing processes.

Engagement of stakeholders

Part of the MRC's commitment to continually improving the PC process is to improve the transparency of the process. The TRR for the Pak Lay HPP therefore includes additional background material to enhance stakeholders' understanding of the prior consultation process and the 1995 Mekong Agreement.

Two main groups of stakeholders are recognised;

> *More frequent and transparent engagement with stakeholders was identified as key to improving the outcomes of the prior consultation process.*

- **Internal stakeholders:** This includes the structures of the MRC, the Council, the Joint Committee and the Secretariat, as well as other government agencies in the Member Countries;
- **External stakeholders:** This includes non-MRC member countries such as development partners, dialogue partners (China and Myanmar), and non-state actors such as NGOs, civil society organizations, research institutions, academics, individuals and other interested groups.

Stakeholder engagement takes place at national and regional levels. National level engagements are conducted by the National Mekong Committees in each notified Member Country and are used to inform that Member Country's position in the JC. The regional consultations are managed by the MRC Secretariat.

In addition to this summary, other documents available on the MRC website also increase the transparency of the process;

- A PLHPP Fact sheet, and an overview of the documents submitted by the LNMC are available at; http://www.mrcmekong.org/topics/pnpca-prior-consultation/pak-lay-hydropower-project/
- Stakeholders can submit their comments at; http://www.mrcmekong.org/stakeholder-consultations
- The results of the first regional stakeholder forum are also available at; http://www.mrcmekong.org/topics/pnpca-prior-consultation/pak-lay-hydropower-project/

This commitment to greater transparency will continue in the post prior consultation process.

The key issues raised by stakeholders

The main TRR includes comment matrices from the regional and national consultations, but the main concerns raised by stakeholders, and the responses, are outlined here;

A. The operation of the cascade of HPP. The Lao PDR is undertaking a study on the conjunctive operation of all the HPP in the Lao portion of the Mekong Mainstream. An update on the status of this study has been requested. The TRR makes recommendations on both the aligning of the design parameters for the mainstream HPP and their conjunctive operation.

B. The need for compensation. Any compensation will need to be governed by Articles 7 and 8 of the 1995 Mekong Agreement. Here the *notified* countries must show the PLHPP has caused *substantial damage* with proper and valid evidence. Proving that the damage is caused by the PLHPP, and not by other developments, will be difficult, and the MRC is exploring options to address these issues, as well as the approaches to the transboundary socio-economic impact assessments.

C. The ongoing design process. It is hoped that the prior consultation process will be concluded with a Statement by the Joint Committee. That may call on the Lao PDR to make every effort to implement the measures identified by the TRR, as well as for a post prior consultation process to maintain open communication with the MRC, aimed at further improving the PLHPP.

D. The use of the Chinese Standards for the design. The MRCS has requested an English translation of these standards to support the review process. However, if the Chinese standards are equal or better than the standards applied by the MRC, then they can be used. Any deviation from this would have to be motivated.

E. The use of 'unapproved' documents, i.e. the DG2018 and the Council Study. The MRC can only *evaluate* the alignment of the design of the PLHPP against approved MRC standards or guidelines. However, other documents may be used to support the conclusions in the TRR, to the extent that they reflect good practice and sound peer reviewed science.

THE PLHPP AT A GLANCE

Location

> *The PLHPP lies some 110 km downstream of Xayaburi and will be heavily influenced by its operations, making alignment of the designs and conjunctive management essential.*

The proposed PLHPP is a run-of-river scheme located in the Mekong mainstream in Pak Lay district, in north-western Lao PDR. It is the 4th HPP (moving downstream) of the 11 hydropower stations planned for the mainstream of the Lower Mekong River, and the 4th to be submitted for prior consultation. It lies approximately 110 km downstream of Xayaburi HPP and will be heavily dependent on its operations, making conjunctive management and alignment of the design parameters critical to minimising impacts. It lies some 100 km upstream of the Sanakham HPP and the border with Thailand.

The power plant is planned to have an installed capacity of 770 MW, with 14 turbines, each producing 55 MW. It is mainly intended for power generation, producing power mostly for export but also for domestic consumption. However, it is hoped it will also serve to improve navigation and tourism. The infrastructure will create an impoundment with a depth of approximately 35 m at the dam wall, and a length of some 109 km, almost to the base of the Xayaburi HPP.

Construction is planned to commence in 2022 and will take about seven years. The power station is expected to start operations in 2029. The project's total cost, prior to the adoption of any of the recommendations made through prior consultation, is estimated at USD 2,134 million and is being developed by PowerChina Resources Ltd and China National Electronics Import-Export Corporation (CEIEC) in a form of Build-Operate-Transfer (BOT) scheme.

The PLHPP at a glance

Developer	PowerChina Resources Ltd and China National Electronics Import-Export Corporation (CEIEC) in a form of Build-Operate-Transfer (BOT) scheme.
Hydropower capacity	A low-head type HPP with an installed capacity of 770 MW, with 14 turbines, each producing 55 MW and a design flow of 6,100 m^3/s
Power output	An installed capacity of 770 MW, with 14 turbines, each producing 55 MW.
Power Purchaser	Mostly Thailand (EGAT), with some for domestic use. (See section below of power purchase options).
Reservoir capacity and length	Normal pool level of 240.00m, which creates an impoundment of 890.1 million m^3 and approximately 109 km long. The minimum pool level under normal operations is 239.00 m, and the regulation/effective storage is 58.4 million m^3.
Dam height	An impoundment with a depth of approximately 35 m at the dam wall. Maximum dam height is about 51 m, and the dam crest length is 942.75 m.
Design Floods	Designed to pass a 1:2,000-year flood or 34,700 m^3/s, and the check flood is based on a 10,000-year return period or 38,800 m^3/s[1].
Flood release gates	11 high-level undershot flood gates, located adjacent to the navigation lock, each 16 m wide × 20 m high.
Sand scour	Two gates of 10 m wide × 10 m high and invert elevation of 201.02 masl. To ensure pressure flow at the outlets, section dimensions of the outlet mouths in front of the bottom outlets are 10 m wide × 12 m high.
Fish pass	A bilateral vertical slot fishway along the left bank, with a width of 6 m, a depth of 2.50 m, and a total length of 1,017 m. The average slope of the fishway is about 2.1%, with resting pools.
Navigation lock	One-way, one-step ship lock capable of passing ships of up to 500-tonnes (t), with space for upgrading to a double-way lock. The maximum working head of the navigation lock is 21 m, and the size of the lock chamber is 120 m long × 12 m wide × 4 m deep.

[1] The design flood will pass through without any damage to the infrastructure. The check flood may cause some damage, but not catastrophic failure.

A Run-of-River project

The PLHPP will be operated as a run-of-river hydropower project, with inflows roughly equivalent to outflows. This means that the HPP will not impact on the season flow regimes into Cambodia and Viet Nam. However, there is a possibility of providing peaking power, which results in rapid and damaging changes in water levels in and immediately downstream of the reservoir.

Operating rules

The operating rules for the PLHPP have been designed to optimise hydropower output while protecting the infrastructure. The intention is to maintain flow conditions and reservoir levels as close to natural as possible during the flood season. To achieve this the HPP will be operated as follows;

- If the inflow is less than 6,100 m^3/s, the power plant will be operated at reduced load. However, to balance the generated load against the demand (hydropeaking), the reservoir level may vary between the minimum pool level (i.e. 239 m) and the normal pool level (i.e. 240 m). Above 6,100 m^3/s the HPP will operate at full load.
- When inflow is forecast to exceed 16,700 m^3/s the flood release facilities will be gradually opened, and the pool level can go down to about 232.5 m. This will facilitate the routing of sediment.
- During drawdown, the outflow is limited to 1,600 m^3/s ***more*** than the inflow to limit the daily water level change to less than 3 m. If there is insufficient head to generate power - generation is shut down.
- As inflows start decreasing below 16,700 m^3/s then flood release facilities will slowly close again, Outflows will be limited to 1,600 m^3/s ***less*** than inflows, and water levels will gradually be restored to 240 m. Generation will start when there is enough head.

Optimising these operating rules to minimise impacts, while maintaining the financial viability of the PLHPP is central to the recommendations made in the TRR. This is also why it is so important to use the best available hydrological data, forecast into the future and taking the operations of Xayaburi into account, while finalising the operating rules and design.

Options for power generation and sales

For flows below 6,100 m^3/s, the power station will operate under the normal generation mode. According to changing daily electric load, the water level may be operated between 239 and 240 m under hydropeaking operations. Here minimum pool levels are chosen 1 m below normal pool level, based on achieving the maximum possible energy output.

The price of the electricity depends on the demand, and at peak times the cost of the energy is higher.

Two options for supplying power to Thailand are being considered:

1) Direct point-to-grid power supply, where power is directly supplied to Thailand (EGAT): in this approach some regulating storage is reserved to provide energy according to demand (pricing based on demand), hence some hydropeaking.
2) Grid-to-grid power supply, where energy is produced for Laos and Thailand, with a single price and no hydropeaking.

Only Option 1, with peaking, is elaborated in the documents provided. Under this Option; EGAT will purchase primary energy for 16 h/day at 100% price, secondary energy for 5.35 h/day at 60% of price and excess energy at 55% of price. This purchase agreement is the basis for the economic feasibility of the project. The developer suggests that under EGAT's power policy, the highest priority is given to the primary energy, followed by secondary energy and then excess energy. Option 1 is only applied during the dry season at low discharges.

