Mekong River Commission
Cambodia • Lao PDR • Thailand • Viet Nam
For sustainable development

# Overview

# of the Pak Lay Hydropower Project and its submitted documents

*This document provides an overview of the Pak Lay Hydropower Project (PLHPP) and the documents submitted to support the prior consultation process under the Procedures for Notification, Prior Consultation and Agreement (PNPCA) for the proposed project received from Lao PDR. It presents key information extracted from the submitted documents, except where stated otherwise. It is intended to provide a summary of the PLHPP to facilitate discussions with stakeholders who may be interested in the PNPCA process. It will enable these stakeholders to find essential information with respect to the project design as well as information on potential negative impacts and proposed mitigation measures, monitoring programmes, and social and environmental impact assessments.*


24 July 2018

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# 1. Introduction

On 13 June 2018, the Mekong River Commission (MRC) Secretariat received notification from the National Mekong Committee of the Lao PDR of their intention to submit the PLHPP for prior consultation under the PNPCA. The proposed PLHPP lies in Lao PDR's northern province of Xayaburi, and is planned as a run-of-river project with an installed capacity of 770 megawatt (MW).

The PLHPP is the fourth proposed project to be submitted for the prior consultation process under the MRC's PNPCA. The earlier three prior consultation processes were for the Xayaburi, the Don Sahong, and the Pak Beng hydropower projects conducted in 2010–2011, 2014–2015, and 2016–2017, respectively.

The PNPCA require the three notified Member Countries, in this case, Cambodia, Thailand, and Viet Nam, to acknowledge and review the documents submitted for prior consultation and to submit their replies to the MRC Joint Committee. The MRC Joint Committee may direct the MRC Secretariat to appoint a task team to assist in the evaluation of the proposed project by undertaking a technical review of the submitted documents. This may include an assessment of possible impacts on other water uses and on the ecological functioning of the river system as well as of any possible impingement on the rights of the Member Countries.

# 2. Purpose of this document

This document serves as a summary of the documents submitted by Lao PDR. It aims to allow stakeholders to access key information on the principles of the project design, likely social and environmental impacts, proposed mitigation measures, and the proposed monitoring and forecasting schemes. The document presents only information extracted from the submitted documents, except where stated otherwise.

# 3. Summary of the PLHPP

## 3.1 Background of the project

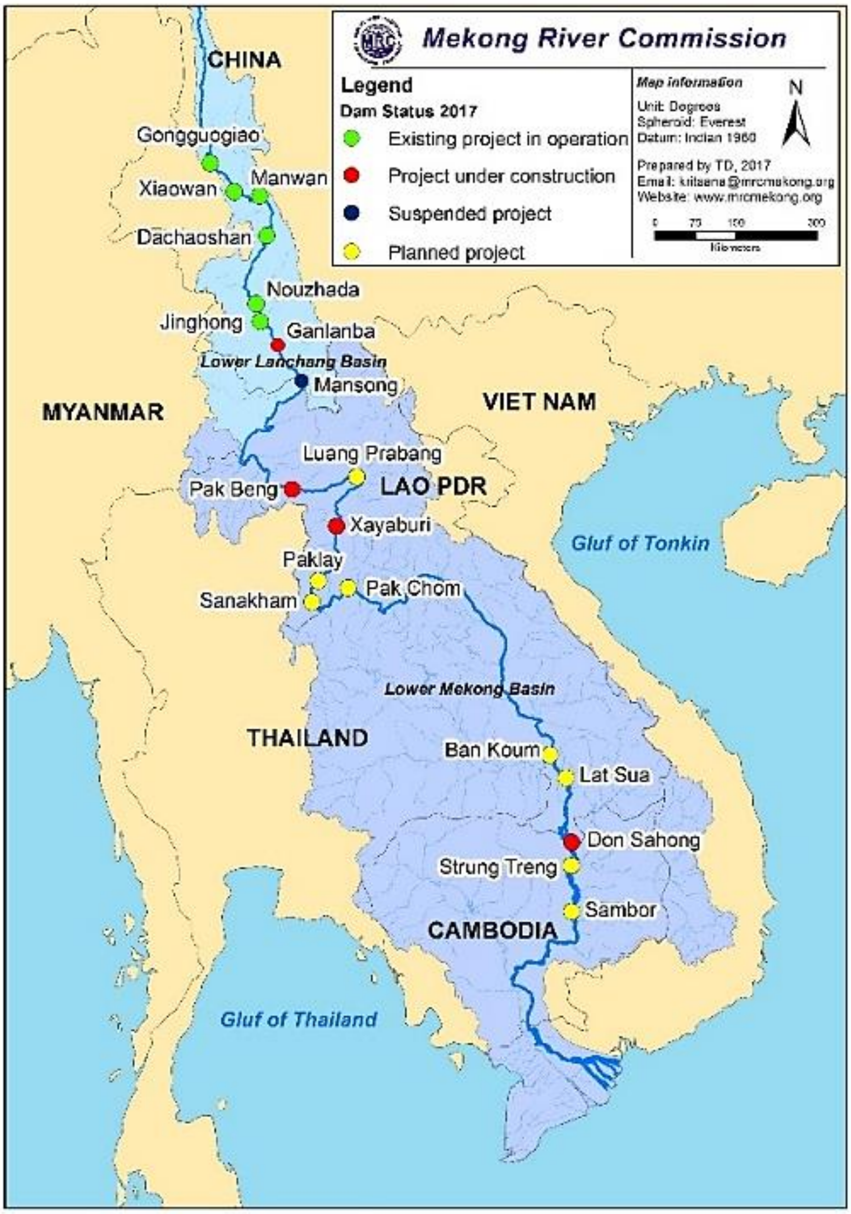
The proposed PLHPP is a run-of-river scheme located in the Mekong mainstream in Pak Lay district, Xayaburi province, in north-western Lao PDR. It is the fourth hydropower station (from upstream to downstream) of the 11 hydropower stations planned for the mainstream of the Lower Mekong River (Figure 1).

The PLHPP sits downstream of the Xayaburi hydropower station, which is under construction, and it is located about 1,829 kilometres (km) from the sea and 241 km upstream of Vientiane. The power plant is planned to have an installed capacity of 770 MW, designed with 14 turbines (generators), each producing 55 MW.

The PLHPP is mainly intended for power generation, but it is hoped it will serve to improve navigation and tourism.

The 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 investment cost is estimated at USD 2,134 million, invested and developed by PowerChina Resources Ltd and China National Electronics Import-Export Corporation (CEIEC) in a form of Build-Operate-Transfer (BOT).




**The PLHPP**

- Run-of-river project
- 241 km upstream of Vientiane
- Fourth in the cascade of hydropower projects in the lower mainstream of the Mekong River
- Installed capacity: 770 MW
- Turbines: 14 of 55 MW
- Expected construction start date: 2022
- Expected operations start date: 2029
- Power generation mainly for export and local consumption

**Figure 1:** The location of the proposed PLHPP.

(Note: While this figure shows the Pak Beng hydropower project as under construction, further development at this site has been suspended while the power purchaser undertakes further studies of its proposed energy mix).

## 3.2 Engineering structures of the proposed project

The project consists of water-retaining structures, water-release structures, the powerhouse, navigation structures, and fish pass structures.

The layout of the proposed PLHPP is shown in Figure 2 and Figure 3.

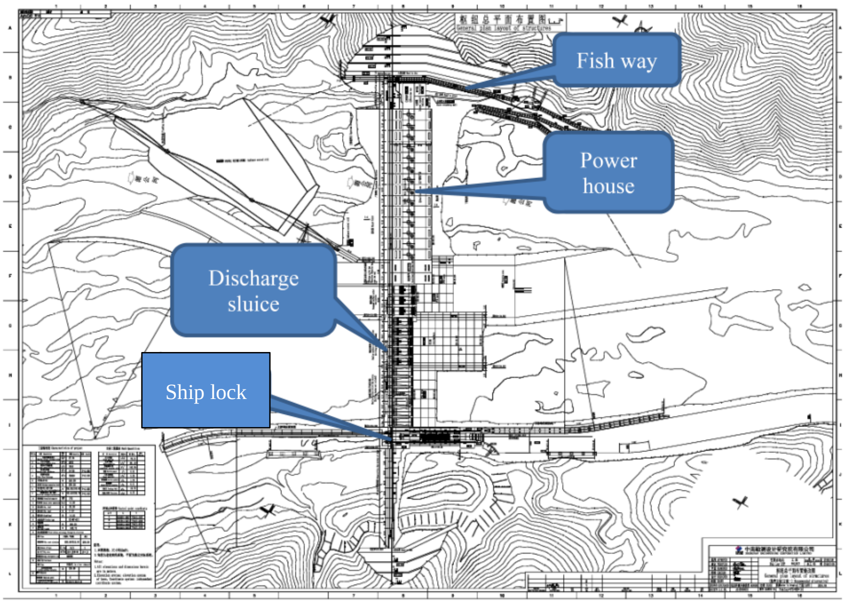



**Figure 2:** Main components and infrastructure of the PLHPP.

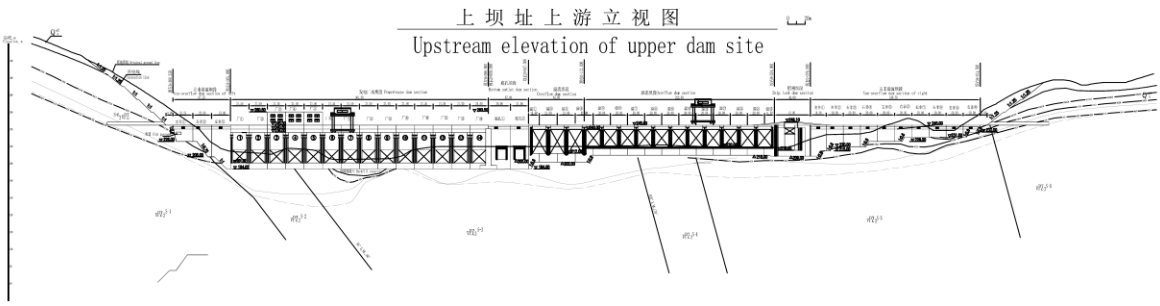



**Figure 3:** Typical section of structures.

### 3.2.1 Water-retaining structures

The water-retaining structures are the non-overflow gravity section on the right bank and the powerhouse section towards the left bank. The dam crest elevation is 245 metres above sea-level (masl), the maximum dam height is about 51 m, and the dam crest length is 942.75 m. The structures include an overflow section, a sediment-flushing section, a powerhouse section, a navigation lock section, and non-overflow sections on the left and right banks.

The overflow and the sediment-flushing sections are composed of 11 open-type high-level surface bays (surface spillways), three open-type low-level surface bays (middle level spillways), and two sediment-flushing bottom outlets. The 11 spillways have a total length of 334 m and a crest elevation of 245 m. The minimum elevation of the foundation surface is 194 m, and the maximum dam height is 51 m.

The water-retaining dam section of the powerhouse is 301 m long and consists of 14 dam sections. The unit spacing is 21.50 m. The total width of the powerhouse dam section, along the water flow direction, is 83.05 m.

### 3.2.2 Water-releasing structures

The water-releasing structures consist of the high- and low-level flood gates, the sediment-flushing bottom outlets, the fish pass, and the navigation lock.

There are 11 high-level **flood gates**, located adjacent to the navigation lock, each 16 m wide × 20 m high, with a weir crest elevation of 220 masl. The three low-level flood gates, located to the left of the high-level flood gates, are 16 m wide × 28 m high, with weir crest elevation of 212 masl. The design of flood standard for such structures as a concrete water retaining structure, water release structure, run-of-the-river, powerhouse, and upper lock head of shiplock is based on a 2,000-year return period, and their flood standard check is based on a 10,000-year return period. The peak discharge of the 2,000-year return period of flood is 34,700 cubic metres per second ($m^3/s$), while for the 10,000-year return period of flood is 38,800 $m^3/s$.

The sediment-flushing bottom outlets are located between the flood gates and the powerhouse with two gates of 10 m wide × 10 m high and invert elevation of 201.02 masl. Together, all the outlets have a length of 85 m along the water flow direction and a bottom elevation of 205 m. 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. A pressing slope is set on the top exit of the outlet, whose section dimensions are 10 m wide × 10 m high.

### 3.2.3 Powerhouse

The **powerhouse,** containing 14 bulb turbines, is on the left side of the main river channel, with a design discharge of 6,101 $m^3/s$. The main powerhouse comprises a generator hall and erection bay, with the dimensions of 400 m long × 22.50 m wide × 52.44 m high and unit spacing of 21.50 m (Figure 4). The auxiliary powerhouse is arranged downstream of the generator hall. The main components of the powerhouse are summarized as follows:

- **Generator hall**: This has a length of 301 m and a net width of 21 m.
- **Erection bays**: These are provided at each end of the generator hall. The main erection bay, located at the left end of the generator hall, has a length of 52 m and a net width of 21 m. The two sediment-flushing bottom outlets pass under the auxiliary erection bay.
- **Auxiliary powerhouse**: This building is a five-story reinforced concrete structure on the downstream side of the generator hall. Its overall dimensions are 26 m long × 21.40 m wide.
- **Turbine passageways**: Each turbine is located within its own passageway under the generator hall and auxiliary powerhouse.
- **Powerhouse intake channel**: The intake channel is the full length of the generator hall, at about 301 m.
- **Tailrace channel**: The tailrace channel is the full length of the generator hall, at about 301 m. The lowest elevation of the channel is 203.06 m, with a slope of 1:4 over 60 m to drop down to the natural riverbed. This channel is concrete lined.

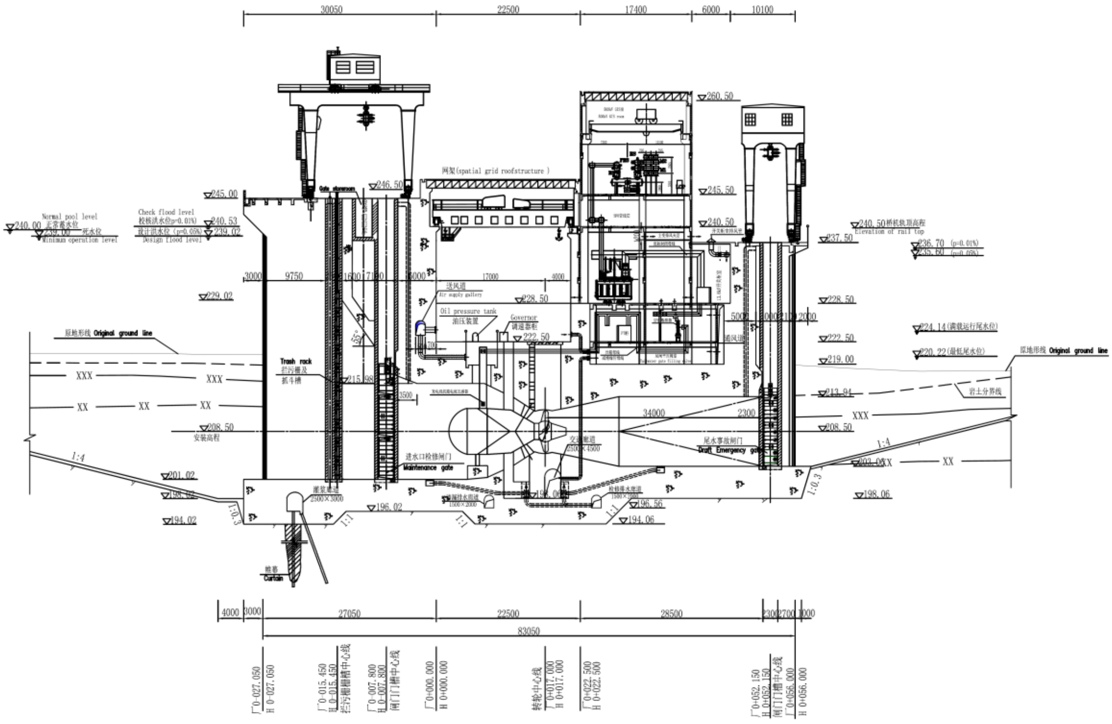


**Figure 4:** Cross section of the powerhouse.

### 3.2.4 Navigation structure

The **navigation structure** is a one-way one-step ship lock for 500-tonnes (t) ships, and a space for upgrading the ship lock into a double-way lock is reserved. 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 (Figure 5). The one-line way and a one-step lock is being designed, with a potential to expand this with a parallel lock.