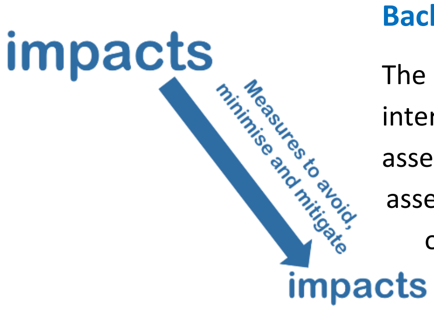
The reviews undertaken by Lao PDR

The Government of the Lao PDR commissioned a separate assessment of the proposals made by the developer, which was undertaken by CNR together with fish passage specialists from Brazil. These were also provided by the LNMC as part of the review documents. Many of the recommendations made in this review appear to have already been taken up by the developer.

While the TRR concurs with many of the recommendations made by CNR, there are some points of divergence. The CNR review suggests that if their recommendations are all taken up, then the design of the PLHPP would mostly comply with the PDG 2009. However, the MRC is unable to assume that the recommendations would be implemented and does not concur with this conclusion.

TECHNICAL REVIEW

Background



The MRCS undertook the technical review of the proposed HPP, with the support of international experts. Six teams were established to deal with the detailed specialist assessments required for the review. These teams have produced detailed assessments, which are attached as Annexes to the main TRR, while the main body of the TRR summarises the main findings, particularly with respect to the requirements of the PC process.

One of the key aims of the TRR is to identify additional measures that can be considered to further avoid minimise and mitigate possible adverse impacts.

The TRR provides general comments on the documentation provided and the impact assessment and data collection processes followed by the developer. However, it also aims to identify additional measures that can avoid, minimise and mitigate potential impacts. For the purposes of the TRR;

- *Avoid* means the measure, if implemented, would ensure that any 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.

The following sections summarise the outcomes of the expert teams' reviews. Stakeholders wishing to gain further insights and details may refer to the final TRR, which will be released after the JC meeting to conclude the 6-month Prior Consultation process of the PLHPP in late March 2019.

Hydrology and Hydraulics

The use of good hydrological data is critical to the way the PLHPP is designed and operated, particularly in the light of some of the recommendations made in the TRR.

Hydrological data

The Pak Lay HPP is located between the Luang Prabang and Chiang Khan flow gauging stations, both of which have data records dating back to the 1960's. Several gauging stations have been established by the developer during their initial studies, and some data from Vientiane (249 km downstream of PLHPP) and at Chiang Saen (upstream) are considered.

Longer term records for the dam site have been derived from the data from the Luang Prabang and Chiang Khan stations. As the methodology is only used for monthly flows it is acceptable. Comparison of these derived flows to the MRC data supports this conclusion. However, the methodology is not suitable for determining daily-average flow.

It is important to forecast the future hydrology for the full lifetime of the HPP, as this determines its financial viability, and hence the additional measures that could be considered.

The developer's methodology to determine daily flows at the dam site has not been shared. The developer notes that the flow data will be improved as the project moves into the final design stage, and that data collection at the dam site is ongoing. It is important, even at the feasibility stage, to forecast the future hydrology to determine economic and environmental risks over lifetime of the PLHPP. This requires taking both the future development of hydropower upstream of Pak Lay, as well as climate change into account. The developer has assessed how the discharge at Pak Lay HPP will be affected by the upstream cascade, but only for the monthly average discharge, and only for the operation of the large storage HPPs in China. These increase monthly average flows in the dry season by some 1,000 m^3/s, and decreasing wet season monthly averages by up to 1,600 m^3/s.

The developer assumes that the impact on monthly flows from the upstream tributary HPPs would be similar, but this has not been quantified. It is assumed that these increases in flows will have positive impacts on power production. However, the influence of this on the optimal hydropower output environmental impact balance is not explored. Similarly, the developer refers to the possible impacts of climate change and general trends for the distant future are mentioned, but do not appear to be included in the forecasted design discharges, and consequently into the financial viability assessments.

Flood peak and frequency

The derivation of flood peak flows and frequencies is essential for the design of the dam and spillways, and the PDG 2018 recommends that consistent design criteria should be followed in the mainstream cascade. These calculations require a long time series of historic flood discharges, corrected for the expected upstream changes due to the new HPPs. The developer has used methodologies based on Chinese standards, but has not compared this to other methods, which is the usual practice.

Flood peaks and frequency must be determined after considering the operation of upstream dams.

The methodologies used by the MRC have been tested for the Mekong Basin and should provide better results, and the developer has indicated that these will be used in the final design stages. However, the maximum peak floods are consistent with those reported by MRC, but there is a large difference with the flood design parameters for the Xayaburi HPP.

The threshold of 16,700 m^3/s in the operating rules for managing peak flows may result in flows higher than proposed in the Procedures for Maintenance of Flows on the Mainstream (PMFM) at Vientiane. The proposed additional release of 1,600m^3/s to draw down the impoundment levels may therefore contribute to *"unstable"* flood levels near Vientiane, and options to manage this process together with the Xayaburi HPP should be investigated. The developer has noted that this will be addressed in the ongoing design process.

Changes in flow regimes

Changes in flow regimes in affect the water quality, aquatic ecosystems, sediment transport processes, fish migration, navigation and dam safety. The larger annual and inter-annual time scale changes are primarily affected by large storage schemes, and the run of river schemes in the mainstream do not affect the seasonal flows in downstream reaches but can still influence the local daily fluctuations during hydropeaking and ramping operations. However, the developer has paid little attention to these local impacts.

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

Modelling tools

Several mathematical modelling tools have been used to support the design process. These include models to determine the likely sediment deposition in the reservoir, and the deposition of sediment near the dam wall. However, there is little information on the models used and their application to other similar dams. The models have not been used to assess the impacts of sediment flushing.

The developer has also used a physical model but has only provided limited details of this model, and notes that the assessment of the results of comparison between the numerical calculation model and the physical model outcomes is being conducted. The physical model was used to the test issues related to the safety of the dam. A proper evaluation of the accuracy of the results is not presented and therefore a definitive assessment of this work is not possible.

Impacts related to hydraulics

Hydraulics" refers to the flow dynamics of water and addresses water depths, velocities, turbulence, the transfer of flood waves, and other properties of flow in rivers and reservoirs. The hydraulics affect scouring, hydropower production, fish migration and navigation and dam safety.

The main water-release structure is in the middle part of the dam, to minimize scouring impacts to the banks, while a concrete apron is provided to protect the downstream river bed from scour which could destabilise the structure. The designs of aprons and stilling basin were tested in the physical model. However, normal practice would require that the conditions must be tested for different combinations of gate opening, tail-water elevation, and bottom level of the stilling basin.

The developer suggests that the length of the aprons and stilling basin are adequate and that they should be consistent with international guidelines. However, quantitative proof has not been provided.

The Hydrological monitoring proposed by the developer

Monitoring hydrology and hydraulics is part of normal operations of the mainstream dams in the Mekong. Monitoring should provide the necessary information to operate the station in a run-of-river mode, but also to manage environmental impacts.

The developer proposes monitoring water levels upstream and downstream of the dam with automatic monitoring devices. A small-scale meteorological station will be installed at a suitable location. In addition, an automatic monitoring and communication system will be used to forecast flows to support reservoir operations. However, these systems are not fully elaborated in the documents provided, particularly where the lead times for changes in flow may be short. There is no reference to the inclusion of forecast models, but the developer has indicated that the MRC and WMO guidelines will be taken into consideration.

Transbounday flow impacts

The Thai border lies some 100km downstream of the PLHPP. Hydrological and ecological impacts that extend beyond this point are considered transboundary and should be carefully predicted and if possible avoided, mitigated or minimized. Although the Sanakham HPP is proposed just upstream of the border and may reduce some of the impacts of Pak Lay, it cannot be assumed that Sanakham HPP will be developed.

> *More information on the methodologies used is needed for a full evaluation, and the data should be shared. However, the developer has committed to updating the hydrology in the ongoing design.*

The developer recognises that the HPP may affect the hydrological characteristics and sedimentation regime downstream all the way to the Mekong Estuary, but suggests that this would be addressed by operating the HPP in run-of-river mode. While this is true for the long-distance flow regimes, it is not the case for sediment transport.

Sediment transport and river morphology

Sediment data

The Pak Lay Feasibility Study has been developed in several stages from 2007 to 2017. This has resulted in different data sets being used at different periods and there are inconsistencies between the reports provided. In addition, sediment loads in the Mekong River have been changing over the last decade due to sediment trapping in the mainstream dams in China and tributary dams, as well as catchment degradation. The data reported from the earlier studies are therefore no longer representative of the current conditions.

Nonetheless, the Feasibility Study is based on generally sound data sets that reflect the present conditions and the processing and analysis of the samples is ongoing. The details of how and where the samples were taken, as well as the data could be provided. Some discussion of how sediment transport is likely to change in the future, and the implications for the Pak Lay project should be undertaken.

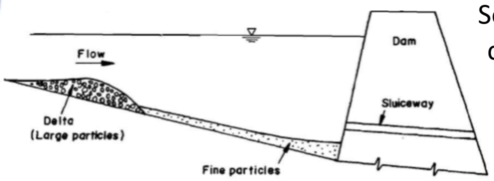
The percentage of suspended sand estimated at Pak Lay (average 30%) is low compared to the average grain-size distributions determined at Luang Prabang (75%) and Nong Khai by the MRC. This could be due to the sampling techniques and possibly natural effects. However, the number of monitoring dates is low, which increases the risk of the results not being representative of the annual inflow.   This is important as it determines the amount of sediment that may be trapped in the impoundment, and these data should be updated as the PLHPP proceeds to the final design stage.

The developer has estimated the bed load from experiences from large rivers in China, but no references are provided. Although this is a common approach, the percentage of bedload can vary greatly within and between catchments, and further justification is required. Information about the grain-size distribution of bed materials are consistent with MRC data sets and what is presently understood with respect to bedload sediments in the region.

Geomorphic information

The Feasibility study provides geomorphic information about the river channel, the area to be impounded, the project area and downstream river characteristics. However, the deep pools within the area to be impounded are not discussed. The geomorphic description of the river does not extend downstream of the project area.

Sediment management infrastructure and operations



Sediment flushing infrastructure is required in the PDG2009.

Sediment management for the power house section is based on a sediment control sill and a trench that connects to the low-level outlets in the middle section of the dam. No sand flushing facilities are incorporated at the base of the turbines in the power house. Two low level sediment flushing gates of 10 m x 10 m are situated next to the powerhouse section in the spillway section, and close to the level of the natural river bed. The non-spill section has no provision for sediment management, except through the navigation locks.

When inflows reach 16,700 m^3/s, the spillway and low-level gates will be progressively opened to allow the river to approach its natural flood level. During this time sediment will pass through the low-level and surface outlets. In addition, reservoir drawdown may occur every 2-5 years specifically for sediment flushing and based on sediment accumulation. The developer also indicates that sediment flushing will be coordinated with other hydropower operators, although the mechanism is not elaborated. Sediment removal from near the power house area will be done through mechanical dredging.

This infrastructure and the management measures are consistent with good sediment management practice. However, the effectiveness of the 2 low-level outlets will be limited by their relatively small size, which together provide an opening of 200 m^2 for flushing. This limits the flow through the outlets and limits the distance behind the dam where sediments can be mobilised during flushing. In comparison, Xayaburi has four bottom outlets with an opening of 768 m^2.

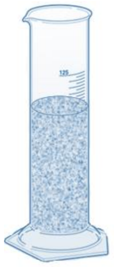
If the PLHPP is operated in peaking mode, the rapid and frequent water level changes will increase the risk of bank erosion in the downstream reach. This may also affect sediment deposition within the impoundment. This should be tested through modelling of sediment trapping within the impoundment with the PLHPP operated in peaking mode.

Sediment transport in the impounded reach was investigated using a mathematical model. The results show that sediment trapping within the reservoir is directly linked to the percentage sand contained in the sediment load. However, the impacts of reservoir drawdown on sediment flushing through the full impounded reach was not investigated.

More detailed mathematical modelling was completed for the reaches just upstream and downstream of the dam site to investigate sedimentation close to the dam and turbines. Downstream of the dam site, local scouring of the bed of up to 2.7 m is projected to occur in the first 2 km within the first 5-years of operations, and sediment deposition of up to 1.3 m is projected to occur at the inlet to the navigation lock over the same time-period.

This was also investigated in the physical model tests. Substantial scour of approximately 3 m was also observed when differences between the upstream and downstream water levels were <12 m, with the gates open 2 m or more. Relatively low rates of scour were observed during periods of flow equivalent to the 16,700 m^3/s threshold for opening all gates.

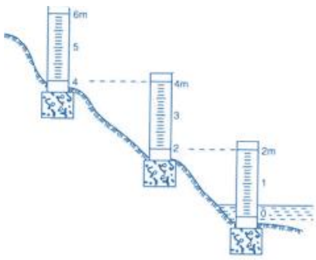
However, as very little information on the calibration or verification of the models was provided, it is difficult to provide detailed comment on these results. Modelling studies by, and sediment data from, the MRC suggest that sediment trapping in the impounded section may be higher than estimated in the developer's models.



Monitoring of the sediment size fractions will improve the modelling results.

Monitoring proposed

The developer proposes monitoring water level, flow and sediment concentration in controlled cross-sections. Bathymetric monitoring will capture the pre-construction bathymetry, and will be repeated during construction and operations, with the frequency to be guided by the rate of sediment accumulation. Additional surveys may be completed following large flood events to understand the relationship between these events and reservoir storage capacity. Material deposited on the bed, banks and bars in the impoundment will be collected along each cross section for grain-size distribution analysis.



Monitoring of the sediment budget of the HPP will be used to improve the sediment flushing regime through adaptive management.

This will be used to establish the sediment budget of the impoundment and analyse the distribution of sediment deposition within the impoundment. The results will be interpreted with respect to how the operations affect sediment movement through the impoundment, and an annual report will be produced summarising the results and making recommendations to address any adverse effects of sedimentation.

This overall approach is good, however, the documents lack specifics about equipment and field and laboratory methods to be used, overall number and exact locations of monitoring sites, how far downstream the monitoring will extend and monitoring frequency. Similarly, there is only a general description of how the results will be used. While this is reasonable given the early phase of the project, further details should be provided if the PLHPP proceeds to detailed design. The potential for coordinated monitoring with the other HPP in the cascade should also be explored.

At a general level, the PLHPP aligns with the PDG2009. However, longer-duration and more detailed information is warranted for several topics, such as sediment characteristics, modelling and monitoring. The ongoing sediment monitoring will address some of these gaps, if the information is used to update and refine the models and operating procedures. The inclusion of adaptive management approaches is laudable, but additional information about this will be applied to operations and mitigation are needed.

> *The sediment transport analysis is good for this stage of the project development, and the proposals for adaptive management are laudable.*
>
> *As the project proceed to final design, consideration should be given to larger sediment flushing gates, updating the modelling with better sediment data and better analysis of the impacts on geomorphology.*

More consideration of the geomorphology of the river within and downstream of the impoundment is required, including discussion of the fate of deep pools within the project reach and greater detail about monitoring and potential mitigation strategies to address erosion along the banks of the impoundment or downstream should be provided. The potential impact of hydropeaking on sediment transport and geomorphic processes should be discussed in greater detail, including an assessment of the drawdown rate (in cm/hour) associated with peaking operations. Many of these topics could easily be addressed in the detailed design phase when more site-specific sediment results are available.

Overall, the documentation provided for prior consultation is considered adequate for understanding the project infrastructure, and potential operating regime and providing a general overview of localised impacts. However, the documents do not provide an understanding of the potential impacts of the project in the regional context, including the identification of transboundary impacts.

Water Quality and Aquatic Ecology

Water quality and aquatic ecology are impacted by hydropower development in rivers, but the scale and intensity of impacts are specific to each HPP and differ between the construction and operational phases. During construction increased pollution is possible, and the development of ancillary industries and human population expansion could increase the risk of degrading water quality. Accidental spillage of construction materials, including washing of concrete, oils and grease and spillages from storage depots and vehicles is also possible. These can largely be managed through good construction practices.

Water quality issues during operations arise mainly from downstream sediment mobilisation caused by changes in hydrology, breakdown of vegetation in the reservoir, especially after impoundment and until the reservoir has stabilised (usually after 5-7 years), and ancillary operations and expansion of human settlements around the reservoir, which can lead to eutrophication and algal growth if the residence times in the impoundment are long enough.

Water quality

The developer notes that the MRC water quality monitoring network indicates that the upper Mekong in Lao PDR has good water quality, and that biodiversity, water quality, flood protection, fisheries and a range of livelihoods in the basin are at risk from loss of wetlands and increasing deforestation.

The results of the water quality monitoring at seven stations upstream and downstream of the PLHPP site confirm this perspective. However, concentrations of nitrates and ammonia may result in eutrophication problems. These values are nonetheless below the concentration limits specified in the MRC's Technical Guidelines for the Procedures for Water Quality.

The water quality monitoring programme must however be expanded and more details on the sampling and analysis methodologies should be provided to provide a better baseline of water quality prior to construction.

Aquatic ecology

Aquatic ecological surveys have been undertaken. Samples were collected for fish species, plankton, benthic invertebrate and aquatic plants. The developer indicates that further sampling in cooperation with LARREC and the Ministry of Agriculture will be done before construction, but no details are provided. However, as with the water quality samples, the monitoring was limited, and definitive conclusions cannot be drawn. Similarly, the design and extent of the surveys are not consistent with international or MRC standards. There is little attempt to relate plankton and benthic invertebrate surveys to the results from MRC studies.

Some attempt has been made to comment on the impacts of the PLHPP on potential changes in aquatic habitats in downstream reaches or in the inundated area of the reservoir, where the habitat will likely change from a flowing to a mostly stagnant water environment. The river will be impounded for some 90-110 km and the riffle habitats, which are important spawning/production areas and dry season habitat for key fish species, will be lost. This loss is not placed in perspective by assessing the value and uniqueness of these aquatic habitats.

The change from a flowing river to an impounded section will eliminate important fish spawning habitats

Studies were also undertaken of forestry products and wildlife in the Pak Lay area, but the loss of forest products and wildlife that may occur due to the PLHPP, and the impact of this on the local diets was not assessed.

Potential impacts on water quality and aquatic ecology

The possible impacts of construction on water quality are addressed, but the report indicates that these can be managed by good practices. The developer therefore considers that there will be no significant impact on water quality during the construction phase. This is possible provided that the practices are put in place and monitored, if the water quality monitoring programme is expanded and if emergency response measures are in place with staff trained to respond to spillages.

Despite all these measures, soil erosion, bank side collapses, spillages and accidents and malfunction of waste water treatment plants may still occur. This will likely have a temporary impact on water quality downstream, perhaps as far as the Thai border and Vientiane. Any increased sediment loadings are likely to have greater impact during the low flow seasons, when the water is naturally clearer, and particular care should be taken during this time.