The ship lock comprises a head bay, a lock chamber, a tail bay, and a water-conveyance system. The head bay and lock chamber are integrated. The passing time of a ship is guaranteed not to exceed 30 minutes (28.38 min). The access channel can generally accommodate two standard vessels of 500 t.

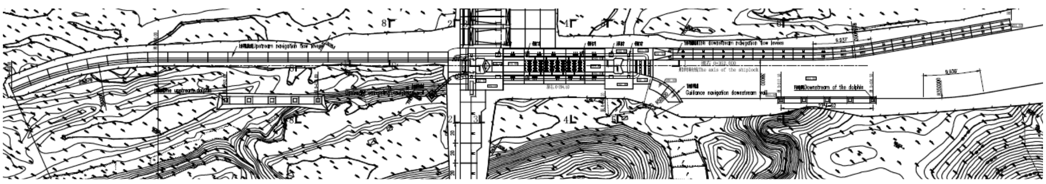


**Figure 5:** General layout of the navigation ship lock.

### 3.2.5 Fishway structure

The fish pass structure includes the fishway, a water-charging system, and a large resting pool. ***Fishway (channel):*** A bilateral vertical slot fishway is arranged along the left bank slope of the powerhouse, with a net width of 6 m, a depth of 2.50 m, and a total length of 1,017 m (Figure 6). The average slope of the fishway is about 2.1%.

The downstream end of the fishway is about 250 m downstream of the hydropower plant tailwater canal, at an elevation of 217.5 m. Water will flow slowly down the fishway, which is below the normal operational water level downstream of the dam (219 m).

The upstream end of the fishway is 100 m upstream of the hydropower plant. The bottom elevation is 237.50 m, which is below the normal operational levels upstream of the dam (239 m ~ 240 m).

Each fishway pond is 5 m long, with a drop between ponds of 0.14 m. A 10 m long resting pond is provided every 10 ponds and at all flow direction change. The width of the vertical slots is 2×0.7 m, and the depth of water in the fish pond is 2.5 m. The discharge of two vertical slots is 2×1.885 $m^3$/s, i.e. 3.7$m^3$/s, and the average flow velocity in the vertical slot is 1.08 $m^3$/s, which is consistent with the migration requirements of the target fish species.

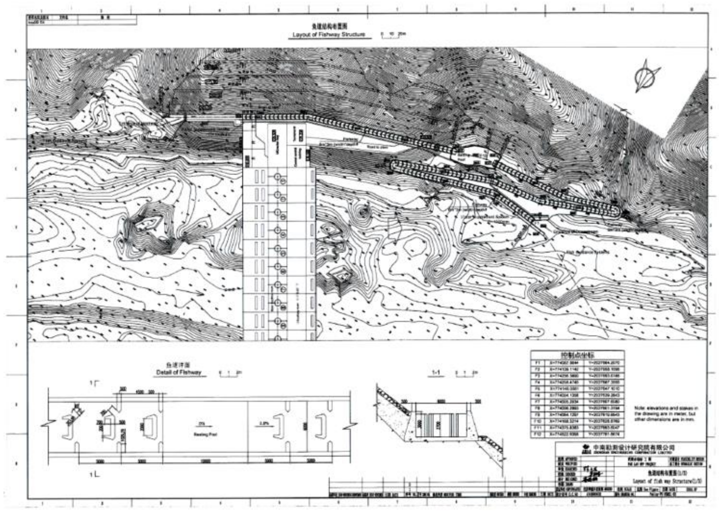


**Figure 6:** Layout of the fish structure.

*Water-charging system (attraction flows):* The water-charging system is arranged along the right side of the fishway. The pipes used are 1 m in diameter and will have a discharge of about 4.7$m^3$/s. The upstream intake of the water-charging system is close to the right side of the fishway and will draw water from the reservoir (see Figure 7). The centre elevation of the intake is 236 m.

Model tests of the hydraulic structures suggest that the surface water flow velocity of the upstream intake area of the fishway will be about 0~0.5 metres per second (m/s). The discharge of the water-charging system and the fishway is 8.50 $m^3$/s in total. Flow with a velocity of 1 m/s will be formed at the upstream intake of the fishway. The flow velocity of the upstream intake of the fishway will be greater than that in the reservoir, forming an apparent flow change, which is intended to attract fish.

Two outlets are set downstream of the water-charging system. Outlet #1 is at the downstream end of the downstream inlet of the fish pass, with an outlet elevation of 226 m. The water drops into the river channel from the outlet and forms a 15 m wide artificial waterfall. This is intended to attract migrating fish (see Figure 8). Outlet #2 increases the flow in the downstream section of the fish pass (see Figure 10). During operations, different fish attraction flow types could therefore be used, according to the species migrating at different times.

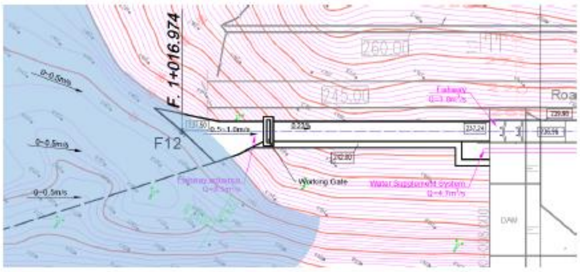



**Figure 7:** Upstream inlet of the fishway and water-charging system.

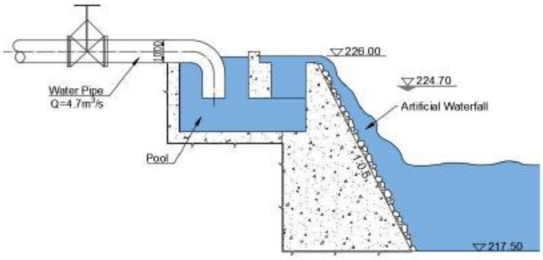



**Figure 8:** Downstream outlet section of the water-charging system.


**Figure 9:** Outlet #2 downstream of the water-charging system.

***Large rest pond:*** A large resting pond/pool is arranged in the middle section of the fishway, i.e. between chainage F. 0+613.834~ and chainage F. 0+670.567. The resting pool is about 56 m long, 23 m wide, and 3~4.5 m deep (Figure 10). The natural ecological slope will be replicated in the pond bank slope. Fishes can rest and prey in the resting pool to complete the migration. In addition to the large resting pool, a horizontal section, of about 10 m of length, is provided for the fishway every 50 m or so. The average flow velocity will be about 0.25 m/s. Fishes can slowly swim in the horizontal section and get a temporary rest.

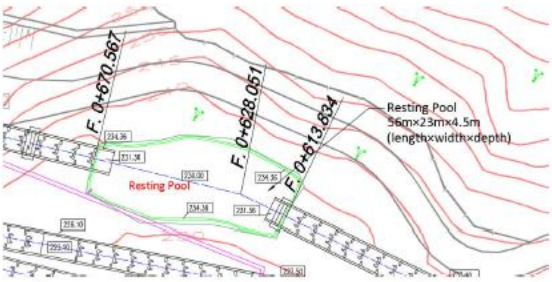



**Figure 10:** Fishway resting pool.

## 3.3 Dam safety

The structures have been designed to withstand extreme seismic and flood events. The adopted design parameters are

- flood standard
    - normal operation - 2,000-year return period with corresponding
        - upstream design flood level of 239.02 m, and
        - downstream design flood level of 235.50 m.
    - abnormal operation - 10,000-year return period with corresponding
        - upstream check flood level of 240.53 m, and
        - downstream check flood level of 236.70 m.

- seismic standard
    - return period of 475 years - peak acceleration is 0.13 g
    - return period of 5,000 years - peak acceleration is 0.384 g.