The water quality problems created by flooding of vegetation will be addressed by removal of surplus vegetation in the reservoir area prior to impoundment. However, this should be planned carefully as removal of vegetation can result in reduced productivity of the reservoir and poor fish production. It is recommended hard wood vegetation is removed selectively and areas left to enhance protection of the fish stocks by creating zones that are difficult to fish, and to enhance food resources for the fish.

Water quality and aquatic ecology during the operational phase

Several potential water quality issues that may arise during the lifetime of the project were noted. These include increased erosion and sedimentation in the impoundment due to forest degradation. The 'sediment hungry' outflows from the reservoir may induce erosion and a scouring downstream. Periodic sediment release from the reservoir will minimise the impacts on the total sediment transported downstream. However, short term impacts on instream habitats are likely. The degradation of vegetation biomass in the reservoir during the early inundation period can also impact downstream river areas.

Human populations, agriculture and aquaculture activities are also likely to expand, which can increase pollution. This may be a problem in the dry season when there is less assimilative capacity in the river and residence times are longer in the impoundment. The nutrient and chemical pollutants could be dispersed to other river reaches so there are potential transboundary impacts. Good practice in agriculture and aquaculture is necessary to prevent eutrophication and safeguard the ecosystem. Increased navigation may also increase the risks of oil spills and other contaminants.

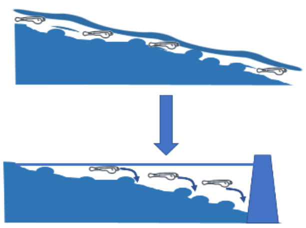
Protecting aquatic habitat and resources

The reports provided an overview of the aquatic habitats and resources. These reviews are, however, largely restricted to exploited fisheries resources, although some information is provided on regional biodiversity. The reports recognise the Mekong as a biological hotspot and highlight the prevalence of threatened species. There is less recognition that the upper reaches around the PLHPP host less species than the lower reaches of the Mekong. Notwithstanding, this region has a high endemicity of aquatic species, particularly in the tributaries associated with the project area.

Despite these findings the developer does not recommend special studies or management plans. The reports highlight that the Mekong giant catfish migrates through the area to its spawning grounds but does not recommend any special measures to monitor and promote this migration other than suggesting the fish pass facilities may mitigate the problem. No information is provided on conservation activities for other aquatic animals

Modified flows

The ecological integrity of a river depends to a high degree on the hydrological regime. The reservoir will create a 110-km long impoundment, and water velocities will be reduced considerably, especially during the dry season. This will have a substantial impact on the aquatic biota, transforming the river to a lake environment and changing the ecosystem functioning. This will impact on drifting organisms especially the egg and larval stages of fish that use flows to disperse downstream to nursery and feeding habitats. This will be exacerbated by the water level fluctuations in the impoundment that will affect biological productivity.



The change from a flowing river to an impounded section will affect the downstream drift of fish larvae

The developer notes that seasonal downstream flow patterns will be maintained as far as possible during the filling phase of the reservoir, and that environmental flow studies should be carried out during the first two years of the construction period to develop appropriate flow regimes necessary to maintain the ecological health of the river. However, as this may affect the economics of the PLHPP this work should be undertaken as soon as possible. If the hydropeaking option is implemented, rapid changes in water levels may be possible downstream. This could have serious implications for aquatic flora and fauna and for river users, both locally and further downstream.

> *The change from a flowing river, to a lake environment for most of the upper reaches of the Mekong Mainstream in the Lao PDR will result in the loss of important habitats.*

The impacts of the cascade

Multiple dams have cumulative impacts through several processes related to both altered erosional and deposition processes, and alteration of habitat characteristics and ecosystem functioning both in the impounded areas and in the downstream reach.

For Pak Lay, it is particularly important to consider the cumulative impacts of the 'existing' Xayaburi and Pak Beng HPPs, and the proposed new HPPs. These will likely have additive impacts on aquatic ecology as the upper reaches of the river in Lao PDR will be converted to a series of close to stagnant.

The cumulative impact assessment on fisheries is largely focussed on the Mekong giant catfish although reference is made to the impacts on the on the quantity and size of fish. While the developer acknowledges that the PLHPP would obstruct migration, they propose that a well-designed fish pass would minimise this effect. This is considered unattainable, particularly in the light of the construction of the other HPP in this reach.

The cumulative impacts of the PLHPP and upstream dams on water quality have been considered for both the construction and operation phases of the development and are largely considered to be the same as the transboundary impacts. Unless major urban or industrial development occurs in association with the reservoir, water quality problems are likely to be associated with nutrient enrichment and decay of vegetation and may accumulate through a series of downstream reservoirs. Perhaps the biggest issue is sediment trapping that will result on long-term geomorphological changes in the downstream reaches and reduction in potential nutrients associated with the sediments.

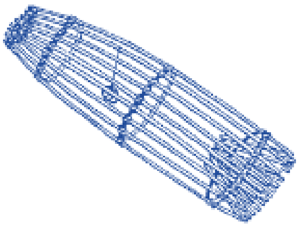
Alignment with the PDG 2009

The documentation provides a reasonable review of the fisheries and aquatic resources in the LMB but is less explicit with respect to the impacts of the PLHPP. Baseline monitoring is still at an initial stage and should be expanded. However, the conclusion that the water quality in the reach is good complies with MRC assessment.

The developer's conclusion that the invertebrate fauna was poor is not justified based on the number of samples taken and the sampling methodology. Detailed water quality and ecological health monitoring programmes were not fully described in the documentation and there is no mention of targeting the

The developer has undertaken a very limited sampling program, and the proposed ongoing monitoring programs need to be expanded in scope.

monitoring systems to identify water quality and ecological health issues or responsive procedures should problems arise. Effective ramping operations have not been considered for hydropeaking operations, and the environmental flow assessment has not yet been undertaken. There is no evidence of an independent panel of experts to assist with the design and implementation of water quality compliance monitoring programmes or the determination of environmental flows.



Fisheries

Dams disrupt the life cycle of migratory fishes, and this impacts on fisheries production upstream, downstream, and in the inundated area or the reservoir. It is possible to minimise these impacts, but the extent to which they are effective depends on integrating the ecological characteristics with hydro-geomorphological characteristics in the design and operation of fish passage facilities.

The PLHPP is in Zone 1 of the Mekong's Ecological Reach. While, the total biomass and catch is lower in this Zone, the reach is associated with the spawning habitat of several important species. Considerable fishing activity takes place in this Zone, and the MRC estimates that some 40,000-60,000 t/yr of fish are caught. Fishing generally occurs during the period of upstream migration. However, migratory species are not the only ones captured; a wide diversity of finfish species is found in the markets, including the non-native species, plus a range of amphibians, snails and Crustacea. In addition, considerable fishing activity takes place in the tributaries associated with this region.

There is likely to be a reduction in the total fishery catch in the area of the PLHPP, and this may impact on livelihoods. This is unlikely to be fully compensated through fish farming and stocking.

The fisheries assessment includes a literature review and field studies assessing fish species diversity, and interviews with fishing communities. However, the monitoring programme is limited and the most recent data from the MRC have not been accessed. The developer made an approximation of the harvest potential of fishes and other aquatic "organisms", which appears to underestimate the importance of fisheries in the region and conflicts with other estimates reported by the developer and the MRC.

It is suggested that impacts on the fisheries would be limited by an effective fishpass system, however, the MRC's Council Study estimated that a 40% reduction in short distance migrating whitefish was possible. There appears to be an assumption that a run-of-river HPP does not affect habitats beyond the immediate dam area. As a result, little attempt has made to relate the fisheries stock dynamics to the expected environmental changes. The impacts of the isolation or flooding of the tributaries by the impoundment has not been considered, and this will likely compromise the wild capture fisheries and the livelihoods of the people that depend on them.

A full assessment of the habitat and environmental conditions both in the impact area and downstream should therefore be undertaken. The developer has noted that a robust fishery monitoring system has been considered in the design period of the PLHPP.

Fish passage

Because the PLHPP is immediately downstream of the Xayaburi HPP any fish passage will need to consider these dams together. It would be impractical to have a much higher standard of fish passage at Xayaburi combined with a lower standard at Pak Lay, which would then become the bottleneck for migratory fish.

Fish pass design

An effective fishpass requires that fish are both *attracted* to it, which is towards the higher flows, and that they can *swim up it*.

Attraction

Upstream and downstream migration is very likely to occur when the spillway or other release structures, as well as when the powerhouse are operating. Upstream migratory fish will therefore be attracted to greater flows through the powerhouse. Although a fish guidance system is proposed, these do not function well in large rivers. As such the fishpass should be designed to carry much larger flows. In addition the developer must ensure that the entrances and exits to the fishpass should be above the water levels at all times.

> *The design of the fishpass facilities should be aligned with those at Xayaburi.*

Fishpass entrances should be provided at the powerhouse and spillway, and it is standard practice to use a *collection gallery*. Fish attraction at the spillway depends on the amount of flow. When the spillway is initially engaged at low flows, only one gate would likely be open, and fish would move onto the apron. At higher flows, all the gates would be used, and fish would aggregate along the sides as they will not be able to swim through the gates. To accommodate this behaviour, fishpass entrances are needed on both sides of the spillways.