A detailed safety monitoring system is proposed for Pak Lay hydropower station and dam, consisting of sensors and instruments to monitor horizontal and vertical movement in all the structures, seepage flow under the structures, stress-strain and temperature, slope, and other elements.

Outlines of the dam safety management system and the emergency preparedness planning for the operational period have been provided in the feasibility study.

## 3.4 Operation

The PLHPP is a low-head type. To reduce reservoir inundation impacts and facilitate sediment-flushing of the reservoir, natural water flow conditions shall be restored as far as possible in the flood season, and the reservoir level shall be as close to the natural water level as possible. According to this principle, and considering inflow characteristics into this project, two reservoir operation modes are proposed at this stage as shown in Figure 11.

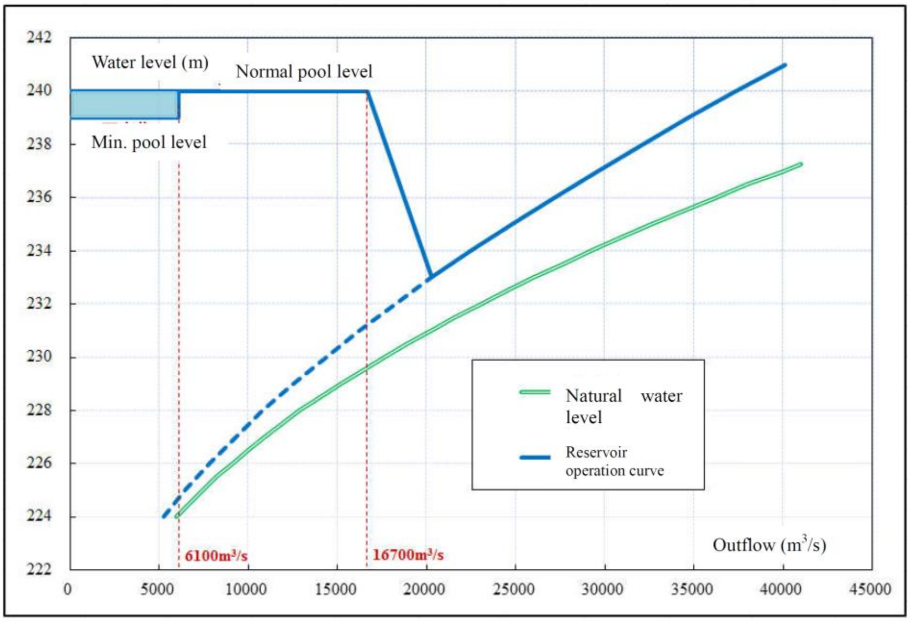


Figure 11: Schematic diagram of the reservoir's operational rules

### 3.4.1 Reservoir operation for normal power generation

Expected inflows will be forecast with an upstream near real time flow and rainfall monitoring network. If the forecasted inflow is less than the design discharge (i.e. 6,100 $m^3$/s) at full load, the power plant will be operated at reduced load. However, to balance the generated load against the demand, the reservoir level may vary between the minimum pool level (i.e. 239 m) and the normal pool level (i.e. 240 m). The minimum operating water level of the reservoir will be no less than 239 m.

### 3.4.2 Reservoir operation at higher than design flows

During flood season, if the forecasted inflow is larger than the design discharge (i.e. 6,100 $m^3$/s), but less than 16,700 $m^3$/s, the reservoir outflow must equal the inflow. The generator units will be operated at their capacity for power generation, and the extra flow will be discharged through the flood discharge facilities, maintaining the reservoir at the normal pool level (i.e. 240 m).

If the inflow is larger than 16,700 $m^3$/s and is forecast to increase further, the power station will stop generating, and the flood discharge facilities will be fully opened. During the flood recession limb, if the inflow is less than 16,700 $m^3$/s and is forecast to decrease, the flood discharge facilities will gradually be closed until the reservoir level return to the normal pool level (i.e. 240 m), and the hydropower project will resume power generation.

## 4. Overview of the submitted documents

Three main documents were submitted: the final feasibility study report, the final environmental and social impact assessment (ESIA) report, and the final review reports from Compagnie Nationale du Rhone (CNR) and Brazilian Fishing Engineering.

The feasibility study report was prepared by Hydrochina Zhongnan through a lengthy process starting in November 2007. The draft feasibility study report was completed in December 2012 and went through various reviews by the China Renewable Energy Engineering Institute, the Laotian Ministry of Energy and Mines, and by CNR together with Brazilian fishing engineering experts. Based on the recommendations put forward in the review report by CNR and the fishing engineering experts, completed in January 2017, the feasibility study report was finalised in March 2017.

**Some facts about the submitted feasibility study report:**

- November 2007: Feasibility study commenced by Hydrochina Zhongnan.
- July 2010: Feasibility study completed.
- April 2011: The study recommended to give up the lower dam site scheme due to the large number of affected people to be relocated (~10,000 inhabitants). Recommended to choose the upper dam site.
- December 2012: Feasibility study report for the upper dam site completed.
- April 2014: Feasibility study report passed the review by China Renewable Energy Engineering Institute.
- July 2015: Feasibility study report passed the interim review by the Ministry of Energy and Mines (MEM) of Lao PDR.
- September 2015: Feasibility study report reviewed by CNR (for hydrology, sediment, navigation, dam safety) and by fishing engineering experts from Brazil (for water quality and fisheries).
- December 2015: CNR submitted an interim review of the feasibility study report.
- January 2016: Meeting on the interim review between MEM, CNR and Hydrochina Zongnan.
- March 2016: Experts from Brazil submitted a report on the interim review for water quality and fishway.
- April 2016: Conducted technical exchange between Hydrochina Zongnan and CNR.
- July 2016: Written exchange between Hydrochina Zongnan and Brazilian experts.
- January 2017: Final CNR review report and fishing engineering experts review report prepared.
- March 2017: Final feasibility study report finalized.

The ESIA report was prepared by the National Consulting Group in August 2011. The final report is dated January 2018.

The following sections provide a summary of each report.

## 4.1 Feasibility study report

The feasibility study report contains 11 chapters, including executive summary, hydrology, engineering geology, project planning, project layout and main structures, monitoring and evaluation (M&E) equipment and hydraulic steel structures, construction design, project management plan, environmental and social impact assessment, project cost estimation, and economic evaluation. Engineering drawings are attached as part of the report. The following sub-sections provide a summary of each section.

### 4.1.1 Hydrology

The chapter discusses the catchment overview, basic hydrological data, runoff, flood, stage–discharge relation at the dam site, sediment, and hydrological telemetry and forecast systems.

*Basic hydrological data*

The Pak Lay hydropower station is located between Luang Prabang and Chiang Khan hydrological stations. Together with the water gauging station at Pak Lay village, these stations formed the basis for the hydrological analysis for the PLHPP.

Four gauging stations were also built, in December 2007, along the full river reach where the PLHPP is planned, i.e. a gauging station at the upper (proposed) dam site, a main channel gauging station at the lower dam site, a right channel gauging station at the lower dam site, and an automatically recording gauging station below the dam sites. Through these stations, water level data of over one year were collected, and flood data in August 2008 were observed. A manual gauging station was established at the upper dam site in March 2016, and a hydrological station on the reaches at the dam site in July, to conduct water level observation, flow measuring, and suspended sediment sampling at the dam site.

*Runoff*

The historical data recorded at Luang Prabang (1960–2015) and Chiang Khan (1967–2015) hydrological stations was used as basis for runoff calculations. The mean annual flow at the upper dam site of 4,060 $m^3/s$ was derived from an interpolation algorithm from the runoffs calculated from the two stations, using the area ratio method.

*Flood*

Analyses for the design floods were based on the data from Chiang Khan and Luang Prabang hydrological stations. The feasibility study adopted the design results from the 2009 Mekong mainstream optimisation study performed by MRC and CNR for MEM.

The design flood hydrographs at the dam site were generated from flood hydrographs at Chiang Khan station in September 2000 and August 2008, which were selected as typical flood hydrographs due to data availability. The amplification method was based on flood peak and flood volume within each period or frequency.