When the spillway is operating the navigation lock can be used to provide fish passage, but it would need to be specifically designed with a dual function of fish passage and navigation. The developer indicates that both the navigation lock and flood discharge gates meet the requirements for fish passage, but no details are provided.

The PLHPP uses an *attraction flow* external to the fishway to improve fish attraction. The fishpass channel has a design discharge of 3.7 m^3/s and external attraction flow of 4.7 m^3/s, for a stated total of 8.5 m^3/s. While external attraction flow is a good design practice, the total discharge for the system is still a very small fraction of flow in the river. Common industry practice is to use 10% of low river flow, as is noted in the CNR review. This would require a flow of some 310 m^3/s.

The fishpass in the Xayaburi HPP uses up to 200 m^3/s in the fishpass facility, with a combination of auxiliary flow and fishway channel flow. Similar design options should be considered for the PLHPP. To dissipate the energy of the additional discharge, larger pools and a lower gradient will be required.

Fish passage

The dual-slot, vertical-slot baffle is a standard design that should suit the behavior of Mekong fishes. However, the application of the design as proposed in the PLHPP will limit the passage of large fish and large numbers of fish.

The fishpass design at the PLHPP is based on theoretical maximum swimming speed. However, this is not used for fishpass design because fish need to navigate turbulence as well as the maximum water velocity, which have not been considered in the Pak Lay case. Larger fish will also not be able to use the resting pools, and they should be made longer. Similarly, the slot width needs to be increased from 0.6 to 1.5 m, which has been adopted in the Xayaburi fishpass. Similarly, the fishway depth needs to be increased to accommodate the conditions when the reservoir water levels are lower.

Downstream fish passage

The potential downstream migration pathways are through the reservoir, fishpass *via* a "fish guidance system", turbine debris screens, turbines, spillway and navigation lock. For flows up to 6,100 m^3/s, which is most of the time, all flow passes to the powerhouse which will first guide downstream-migrating fish to the "fish guidance system" and then the debris screens and turbines.

Many Mekong riverine fish species have drifting larvae, which typically require a minimum mean channel velocity of at least 0.3 m/s to be maintained in the water column. If the water velocity is too low the larvae may either, settle to the bottom of the reservoir and die, starve from lack of suitable planktonic food, or are subject to greater predation in the static, less-turbid water of the reservoir.

The modelling studies reported above show that at discharges above 6,100 m^3/s mean channel velocities are greater than 0.3 m/s, so larval drift will likely be maintained when the spillways and turbines are operational. However, in dry years flows less than 6,100m^3/s can occur for 80% of the time, while the physical model suggests that at 1,940 m^3/s, the velocity in the reservoir immediately upstream of the dam is less than 0.2 m/s. The impacts on larval drift can be mitigated by lowering the reservoir level to maintain water velocity throughout the reservoir, and it is recommended that the reservoir management system is reviewed to assess the potential to maintain water velocities for larval drift at flows less than 6,100m^3/s, even if only for limited (and critical times).

The developer indicates that a fish guidance system will be provided at the upper inlet of the fishway to prevent the fishes from entering the turbines and guide them to the fishway. However, no concept sketches, detailed plans or descriptions have been provided. Behavioural guidance systems are used in shallow, low discharge environments that have a low water velocity, but these are unlikely to be suitable for the Mekong. A physical screen could be used but none have been designed for 6,100 m^3/s. The independent fish experts believe that it is possible to design screens that can divert fish away from the powerhouse. However, the developer has indicated that it is difficult to find suitable screens.

Downstream passage through the fishpass is possible but very few fish would locate the upstream entrance. There is no hydraulic cue for downstream-migrating fish to enter the fishpass at the upstream end and the fishpass uses a very small flow compared with the flow through the turbines. While the powerhouse is operating without the spillway, almost all fish would migrate to the debris screens and turbine intakes.

Low	Moderate	High	Very High

Risks to fish migration before mitigation

	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 Pak Lay site – including spillway and turbines	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	Very High	Low	Moderate	Very High	High	Moderate
Medium-bodied (30-150 cm)	Very High	High	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	High	High	Low	Low	Very High	High	Moderate
Mid-water	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	High	High	Low	Low	Very High	Very High	High

Risks to fish migration after mitigation

	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 Pak Lay 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

It is expected that implementing the recommendations in the TRR will significantly reduce the risks to fish migration.

Fish approaching the turbines firstly encounter a debris screen. The details of the debris screens in the PLHPP have not been provided, but they are typically vertical bars with gaps of 12 to 20-cm. The gaps allow eggs, larvae, juveniles and adult fish up to approximately 75-cm long to pass through to the turbines. However, larger fish can be trapped against the screens and die. This is a very high risk for adult fish in the PLHPP that needs to be addressed by developing the screen design with a fish collection system and diversion channel. The Xayaburi HPP has this type of system to divert fish from the turbines.

Fish experience three impacts passing through turbines: pressure, shear and blade strike. The extent of injuries and mortality from these impacts depends on size, swim bladder (gas bladder) morphology and the fragility of the species, as well as the turbine design. The physical attributes of the turbines in the PLHPP are described in the documentation but there are no data on the impacts of blade strike, shear or pressure, and how this might potentially impact fish. There are no specific data of these impacts on Mekong fishes, but some aspects can be extrapolated from other species.

The spillway will be used mainly when river flows exceed the powerhouse flows of 6,100 m^3/s but may be used at other periods to balance flow through the turbines. At flows above 16,700m^3/s the spillway gates are fully lifted and the reservoir level drops. Larvae, sub-adult and adult fish are likely to be migrating downstream when the spillway is in use. However, the spillway uses undershot radial gates, which have a high risk of injuring fish if they partly open. If the gates are operated fully open there is little risk for fish. It is therefore preferable to operate with fewer gates fully open than more gates partly open.

Gate operation has a significant influence on flow patterns downstream and the effectiveness of fishpass entrances. Various configurations of gate operation need to be tested in physical modelling to integrate flow patterns with the spillway entrances for the fish passes.

The CNR review

While the CNR review agrees with many of the recommendations made in the TRR, there are several areas not addressed in the CNR review. Importantly, the CNR review concludes that the "*PLHPP is nearly fully compliant with MRC guidelines and international standards, and that any remaining issues should be easily addressed during the next stage of the project*". However, the TRR suggests that there is much that can still be done to further avoid, minimise or mitigate the impacts.

The CNR review did not appear to appreciate the complexity and cost of some of the recommendations such as fish screens, or the size of the fishway that is required to pass 10% of low flows. The recommendations proposed - many of which CNR agrees with - require a complete redesign of upstream and downstream fish passage for the PLHPP. These are not minor changes and will require a major increase in the budget, and hence affect the economic viability of the proposed HPP.

The implications of the cascade and transboundary impacts

Placing the impacts of the PLHPP in the context of the other tributary and mainstream dams is central to any determination of whether it is a reasonable and equitable use. Dams act as barriers to movement, which can potentially be mitigated through provision of suitable fish passage facilities. However, fish passes are rarely, if ever, 100% efficient, especially for passing the highly diverse fish species fauna found in tropical rivers. Each dam will potentially reduce the number of fish that are able to move further upstream. The cumulative effects of reducing migration success at each dam will multiply the impacts at each facility. In addition, the probability of bypassing several dams in series decreases with each successive dam, irrespective of the efficiency of each fishpass facility.

Substantial mortality is likely for downstream migration should fish and larvae pass through the turbines. Similar high mortalities are also likely to occur if the larvae pass over the spillway. However, without adjustment to the operating rules, most larval stages of fish are unlikely to bypass the impounded reach because they depend on flow. Consequently, the cumulative mortality rates past successive dams are likely to be considerable, to the detriment of fish recruitment and production, and ultimately catches.

Transboundary fisheries impacts

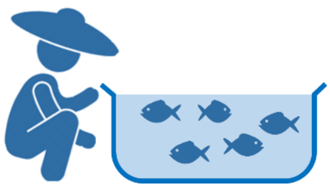
The developer provides a generic description of the fisheries in the Lower Mekong Basin impacts on fisheries production. However, no comprehensive trans-boundary fisheries risk and impact assessment has been provided, other than a general description of the potential transboundary impacts.

The modified hydrological regime due to the HPPs in China and larger tributary projects, linked with the depleted sediment loading expected over the longer term, is likely to have major impact on productivity in the Lower Mekong Basin, with knock-on effects on fish and fisheries. The developer notes that the Pak Lay HPP would cause some impacts, but that these would be limited due to the fishpass facility. However, this is a rather superficial assessment, which assumes that the fishpass facilities will address all the concerns.

This is not likely to be the case, and there is a need for a dedicated transboundary impact assessment including the potential socio-economic impacts.

Monitoring

The developer provides a limited baseline assessment, which was also noted by the CNR review team. The CNR team recommended a more comprehensive monitoring programme, but this has not yet been adopted. This programme should run for a minimum of 2 years before construction and should be maintained throughout the construction and operational phases, although additional activities will be required during the construction phase. International standard protocols exist for these monitoring components and MRC is establishing standard procedures as part of the Joint Environmental Monitoring project (JEM) and the Fisheries Abundance and monitoring (FADM) initiative. The developer should liaise and engage with the MRC to adopt these procedures to harmonise sampling methods and develop the capacity to share data and improve on the assessment results.



The fisheries mitigation options outlined are unlikely to fully compensate for the lost fisheries production.

Fisheries management and mitigation measures

In addition to the fishpass, the developer proposes several measures to manage and mitigate impacts on the fisheries including:

- Release of a flood pulse at the onset of the wet season to encourage upstream migration of fish;
- A mobile fish transport unit with large aerated containers to collected fish from downstream or the resting pool in the fishpass;
- Fishery conservation management should be implemented in the project area, but no details are provided; and
- Adoption of aquaculture within the reservoir area and establish community fisheries and individual household fish/frog ponds. For farmers who have paddy fields the rice-cum-fish system will be introduced and promoted.

These measures are unlikely to fully compensate for the lost fisheries production. They also do not address social and economic issues associated with the establishment of aquaculture, as most communities do not have the skills or capacity to invest in these activities.

> *The fish pass design outlined in the feasibility level documents is unlikely to function well. It is understood that that the developer is addressing the recommendations made in the CNR review.*

Conclusion

The current fish passage solution for PLHPP has a very high risk of passing very few fish safely. Almost all migrating fish will be blocked from continuing to migrate upstream, as well as significant impacts on fish passing downstream. If the fish passage remains unaltered, it will very likely have significant transboundary impacts on migratory fish populations.

Following the recommendations in the TRR greatly reduces this risk but will significantly increase cost. The present budget for fish passage is USD 8.59 million, which is 0.4% of the total project cost. An effective fish passage solution would likely be closer to 10% of the project cost.

Socio-Economic Impacts

The socio-economic impacts of hydropower development stem not only from the knock-on impacts on the environmental goods and services on which people (even those far from the dam site) depend, but also from the direct impacts of the impounded area and construction activities.

A systematic socio-economic impact assessment typically describes the **baseline** situation (pre-project or without project), predicts the **impacts** of the project (before mitigation), defines **mitigation** measures, and presents the **residual impacts after mitigation**.

Baseline

The baseline information is most detailed for the population living close to and potentially affected by the project. This covers 256 households (1,377 people) upstream of the impounded area, 8 villages and 744 households (3,647 people) who would be displaced by the reservoir, 12 villages and 2,913 households (15,363 people) downstream of the dam and 3 villages with 354 households (1,714 people) who will be impacted by the resettlement.

The documents indicate that some 80% of this workforce is engaged in agriculture, and that fishing is not the main occupation, but a supplementary source of income and the main source of protein. Assessments of the communities who may be affected further downstream is based on a 5km corridor on either side of the Mekong and divided into the Zones as defined by the MRC. Besides outlining the population of these Zones, the documentation includes descriptions of selected villages or districts, and information on tourism. The reports also present a ‘degree of dependence’ on the river in the different zones and on either side of the river, on a scale of 1-5. This shows that the highest dependency on the river is in Cambodia and Viet Nam, with the lowest dependency along the Lao / Thai border. The methodology to determine these dependencies is not elaborated.

Impacts

The developer has estimated impacts on the people in the vicinity of the PLHPP from ‘major negative’ to ‘major beneficial’, but there is little detail provided on these impacts. The transboundary and cumulative impact assessments are quantified by adding up land requirements and people resettled for all seven mainstream hydropower projects in Laos, which would result in the resettlement of 30,000 people and the loss of 18,000 ha of productive land. The documents indicate that these are significant impacts. Beneficial changes such as improvement in basic social infrastructures and facilities, increased revenue for the Government of the Lao PDR and local employment are not quantified but are also seen as of medium to major significance.

> *The socio-economic impacts on the communities in the direct vicinity of the PLHPP are well described, and funded mitigation measures have been proposed.*
>
> *The impacts on communities further downstream and in the other MC are less well described and no mitigation measures are proposed.*

Six categories of impacts are identified for each transboundary Zone defined by the MRC as follows:

- Improved access to domestic and irrigation water due to higher water levels in the dry season;
- Improved cropping due to easier access to the river, but loss of some riverbank cropping areas;
- Improved health and nutrition due to improvement of infrastructure, facilities and communication, but some loss of protein due to obstruction of fish migration;
- Improved tourism due to improvement of infrastructure, facilities and communication, but negative impacts on some tourist sites such as rapids;
- Socio-political conflict between groups of people who agree and disagree with the projects; and
- Mitigation of climate change due to displacement of fossil fuels.

The transboundary socio-economic impacts are therefore seen as mostly beneficial with some adverse effects on fisheries potential.

Mitigation

The Feasibility Study compared two options for the dam site, and ultimately selected the upper dam site in part due to the smaller number of people that would be displaced.

The developer describes several mitigation measures to reduce the impacts on fisheries, sediment transport, water quality, and navigation. Direct social mitigation measures are described through the development of alternate livelihoods strategies, health and safety during construction and operations disease prevention and control and emergency preparedness, with a budget of US$ 880,000. The overall intention is to improve the welfare of the people living in the project area who might be adversely affected by the project through a range of measures with an estimated budget of US$ 90.6 million (including fees to be paid to Government of Laos for implementation). The compensation and resettlement costs are estimated at US$ 87.9 million.

The interim mitigation measures for the access road includes a specific social compensation and monitoring measures, with a budget of US$ 29,000 for social monitoring and US$ 105,000 for compensation and ritual feasting.

Comments on the socioeconomic assessments

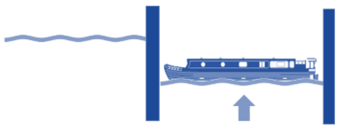
While the developer mentions data limitations in several places, they make very little use of more recent information at Member Country and MRC levels. Most of the typical direct impacts on local populations are covered, but are not differentiated by gender, ethnicity, poverty or other categories, and vulnerable groups that might require different approaches to mitigation. The impacts on communities further from the PLHPP are simply added up, without discussing potential synergies and limits (for example, availability of land for resettlement).

Ecosystem-related cumulative impacts on people are not addressed. It would be preferable to compare future scenarios with the PLHPP to a possible future without the PLHPP, rather than before- and after-project scenarios. It would be advisable to remain consistent with the approach taken in the MRC Council Study and other assessment tools developed by the MRC, which are based on the best available science.

Mitigation measures related to the physical and economic displacement of people in the immediate project area are relatively well defined. The measures for villages that are not directly displaced but are upstream or downstream from the project or will function as host communities are not as clearly described. It is uncertain whether the same objectives with regards to livelihoods and living standards apply to these villages which mitigation measures they will benefit from.

Despite a strong dependence on the river and its ecosystems in the Cambodia and Vietnamese Zones, and the expected medium to major negative impacts, no mitigation measures are identified for these Zones.

Navigation



Article 9 of the 1995 Mekong Agreement notes that navigation is not assured a priority over other uses but should be integrated into any mainstream project with a view to minimising the impacts. The harmful effects to navigation, therefore, mainly relate to the unnecessary slowing down of shipping due to excessive down time of the lock system for repairs. There may also be dangers posed to shipping due to the design of lock, and crew may also suffer some inconvenience while waiting to use the lock, especially if they need to moor overnight.

However, there may be positive effects related to easier and safer navigation on the reservoir behind the dam, and the navigation lock design could make for safer mooring for crew to go ashore for provisioning purposes.

The review of the navigation facilities at the PLHPP was hampered by the lack of AutoCAD drawings and the non-standardised MRC terminology. The review has highlighted the following design issues that should be addressed:

> *There several design recommendations that will make use of the navigation lock system safer, consistent with the MRC Guidelines, and will reduce maintenance requirements and limit downtimes.*

- The bridge over the upper lockhead is too low and should be standardised to the latest "*Design of a Master Plan for Regional Waterborne Transport in the Mekong River Basin*";
- The area for the second ship lock has not been clearly defined and construction of the parallel lock must be feasible so as not to leave the Lao PDR with excessive costs when it is needed;
- There is not enough space to install the stoppage cable to gently stop oncoming vessels;
- The ship lock is situated at the right river bank, whereas the present navigation channel is on the left bank. This is a necessary component of the overall design, but it does mean that shipping will have to cross in front of the powerhouse and water releasing structures, which can pose a danger.

It is therefore expected that substantial excavation work will have to be done to accommodate a wide, deep and straight lock approaches;

- The guidance walls should be curved outwards to guide shipping away from the spillway and the powerhouse-intake.
- There should be sufficient space for three zones in the approach of the lock, *viz.* a lay-by area, a waiting area and an overnight area as recommended by PIANC;
- The downstream guidance wall should have a vertical front as is the case with the upstream guidance wall;
- There is little information on the road connection to all parts of the ship lock, as is required under the PDG2009;
- Both lock accesses are not aligned with the PDG2009, particularly with respect to the downstream lock access and future second parallel ship lock's access channels that will have to share the approach channel;
- The developer indicates that the European standards have been applied, but these are not referenced. Similarly, frequent mention is made to the Chinese standards. However, these are not in common usage. The PDG2009 proposes the PIANC shipping association recommendations;
- The backflow at the end of the guidance wall mentioned in the Feasibility Study needs further investigation as this may pose a danger to shipping;
- Three ladders in each lock chamber wall are not enough. It is recommended that 4 ladders on each side of the lock chamber should be installed in wall recesses;
- It is recommended that Pak Lay should use the same number of floating bollards in the lock as is provided for Xayaburi;
- Contrary to the PDG2009, the DG2018 does not pay much attention to the lockage time, but rather emphasizes safety during filling of the lock chamber. The shorter the lockage time, the greater the turbulence and flow patterns are more dangerous. It is more important to ensure safe locking than faster locking. This principle should be emphasised in the operational rules for the ship lock;
- There may be a real danger of cavitation with the faster filling speeds. The proposal to reinforce the concrete in the valve sections with steel linings is therefore laudable;
- The waterway classification is made according to Chinese norms, rather than the Lao PDR classification system. In the absence of an existing Lao waterway classification, the guidelines from PIANC should be applied;
- Cargo vessels of 2,000 t should also be included in the classification instead of only 500t push convoys. These may have dimensions of 110m x 11.40m x 3.00m, which can be accommodated in the ship lock;
- The design water levels should not assume that the Sanakham HPP will be constructed until it has completed the prior consultation process;

The following auxiliary systems are recommended (even though they are not specifically requested in the PDG2009):

i. Line hooks in the lock chamber and the guidance walls at various levels. These line hooks should be adjacent to the ladders;
ii. The mechanism for the Stop cables should be explained;
iii. Additional ladders in the upper and lower guidance walls;
iv. Provision of fish passage structure[s] through the lock chamber during idle navigation times; and
v. An emergency overhead rolling crane to remove floating or sunken heavy debris and to position the bulkheads in their recesses.