*Stage–discharge relation at dam site*

The stage–discharge relation at the Pak Lay upper dam site was adopted after comparison to the water level data collected at the upper dam site from January 2008 to March 2009, together with the relationship synthesised from the Chiang Khan and Luang Prabang stations, and the measurements undertaken using a flow meter (September 2015 to September 2016) and an Acoustic Doppler Current Profiler or ADCP (July to September 2016). The developer intends to verify the stage–discharge relationship after one year of stage and discharge measurements at the dam site.

*Sediment*

Because there is no data on sediment at the dam site, the characteristic values of sediment and the monthly average sediment discharge at the dam site were calculated using the sediment data from the Chiang Khan hydrological station. Sediment data are available from Chiang Khan from April 1967 to March 1968, for March 1977, and recently from 2009 to 2015 (189 measurements). The developer adopted the recent measurements at Chiang Khan station for the flow–sediment discharge relationship for the calculations at the dam site. The annual average suspended sediment load at the project site was estimated to be 16.5 million t per year or 0.129 kg/$m^3$.

A set of *in situ* observations was collected at the dam site and in the reservoir reach, which were used to analyse the concentration and the grain size distribution of the suspended load, concentration of graded suspended load, and gradation curve of bed load. However, after the review and the analysis conducted by CNR, the developer decided to adopt the result determined by CNR (in 2013) for the average sediment particle grain curve and its variation range in the dam site and reservoir reach for the moment.

Sediment monitoring is planned to include the following main tasks:

a) Monitoring the water and sediment entering and exiting the reservoir;
b) Determining the loss of storage capacity and its process to serve the reasonable dispatching of the reservoir;
c) Estimating the influence of sedimentation in the reservoir on the hydropower station, providing basis for the dispatching and operation of the reservoir during flood season;
d) Monitoring the scouring of clear water in the downstream from the hydropower station.

Monitoring would aim to determine the inflow and outflow of sediments to and from the reservoir, measure accumulation by cross sections of sediments in the reservoir, observe the water level in the reservoir, and analyse sediment samplings from the reservoir and particle grading.

*Hydrological telemetry and forecast systems*

A telemetry station network is planned and will be maintained during the operational period. The system is planned to collect real time water and rainfall data, alert, analyse and compile data, query reservoir inflows, and provide flow forecasts. The system will start from the Luang Prabang station and end at the PLHPP, covering an area of about 10,400 square kilometres. In addition, temporary, manual water level observation stations will be established at key flood control points in the construction area to monitor flood during flood season as well as to ensure the safety of dams and other facilities. These will be removed when construction is complete.

### 4.1.2 Engineering geology

The engineering geological survey began in November 2007, and the field survey was completed in May 2008. The supplementary exploration at the proposed upper dam site was carried out from November 2011 to May 2012.

The region is located at the juncture of the eastern edge of the Tethyan orogenic region and the ancient Pacific overprinted orogenic belt. Due to the Dien Bien Phu strike–slip fault zone, the regional tectonic strike presents a group of nearly North-Northeast (NNE) compression–torsion structure and a group of Northeast (NE) secondary structure. Regional metamorphism is relatively strong, and most rocks are steeply dipping. A simplified map of the regional geology and project location is shown in Figure 12.

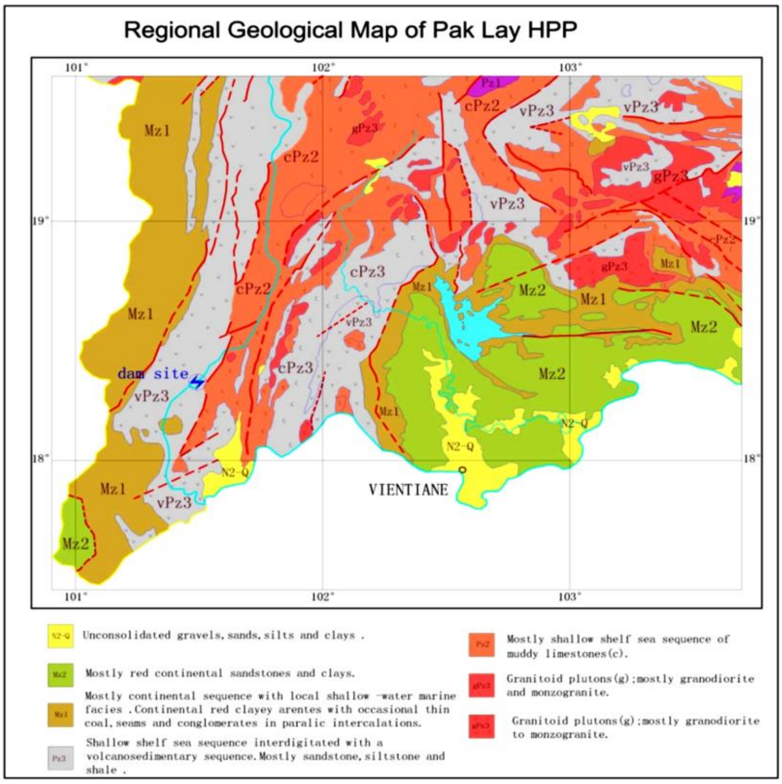



**Figure 12:** A simplified map of the regional geology

A detailed comparison of the two potential dam sites was carried out during the feasibility study. Both dam sites have similar engineering geological conditions and both meet the requirements for the planned project. Ultimately, the selection of the preferred dam site was based on social factors, such as the amount of resettlement required, and hence the upper dam site was selected.

The seismic hazard assessment presented in the feasibility report for the proposed project site determined that the horizontal seismic peak ground acceleration for the design (10% in 50 years, 475-year return period) and check earthquakes (2% in 100 years, 5,000-year return period) are 0.133 g and 0.384 g, respectively. The basic earthquake intensity of the dam site is considered to be VII (Modified Mercalli Scale).

However, the developers intend to carry out a project site seismic safety evaluation for the upper dam site in the next phase. In addition, the geology shall be reviewed during the construction phase and the design adjusted if any geological defects are revealed during construction.

### 4.1.3 Project layout and main structures

This chapter has been presented in the above section on the overview of the PLHPP.

### 4.1.4 M&E equipment and hydraulic steel structures

*Hydraulic machinery*

Auxiliary hydraulic equipment includes lifting equipment in the plant (two 200 t/30 t/10 t single-trolley double-beam electric bridge cranes), a technical water supply system (two steady pressure tanks with effective volume of 100 $m^3$), a compressed air system in the plant, an oil system (two 20 $m^3$ net oil drums and two 20 $m^3$ operating oil drums are provided for the turbine oil system, two 35 $m^3$ net oil drums and two 35 $m^3$ operating oil drums are provided for the insulating oil system), and a hydraulic measurement system.

*Primary electrical system*

The main electrical equipment is composed of 14-bulb type tabular turbine generators (Model: SFWG55-64/8000); generator voltage distribution devices; three-phase, dual-winding, ODWF, copper winding, non-excitation voltage-regulation boosting power transformer; and 500 kilovolt (kV) HV distribution equipment (indoor SF6 gas insulated switchgear (GIS) is proposed for 500 kV switchgear).

The roof lightning strips of the main powerhouse and the auxiliary powerhouse of the hydropower project will be used to protect them from direct lightning strikes. A scheme of 500 kV arrester of the hydropower project will be arranged for over-voltage protection against lightning invasion wave.

The grounding system of the whole plant is mainly composed of three parts, including the reservoir area grounding grid in front of the dam, the underwater grounding grid behind dam, and the grounding grid used for main powerhouse, auxiliary powerhouse, and ship lock. The grounding grids at each position are interconnected with each other in multiple manners.

It is proposed that two circuits of 500 kV transmission lines be linked to the 500-kV joint switchyard of Lao PDR at the border between Lao PDR and Thailand.

*Metal structure*

The metal structure equipment of the PLHPP is mainly distributed in the flood discharge system, headrace, power-generation system, ship lock system, and fish pass structures. The work quantity of the hydraulic metal structures is 23,170 t in total.