Dam Safety

Dam break and impact assessment modelling is standard in large projects, and this establishes the risk profile of the structure and hence its design requirements. the review team understands that this analysis has been done, but the detailed results have not been made available for the review.

Relevant Compliance and Guidance Documents

CNR, in their review conclude that the design was 71% compliant and 29% not fully compliant to the PDG2009 for dam safety. However, the developer does not appear to have correctly interpreted the ICOLD guidelines which are specified in the PDG2009. The requirements for dam safety plans are acknowledged in the Feasibility Report and relatively detailed descriptions of these proposed plans are included, and it is assumed that these will be developed further during the detailed design stages. However, the need for these to be completed before impoundment of the reservoir is not highlighted.

> *"The feasibility level design is generally aligned with the PDG2009, but there is more work to be done during the detailed design stage to ensure compliance.*

The developer does not indicate if an independent Panel of Experts has been appointed as proposed in the PDG2009. This panel should be constituted at the Feasibility Stage, so that they can review and advise throughout the detailed design and construction.

Therefore, whilst the developer has generally complied with the PDG in most areas, they have more work to do to demonstrate full compliance before and during the detailed design, construction and operation stage. Importantly the ICOLD Bulletins recommend that the consequences of dam failure (consequence assessments) are used to define hazard categories for the dam, and that these be used to select the relevant design parameters. This has not been done and the design parameters cannot, therefore, be confirmed as relevant for Pak Lay. They are also not consistent with those used for the Xayaburi HPP, immediately upstream.

The Developer acknowledges that the Laos Electric Power Technical Standards must be followed. However, there are very few references to these standards in their documents and it does not appear that they have either followed these standards nor have they provided evidence that they are designing the project to higher standards.

Site Geology

The Feasibility Report describes a band of karstic limestone through the reservoir basin site but suggests that, due to the low-lying nature of the river in the regional topography, water cannot escape from the reservoir. This limestone band is not clearly identified in the drawings and further information should be provided to give confidence that the reservoir will not leak.

The developer has identified that the geology of the dam foundation has potential for seepage under the dam and that the ground needs treatment to prevent seepage in quantities that could deform the rock. There are several areas where the foundations are expected to be on strongly or moderately weathered rock. The developer plans backfilling the area under the powerhouse with concrete, but no additional treatment has been identified for the other locations. Discussions with the developer's engineers indicated that they intend to provide concrete slab protection over this weaker rock downstream to prevent scour, but this is not yet shown on the drawings.

The extent of scour downstream of the flood gates has been considered in the feasibility design. While, 12m of scour is reported as possible, the rock cores for this area were inspected and the rock appeared to be of reasonable quality and scour depths in this area may be less than anticipated. However, the extent of scour and its impact on the design must be reconsidered during the detailed design.

Whilst the construction of the dam does not require significant excavation on the abutments slippage on the left abutment may occur and rock support may be required. This must be installed as the works start to protect the workers. Slips after construction are also likely to affect the fish pass.

Project Layout

The Feasibility Study Report was prepared before the decision was made to adopt the upper dam site, and a final set of documents must be prepared for the upper site. In addition, the final design criteria and operational parameters for Xayaburi must be considered.

The developer has used a physical hydraulic model to confirm the safe performance of the dam, but this report has not yet been provided.

Failure Modes Assessment and Downstream Impacts

A detailed failure modes assessment is now standard international dam safety practice. This provides inputs to dam break and downstream inundation modelling and hence informs the consequence assessment. That in turn guides the dam safety plans and appropriate instrumentation for monitoring the development of failure modes, assists in preparation of emergency plans and the need for downstream evacuation plans.

In the Pak Lay case, this is needed as there are likely to be impacts felt at the Thai border some 100km downstream. Moreover, several villages lie along the banks of the Mekong immediately downstream of the dam site. The impact of failure of the dam under worst case scenarios, must therefore be investigated.

The developer has noted that a dam break study will be conducted if the Pak Lay HPP progresses to the next stage. They also note that there is a safety margin in the design, that the probability of dam failure is very small, and that protective measures such as building dikes and retaining walls would be considered based on the dam failure analysis.

The Design Criteria

Flood safety

International guidelines recommend that flood design standards should be based on hazard categories rather that the 1:2000 and 1:10,000 events as interpreted by the developer. In addition, the developer indicates that the design flood for the energy dissipation and anti-scour structures is the 1 in 100 yr flood. These structures are located close to the main power station and flood gate sections. Therefore, if they become damaged during larger floods, the main structures may be undermined by back scour. There are several areas where the stilling basins are founded on strongly weathered materials, which makes this more likely.

> *"The design criteria for Pak Lay should be aligned with those at Xayaburi and based on failure modes and consequence assessments.*

The design and check floods have been estimated as being 34,700 and 38,800 m^3/s respectively. However, these design and check flood flows are significantly lower than those used in the detailed design of the Xayaburi HPP. The size of the design floods is a critical dam safety design criterion that needs to be confirmed at the feasibility stage, and the discrepancies between the extreme floods between Xayaburi and Pak Lay need to be identified and agreed as soon as possible.

Seismic safety

The seismic assessment refers to a 2016 seismic hazard assessment, which has not been provided as part of the PNPCA documentation. However, the Feasibility Report does include provide some of details. The 5,000 yr earthquake has been selected based on ICOLD Bulletin 148, 2010, but this Bulletin recommends either the 1,000yr, 5,000yr or the 10,000yr earthquake depending on the consequence rating for the dam.

At Xayaburi the 10,000 yr earthquake was used due to the expected high impact of failure of the dam. The consequences of a failure at Pak Lay may have a similar consequence of failure, and therefore it should be assumed that this would also be a high hazard dam requiring a 10,000 yr criterion.

Structural Stability

The approach to structural stability appears acceptable. However, the design appears to rely upon a pumped drainage system. This needs to be reconsidered under guidance from the Panel of Experts to ensure the systems are adequate to deal with the possible seepage, or indeed if the system is advisable. If the drainage system is required, then there must be sufficient redundancy and back-up systems to ensure that it will operate under all operational scenarios.

Dam and Reservoir Operation

Operation of the dam in flood conditions is described along with the anticipated gate operation at all stages of the flood, rising and falling limbs of the flood wave. In addition, the impacts of the dam operation during both normal and extreme flood has been modelled, although there are no clear maps showing the extent of inundation due to the impoundment of the reservoir and no maps to show the extent of downstream flooding, which are important for emergency preparedness.

Safety monitoring of the dam has been described, and the proposed monitoring appears to be comprehensive. However, again it does not appear to have been based on a detailed failure modes assessment and some of the proposed monitoring may not be effective. The proposed operational strategy must be consistent with the operation of other hydropower schemes on the Mekong. This will require operational information sharing with Xayaburi to ensure that releases from Xayaburi do not affect the safety of Pak Lay. In the future, this strategy will need to consider the Sanakham project if it is developed.

Dam Safety Management

Details of the proposed dam safety management system, including an Emergency Preparedness Plan have been made available, and in general, these appear reasonable for the feasibility stage of the project. However, as indicated, a consequence analysis should inform the downstream Emergency Preparedness Plan involving both Lao and Thai emergency disaster management teams, and the instrumentation and dam safety monitoring must be targeted to the failure modes assessment. The dam safety management system must also comply with the Government of Lao PDR guidelines, and must be implemented at the start of the construction period.

Emergency Preparedness plans must be based on the expected consequences of dam failure and must include both Lao and Thai Authorities

TRANSBOUNDARY IMPACTS

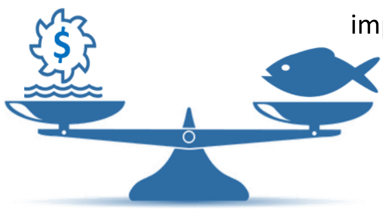
Background

Sustainable development recognises that all the world's nations have a responsibility to protect the environment, but that developing nations have a right to develop. This is inherent in the 1995 Mekong Agreement, and there was an expectation that the Mekong River System would be further developed. It was recognised that this would include hydropower development. However, the Member Countries also agreed, *inter alia*, to protect the ecological balance of the Mekong River Basin, use the shared waters in a reasonable and equitable way, and to make every effort to avoid, minimise and mitigate harmful effects.

The prior consultation process is a cooperative process aimed at promoting these principles and objectives, especially where developments may have transboundary impacts. It allows the notified Countries highlight their concerns with the proposed development, and for the notifying Country to take these concerns into account. It must be more than an administrative process and must entail a genuine effort to recognise the needs and concerns of all the Member Countries.

To do this, developers must identify what transboundary impacts ***may*** occur due to the notified proposed use, but also assess this as part of a cumulative impact assessment that considers the ***additional*** transboundary impacts that may occur due to the development, and the impacts on existing, planned and foreseeable future developments. This is central determining whether the proposed water use is reasonable and equitable and is necessary for the notified Countries to evaluate the potential impacts of the proposed use on their existing and proposed future use of the shared watercourse. This must include all possible impacts, and not only those associated with hydropower development. It would not be reasonable to limit a proposed development, while allowing the same impacts through other factors in your own country.

The PLHPP developer has not undertaken a rigorous transboundary and cumulative impacts assessment and has copied much from the Pak Beng case. While the Pak Beng impacts are relevant in generic terms the ***specific and cumulative impacts and contributions from the PLHPP*** must be assessed.



This is complicated by notification at the feasibility stage of the development process, as the final impacts are not yet known. The transboundary and cumulative impacts of hydropower development have been intensely investigated as part of the Council Study, and the developer should have made use of these studies in the transboundary and cumulative assessments. However, as it is now clear that most developments will have some transboundary impacts, provided that all viable efforts have been made to avoid minimise and mitigate adverse impacts, it is important that some measure of transboundary impact could still be regarded as reasonable and equitable.

A determination of whether the PLHPP is a reasonable and equitable use must balance the rights of all the Member Countries to develop, the financial impacts of measures to minimise transboundary impacts, and the extent of these impacts relative to other impacts and developments

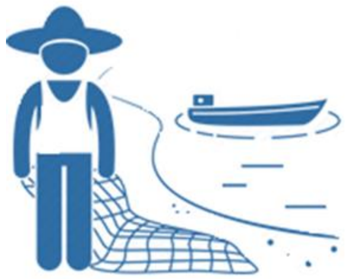
Minimising transboundary impacts

The PLHPP lies in the Upper Lao Cascade of planned and existing HPPs. Upstream of Pak Lay, the Xayaburi HPP is nearing completion and is scheduled for commissioning in 2019. The Pak Beng HPP has undergone prior consultation, but development has been suspended while the power purchaser undertakes further studies. Two more potential HPPs have been identified in the upper cascade. The Luang Prabang HPP lies between Xayaburi and Pak Beng, and the Sanakham HPP is planned downstream of Pak Lay.

> *Development of the full cascade of HPPs in the upper Zone will completely change the ecosystems of this reach.*
>
> *Leaving some gaps between headwaters of one HPP and the next upstream dam, together with better fish passage design, will reduce these impacts.*

If all these mainstream HPPs are completed, the tailwaters of the downstream HPPs, will back up close to the next upstream dam, transforming virtually the entire upper Mekong stretch in Lao PDR from a flowing river, to a standing water ecosystem. The slowly flowing waters in the impounded reaches will affect downstream drift of fish larvae and will trap sediments upstream of the dams. The loss of fish larvae combined with impacts on upstream migration will quickly be reflected in lost fisheries potential in the upper Zone and on the long-distance migrators in the middle and lower Zones. This will also affect local fisheries which are expected to show a significant decline. Key species, including the Mekong Giant Catfish, are likely to become extinct, although this may happen even without mainstream hydropower development.

However, because the upper migration Zone has a lower diversity and lower biomass of fish it is less clear what impacts these HPP will have on fisheries potential in Cambodia and Viet Nam, or on Thailand in the middle migration Zone. Nonetheless, the interconnected nature of the shared ecosystem is likely to result in some transboundary impacts. This will have knock on socio-economic impacts. The reduced downstream sediment transport may take decades to have transboundary impacts but impacts on ecological functioning are likely sooner.



There are likely to be some impacts on fisheries due to the cumulative impacts of all the proposed developments. But the contribution from the PLHPP is less clear.

However, these impacts can be minimised through improved design and operations of the HPPs especially if they are conjunctively managed. Moreover, the transboundary impacts of the PLHPP in isolation may not be significant as those associated with the larger storage reservoirs, but it could be additive. Importantly, the technical review has highlighted that some measures could be implemented to further minimise the impacts of the PLHPP.

Improved fishpass design, larger sediment flushing gates, and operations that allow for reservoir drawdown more often than when flows are very high, and dam safety measures linked to a consequence assessment will all have positive spinoffs. But hydropeaking and ramping operations will have impacts in the river reaches just downstream of the HPP and should be avoided if possible. Improved design of the navigation facilities can avoid the dangers of locking and navigation in the impounded reaches may be facilitated. However, together these measures could have significant impacts on the financial viability of the HPP.

COMMENTS, RECOMMENDATIONS AND WAY FORWARD

Background

This section presents some general comments from the review team and presents an option to further minimise the impacts through modified operating rules.

General comments

The developer has made efforts to address the potential impacts of the PLHPP.

However, the technical review suggests that more could be done.

The developer has made efforts to address the potential impacts of the PLHPP, and the provisions of the PDG, even at the feasibility stage. The independent review commissioned by the Government of the Lao PDR has identified several issues, many of which have been confirmed by this review. Some of these have already been addressed, and the developer has provided comments on the 1st draft of the TRR which provide clarity on some of the issues raised.

However, the review has identified issues that should still be addressed and is based only on the documentation that has been formally submitted and not on commitments to present further studies. As with the previous processes, the developer has paid limited attention to collecting baseline data, and the ongoing monitoring programmes are not well described. The transboundary and cumulative impacts are rudimentary and largely copied from the Pak Beng case.

There are opportunities to further minimise the potential impacts, and further minimise the impacts of the HPP. Increasing the size of the bottom sediment flushing gates and timing the flushing process with actions at Xayaburi together with changed operating rules can pass considerably more sediment and facilitate downstream migration of larvae. Redesigning the upstream fish pass facilities may reduce the potential impacts of the proposed HPP.

Addressing the concerns raised with respect to the navigation facilities will make them more durable and safer to use. Designing the infrastructure based on international and Lao PDR safety standards and on a consequence assessment will improve dam safety. In all cases, better aligning the infrastructure design and operations with those at Xayaburi will lead to a better project.

These recommendations will require careful reconsideration of the economic viability of the PLHPP and are only likely to be feasible if some of the external environmental costs are absorbed by the power purchaser, the developer or the notifying country. Some of this may be offset by improving the hydrological data based on the likely future flows.

However, even if these issues are addressed, some residual impacts will remain. The change from a flowing water to a standing water ecosystem are unavoidable. Some loss of sediment is inevitable, and no fishpass facility will be 100% effective.

Whether these residual impacts may rise to the level of substantial damage as contemplated in Articles 7 and 8 of the 1995 Mekong Agreement is complex and beyond the scope of a technical review. This determination must, in any event, be made by the notified Countries.

Alternative operating rules

The current operating rules for the PLHPP propose that the impoundment is operated at 240m for flows below 16,700 m^3/s and are only lowered when inflows are forecast to increase above this level in the wet season. At higher flow the turbines may be shut down if the operating head becomes too low (< 7m). The capacity of the turbines is reached when flows reach 6,100m^3/s. This means that at inflows between 6,100m^3/s and 16,700m^3/s water is released through the lower sediment flushing gates and through the higher spillway gates to maintain the operating level at 240m.

Flow velocities above 0.3m/s are required to maintain drifting larvae and to promote the transport of sediment through the impounded section. In the case of the PLHPP flow velocities in the impoundment will most likely drop below 0.3 m/s with inflows below 3,500m^3/s, if operating levels of 240m are maintained. Flows are likely to be below this threshold for some 55% of the time (after considering the impacts of the Lancang cascade), thus increasing larval and sediment losses.

However, if the reservoir operating levels could be gradually decreased to 230m at certain critical times then it may be possible to maintain flow velocities over 0.3 m/s and reduce the loss of drifting fish larvae and transport more sediment through the reservoir. If the bottom sediment flushing gates are used to balance the inflows and outflows to achieve this, and if these gates were enlarged it is likely that considerably more sediment would be transported through the impoundment. However, without similar actions at the upstream HPP the benefits of these measures will be limited.

This will reduce the total power output, increase the payback period and increase the costs of the loan financing. These challenges can be addressed by either increasing the Concession period, or increasing the price of the power, either uniformly, or just when operating levels are decreased below 240m. Some optimum between the environmental impacts, and economics of the PLHPP should be explored. Monitoring regimes can be devised to optimise these operations on an adaptive management basis.

What happens after prior consultation?

The end point of prior consultation is outlined in the PNPCA and indicates that the MRC JC should aim at arriving at an agreement and conditions (or measures) that could be applied to the proposed use. The previous prior consultation processes have highlighted that its success lies in a focus on agreeing a set of measures that avoid, minimise and mitigate any potential impacts, and not a ‘yes’ or ‘no’ on the proposed use itself.

In the Pak Beng case this set of measures was outlined in a "*Statement on the Prior Consultation Process on the Pak Beng Hydropower project in Lao PDR*" which was agreed by the MRC JC. It is anticipated that the Pak Lay process will similarly end in an agreed Statement. This is particularly important in the light of notification at the feasibility stage.

However, for the notified Countries' to gain some confidence that these measures are being applied, some post prior consultation process is necessary. In the Pak Beng case this was proposed as a Joint Action Plan (JAP). The purpose of the JAP is to support and track the implementation of the Statement, provide ongoing opportunities for discussions aimed at further improving the proposed project, and to present regular updates on progress with the final design and construction. This means that the notified Countries and stakeholders can remain engaged in the development of the project through its final design and development of the operating rules, which ultimately determine the impact of the proposed use on their use of the Mekong River System.