The metal structures of the flood and sediment-flushing system includes the bulkhead gates at the upstream and downstream ends of the sluice gates, the service gates for the sluice gates, the emergency bulkhead gate for the sediment-flushing bottom outlet, the service gates for these bottom outlets, the bulkhead gate at the outlet of sediment-flushing bottom outlet, and the corresponding hoists.

In total, 14 units will be installed for the headrace and power-generation system, and each of them will be of single conduit and single draft tube. The metal structure equipment of the headrace and power-generation system mainly includes the water inlet trash barrier, the intake trash rack, the water inlet bulkhead gate, the tailrace emergency gate, and the corresponding hoists.

One service gate (immersed plain gate) for flood control shall be designed at the fishway in front of the dam, with high-strength, low-abrasion composite sliding blocks for the bearings. The gate will be subject to hydrodynamic opening/closing by a fixed winch hoist on a bent frame at the dam crest.

*Ventilation and air conditioning*

A ventilation and air conditioning design scheme, in which mechanical ventilation plays a predominant role supplemented by multiple online air conditioners, will be used for the whole hydropower project. According to the layout of the M&E equipment, a mechanical air supply/exhaust mode, characterised by air supply at the upstream side and air exhaust at the downstream side, shall be used for the whole hydropower project. Multiple online, central air conditioning systems shall be designed for the equipment room with large thermal loads. According to the relevant regulations, a purging system will be designed for the generator floor of the main powerhouse and the transport channel of the main transformer.

*Fire protection design*

The firefighting facilities and devices will be provided according to the degrees of importance of production and risk of fire. Special firefighting measures will be taken for special locations, according to fire prevention codes. An automatic fire alarm control system will be provided for the central control room.

Four extinguishing modes, i.e. water spray, fire hydrant, dry powder fire extinguisher, and carbon dioxide ($CO_2$) firefighting equipment, will be adopted. Water for firefighting will be taken from the reliable and abundant upstream reservoir. An independent double-loop power supply will be used for the firefighting power supply. A ventilation and smoke evacuation system has been planned. Electrical equipment with flame-resistant material or flame-retardant material will be adopted as far as possible. Fireproof materials will be used to isolate equipment rooms with fire risks and seal holes and cable conduits. Fire separation zones will be established to prevent fire from spreading.

### 4.1.5 Construction organisation design

According to the overall construction schedule and the layout of the hydraulic structures, the project construction is divided into two phases within the seven-year construction period. In Phase I, a coffer-dam will be constructed from the right bank to enclose the area of the ship lock, flood-release sluice, and non-overflow dam section. In Phase II, the river will be diverted through the completed structures, and coffer-dams will be constructed across the deep river channel to the left bank to allow construction of the powerhouse (14 turbine-generator units) and the non-overflow dam section on the left bank. The diversion procedure is critical and important during the construction.

### 4.1.6 Project management plan

There are three aspects in this report covering (1) project construction supervision and quality assurance, (2) project operation management, and (3) emergency preparedness plans. The overview of the contents is as follows:

**Project construction supervision and quality assurance**: The supervising engineer will adopt a series of practicable and effective operation technologies for construction supervision and quality assurance and will carry out the corresponding activities.

**Project operation management**: During the operation and maintenance phase, eight major departments will be set up, including the Work Safety Department, the Engineering Department, the Contract Planning Department, the Resettlement and Environmental Protection Department, the General Manager Working Department, the Human Resources Department, and the Equipment Supply Department. The management consists of project scheduling, operation management for structures, project quality detection, management of flood storage and relief, dam safety, formulation of engineering system, etc.

**Emergency preparedness plans**: The formulation of emergency preparedness plans for corresponding risks will be carefully analysed by the operation management unit to strengthen reservoir and dam safety management, improve the capability to respond to emergencies, ensure reservoir and dam safety, and reduce personal casualties and property losses. The emergency preparedness plans mainly cover dam break, natural hazard, accident disaster, public sanitation events, and social security incidents.

### 4.1.7 Project cost estimation

As noted in the documents submitted by the Lao Government, the project's total investment cost is **US$2,134 million.** Project's cost, as taken directly from the project documents, is summarized as follows:

Table 1: Project cost estimate

| No. | Item | US$ |
|---|---|---|
| 1 | Project main construction works | 1,082,487,564 |
| 2 | Transmission line construction and substation upgrading work | 90,000,000 |
| 3 | Project monitoring and management works | 25,000,000 |
| 4 | Land acquisition and resettlement | 75,000,000 |
| 5 | Company's scope of work (consultancy for various studies, supervision, management) | 221,989,851 |
| 6 | Basic contingency | 55,000,000 |
| 7 | Cost estimation for exchange rate risk | 7,000,000 |
| 8 | Price contingency | 25,000,000 |
| 9 | Financing cost | 552,767,005 |
| | **Total investment cost** | **2,134,244,420** |

### 4.1.8 Economic evaluation

Economic analysis shows that the project has an internal rate of return (IRR) on project investment of 10,22% and a payback period of 11.7 years (starting from the date that all units are officially put into commercial operation). Sensitivity analysis shows a variation of project IRR from 8.51% to 11.89% when the project investment, energy output, or interest rates vary within a range of plus or minus 10%.

## 4.2 Environmental and social impact assessment report

The ESIA report contains nine chapters including the executive summary, environmental impact assessment (EIA), environmental management and monitoring plan (EMMP), social impact assessment (SIA), health impact assessment (HIA), social management and monitoring plan (SMMP), resettlement action plan (RAP), initial environmental examination (IEE) for access road, and transboundary environmental and social impact assessment and cumulative impact assessment (TbESIA & CIA).

The following sub-sections provide a summary of each chapter.

### 4.2.1 Environmental impact assessment (EIA)

The EIA report includes nine chapters: introduction, project description, objectives, policy framework, baseline environmental conditions, social baseline conditions, downstream environmental and social baseline study, assessment of environmental impact, and public involvement.

The EIA report provides detailed information on the project area, potential impacts on the environment and social factors, assessment methodology and results, and recommendations. Three types of potential impacts were identified: (i) project implementation impacts; (ii) global impacts; and (iii) downstream area impacts.

During the construction phase, six potential impacts were identified, as follows: impacts on water quality, land and soil, solid waste, sewage and wastewater, terrestrial environment, and fisheries. During the operation phase, two potential impacts were determined: impacts on the terrestrial environment and on fisheries.

The report identifies some mitigation measures, as follows:

- Implement construction best practices to minimise negative effects on water quality during the construction phase;
- Plan and arrange for five solid waste disposal areas during the construction phase, three on the left bank and two on the right bank;
- Monitor the project as defined in the EMMP;
- Formulate a detailed forest clearing plan linked with salvage logging and biomass clearing plans;
- Develop a wildlife management plan in connection with the forest management plan;
- Establish a program to monitor the effects of the project on biodiversity and ecological resource use;
- Install the fish pass as defined by MRC's standards as well as international best practices;
- Set up a fish hatchery to breed indigenous fish species;
- Adopt aquaculture within the head-pond area;
- Implement fishery conservation; and
- Monitor erosion during the operation phase.

### 4.2.2 Environmental mitigation and monitoring plan (EMMP)

The EMMP report comprises nine chapters: introduction, policy framework, description of project, mitigation measures, institutional arrangement, management of environmental impacts during construction, control and corrective actions for EMMP, specific environmental monitoring activities, and references.

The total costs of the implementation of the EMMP during the pre-construction, construction, and operation phases will be US$23 million, i.e. about 0.93% of the total investment costs of US$2,134 million.

The detailed mitigation measures which will be implemented during the construction and operation phases were identified. During the construction phase, ten mitigation measures for impact on the physical environment were identified. These concern (1) climate and air quality, (2) noise and vibration, (3) geology and seismicity, (4) soils, (5) solid waste materials, (6) hydrology, (7) wastewater, (8) reservoir water quality, (9) groundwater hydrology and quality, and (10) sediment transport. Furthermore, the report also documents five mitigation measures for impacts on the biological environment. These concern (1) vegetation and land cover, (2) terrestrial habitats and fauna, (3) aquatic habitats and fish, (4) non-timber forest products (NTFPs), and (5) existing management and conservation.

During the operation phase, six mitigation measures for impacts on the physical environment were identified, namely concerning (1) climate and air quality, (2) contribution to climate change, (3) evaporation, (4) geology and seismicity, (5) soils, and (6) hydrology. Measures for mitigating impacts on the biological environment, especially the pressure on biological resources such as wildlife and NTFPs, were proposed to be implemented.

The important mitigation measures are summarised as follows:

- Coordination or conjunctive management can add greater value to the environmental flood flows of each individual Mekong River dam site and be used to maintain ecosystem services such as recharging groundwater in the flood plain and triggering fish migrations.
- Coordination in watershed management can foster a more consistent application of management techniques, provide a shared learning experience, and spread the economic benefits over the whole basin, rather than on isolated sections of the watershed.
- Co-operation in addressing the issues of an even greater than loss of the river fishery, which is the main income generated from the mainstream, should exist between all Mekong River development projects as this will be more productive than individual initiatives.

### 4.2.3 Social impact assessment (SIA)

The report contains nine chapters: introduction, objectives and methodology, project description, policy and legislation, social conditions, impacts and mitigation measures, social development plan, public consultation, and conclusions.

The objectives of the SIA are to

- assess the social issues and impacts on affected persons requiring targeted project investments and to identify the stakeholders and interactions among them;
- help in the design of social services that may be provided to improve the quality of life for affected persons and achieving the project's economic and social goals; and
- help in the formulation of a social strategy for participatory implementation.

The methodology used involves a desk study, a field survey, including a household census, and village interviews and meetings.

The SIA provides baseline information relating to existing and potential impact on social and environmental issues, including population and communities, socio-economics, land use, infrastructure facilities, water use and water supply, transportation, navigation, energy sources, public health, public safety and occupational health, agriculture, industries, mineral development, archaeology, aesthetic and recreation, tourism, flood control, land acquisition and compensation, livelihoods, gender, ethnic studies, culture, and education. It also reviews development plans and policies as well as laws and regulations relating to hydropower development and resettlement and compensation.

The study looked at two options for the dam site, the upper and the lower option. It was found that the population impacted by inundation in the lower dam site scheme would exceed the population impacted in the upper dam site scheme by 10,000 people. For the upper dam site, it is estimated that eight villages with **744 households and 3,647 people** will be affected by impoundment, 256 households and 1,377 people indirectly affected, 2,913 households and 15,363 people affected in downstream areas of the reservoir, and 354 households and 1,714 people affected in the hosting community for the resettled population, totalling 4,267 households and 22,101 people.

The main livelihoods are cultivation of rice, maize, and cassava, with some tree plantations of rubber and tea, for 80% of the total work force. Interviews with community leaders show that fishing is not the main occupation, but is a supplementary income activity and the main source of protein.

Sticky rice field (Right Bank | Maize Plantation

Fishing by Women near Ban Don Keuang (Left Bank) Upstream of Upper Dam site | River Bank Erosion and Garbage Dumping Normally Obzerved at Right-Bank Villages

The census indicates that household income ranges from US$2,800 to 6,900, averaging US$3,450 per family per year, coming from trading, cropping, wage employment, livestock, gold panning, and other activities. Household expenditure ranges from US$1,400 to US$3,700 per year.

The SIA identifies potential impacts and proposes a number of measures to deal with impacts on livelihoods, through resettlement and capacity building and training, water quality, transport, navigation, and public and occupational health. The total compensation and resettlement cost is estimated at US$87.9 million, as directly reported in the SIA.

### 4.2.4 Health impact assessment (HIA)

The HIA aims to manage health and safety issues for local communities as well as for labourers and workers during the construction and operation phases of the project. It covers key health issues at the national and provincial levels, and in the districts affected by the project. In the Pak Lay district, health facilities include a district hospital with 30 beds as well as 30 health clinics and 77 health staff. In the Met district there are five health clinics with 26 health staff. The HIA listed a number of health risks related to the project, with a mission statement to ensure health and safety for communities involved with the project.

The proposed health management and monitoring plan has the following components:

- Health and safety during the construction phase plan;
- Health and safety during the operations phase plan;
- Waterborne diseases prevention and control plan;
- Communicable diseases prevention and control plan; and
- Emergency preparedness.

The total proposed budget for the plan is US$880,000.

### 4.2.5 Social management and monitoring plan (SMMP)

The SMMP was developed based on the SIA study and is a project requirement under the laws and guidelines of the Government of Lao PDR. The overall objective of the SMMP is to improve the welfare of the people living in the project area who might be adversely affected by the project. The report defines and recommends the procedures that the project developer should follow during and after construction.

The SMMP is developed under the following guiding principles:

- Minimise the resettlement of the project-affected population (PAP);
- Provide adequate funding and support from the project to ensure that the living standard of the PAP is restored to at least the same level as prior to the project development;
- Allow the PAP to participate in the design, planning, and implementation of the resettlement action plan (RAP);
- Identify gender and ethnic group concerns and include their specific needs and perspectives in all components, strategies, and planned activities;
- Maintain the social and cultural cohesion of villages to minimise cultural and livelihood disturbance;
- Provide adequate livelihood restoration activities and infrastructure to minimise livelihood disturbance; and
- Have a transparent methodology for all planning, implementation, and compensation tasks.

The SMMP also includes:

- Institutional responsibilities;
- Budget estimations;
- Time and duration schedules; and
- Internal and external monitoring plans.

The SMMP covers issues similar to the SIA, such as livelihoods, population, and resettlement with differentiated needs for men and women. The budget proposed for social management and monitoring, including resettlement, is US$90.6 million, as stated in the original report.

### 4.2.6 Resettlement action plan (RAP)

The RAP is part of the ESIA. A resettlement implementation plan will be established and undertaken after project approval. The main aims of the RAP report are to:

- Prepare an action plan for the PAP to improve or at least retain the living standards in the post-resettlement period;
- Outline the entitlements of the PAP for payment of compensation and assistance for establishing their livelihoods;
- Develop communication mechanisms to establish a harmonious relationship between implementing agencies and the PAP; and

- Ensure adequate mechanisms and expeditious implementation of relocation, resettlement, and rehabilitation.

Compensation for loss of land and trees will be based on the official rate set by the committees that will be appointed by the Government of Lao PDR after project approval. For compensation costs, the estimates will be based on recent official compensation rates paid in the nearby area. The compensation and resettlement cost for the PLHPP is estimated at US$87,920,000, as stated in the original report.

### 4.2.7 Initial Environmental Examination (IEE) for Access Road

The report comprises sixteen chapters: introduction; institutional and legislative framework, and international agreement in Lao PDR; project description; description of the environment; screening of potential environmental impacts and mitigation measures; environmental management and monitoring plan (EMMP); environmental and social management and monitoring plan (ESMMP); institutional arrangement, institutional requirement, monitoring program and costs; monitoring programme; cost of environmental mitigation measures and project monitoring; public consultation and information disclosure; resettlement policy framework; RAP (resettlement action plan) updating and implementation; implementation schedule; findings and recommendations; conclusions; references; and appendices.

The objectives of the study are to provide a detailed description of the direct and indirect environmental effects associated with the proposed project during key milestones of work, the extent, duration and severity of the impacts, and a set of mitigated actions in the form of the ESMMP. This study is undertaken to meet the requirement of the Environmental Protection Law, and Regulation on Environmental Assessment in the Lao PDR (2002), as well as the Regulation on Environmental Impact Assessment of Road Project in Lao PDR (2004), of the Ministry of Public Works and Transport (MPWT).

The access road to the dam site and Project's area requires a roadway improvement, involving the construction of only a small portion of new road segments or realignments. The Project has been classified under Environmental Reduction Guideline for Road Project in Lao PDR (Red Book-1999) as Environmental Category B because the Project's environmental impacts will be minor as the work will consist mainly of the rehabilitation and upgrading of the existing road and the road does not affect any environmentally sensitive areas very much. The boundaries of the study are 15x2 m on either side of the road center line and still locate in the ROW (Right-Of-Way).

Major impacts were identified, including: (i) encroachment into important ecological areas; (ii) encroachment into historical and cultural sites; (iii) risks to potential tourism sites; (iv) erosion and silt runoff; (v) impairment of water uses; (vi) impacts on environmental aesthetics; (vii) air pollution hazards; (viii) noise and vibration disturbance; and (ix) risks from increased traffic volume and speed.

The important mitigation measures for the expected impacts from the construction and operation of access road are summarized as follows:

- Design and construct site drainage structures to avoid a cascade effect and to ensure that runoff is conveyed into natural drainage lines at controlled velocities. The sufficient number of drainage outlets must be incorporated such that flow from any individual outlet is not excessive.
- Where road alignment is close to the rivers, widening or re-alignment will be on the side not adjacent to the river.
- Road engineers will work with the Lao Clean Water Supply Authority in each province during the detailed design phase to identify places where there are existing and planned water pipes and to find appropriate ways to manage working around water pipes.
- Dispose of spoil only where permitted by Environmental and Local Authorities. To the extent feasible, avoid disposal on slopes greater than 30 percent.
- In case of new quarries, the quarries will be approved by the environmental monitoring authorities. Quarrying activity will be limited to a minimum of necessary sites, with previously used sites preferred.
- Contractors will pay a fee to villagers for damages to water systems, based on number of days without water until the system is fixed. Or Contractor has to provide potable water in the meantime as well.
- Where possible, limit extraction to the riverbank. Spread extraction out over a broad area at the site on the Mekong. Limit extraction of river sand and gravel to as few sites as possible, preferably using sites that are already impacted.

Only budget for monitoring and capacity development was identified in the report. It costs US$275,000 about 0.01% of the total investment costs of US$2,134 million. This includes the expenses for the Monitoring Committee to carry out quarterly monitoring, and for the ESRS' to carrying monthly monitoring.

### 4.2.8 Transboundary environmental and social impact assessment and cumulative impact assessment (TbESIA & CIA)

The report comprises of eight chapters: introduction; project description; baseline conditions; hydrology and sediment change; transboundary and cumulative impact assessment; mitigation and management interventions; public involvement; and conclusions and recommendations.

The objectives of the TbESIA and CIA study are to provide decision makers with timely information on the potential transboundary and cumulative environmental and social consequences. The study will help ensure that decisions on such projects take into account such consequences as well as facilitate mechanisms for potentially affected people and governments to participate in the prior consultation process.

Five studied zones in the Lower Mekong Basin were identified. They include Zone 1: Northern Lao PDR; Zone 2: Thailand–Lao PDR; Zone 3: Southern Lao PDR; Zone 4: Cambodia; Zone 5: Viet Nam Delta. The study zones were based on the combined nature of transboundary resources and political boundaries. The general framework for the study is illustrated in Figure 13.

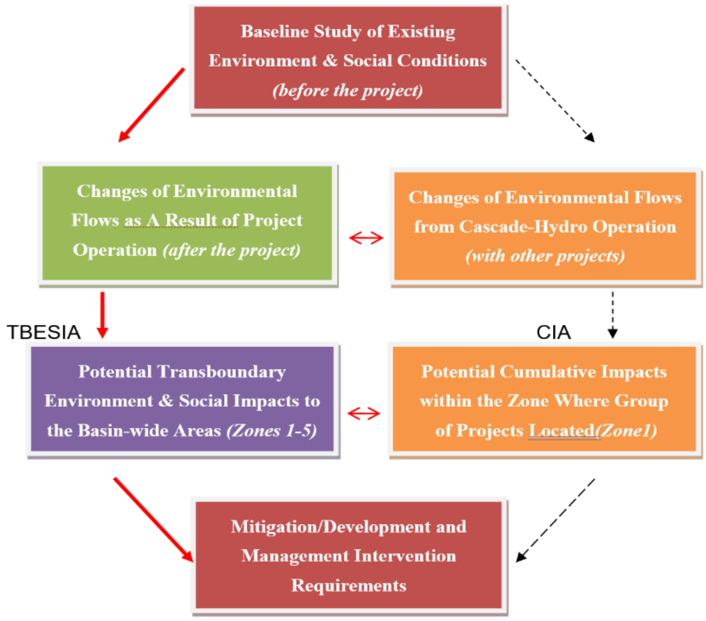



**Figure 13:** The framework for the TbESIA & CIA

Detailed transboundary and cumulative impact assessments access were provided on the aspects of fish migration and fisheries, navigation, water quality, dam safety, climate change, and social impacts.

Significant transboundary impacts include obstruction of fish migration, limitation of fish habitats, impact on fish population, severe depletion of fish species listed on the International Union for Conservation of Nature's Red List of Threatened Species, increased risks of fish being caught before migrating to the tributaries, impacts on water quality, and social impacts.

Three transboundary social impact zones were identified: right bank Thailand (Zone 2), Cambodia (Zone 4), and Viet Nam (Zone 5), although no elaboration was provided in the original report. The significant transboundary social impacts vary in each zone and are summarized as follows:

- For right bank Thailand (Zone 2), domestic and irrigation water use, cropping, health and nutrition, tourism, and climate change were assessed as areas within which medium impacts would occur;
- For Cambodia (Zone 4), cropping and socio–political conflict was assessed as areas within which medium to major impacts would occur, while domestic and irrigation water use, health and nutrition, tourism, and climate change were assessed as areas within which medium impacts would occur;
- For Viet Nam (Zone 5), socio–political conflict was assessed as an area within which medium to major impacts would occur, while domestic and irrigation water use, cropping, health and nutrition, and climate change were assessed to be prone to medium impacts and tourism to minor impacts.

The important mitigation measures for the transboundary impacts are summarized as follows:

- Minimising soil erosion and sedimentation during the construction phase through good practices with the emphasis on land clearance. A sedimentation pond should be constructed at the bottom end of the construction area to trap eroded particles prior to discharge to the river.
- Minimising riverbank erosion and riverbed scouring during operation by periodically releasing sediment from the reservoir.
- Removing biomass in the reservoir area before storing water as appropriately designed for the location and amount. This can be estimated through mathematical modelling.
- Basing appropriate designs for the fish pass on a comprehensive study of fish migration behaviour and implementing a fish monitoring programme to protect and possibly enhance the fisheries in this area of the Mekong River.
- Appropriately design the navigation ship lock to reduce the impacts on the transport of goods. The tourism route should be modified to promote tourism at the site.

## 4.3 Review reports from CNR

### 4.3.1 Feasibility study review report by CNR

CNR supported the Government of Lao PDR with a review of the feasibility study report. The review focused on four technical topics: hydrology, dam safety, sediment transport and river morphology, and navigation. The final review report of CNR is dated January 2017. CNR has provided a final conclusion for each of these topics, as summarized below.

*Hydrology*

- The design flood and check flood values have been reviewed with respect to international standards and to ensure the consistency of PKHPP in the cascade of dams upstream of Vientiane. This point was a major concern and has been addressed by the developer.
- Some efforts have been made to start monitoring the flow in the vicinity of the project; however, there is still a lack of a quality assurance and quality control (QA & QC) process. The developer plans to add more QA & QC processes once at least one year of data will have been collected.
- The operation pattern has been reviewed and is now consistent with the run-of-river concept. The developer still needs to demonstrate the efficiency of the operational plan for some ranges of discharge, but the run-of-river concept has been accepted and understood.
- The monitoring and forecasting system is presented in the feasibility study. The proposed technical solution is consistent for flood management, but will show some major limitations regarding power generation management. This can be addressed later and before construction starts.

*Dam safety*

The review result shows that generally the design is sound and that the PKHPP design is about 71% aligned with the Preliminary Design Guidance (PDG) (Figure 14). CNR also provided some recommendations for the developer, including:

- The feasibility study should be cleaned of former assumptions and designs so that design, design criteria, and drawings are consistent throughout.
- The developer shall update the construction drawings at the feasibility stage to have a consistent design throughout the report and drawings.
- The general construction schedule was not updated in final documentation. It should be provided in the feasibility study.
- The comprehensive dam safety reviews shall be mentioned.
- The broad framework of the Emergency Preparedness Plan is consistent with that of the World Bank, Bank Procedure 4.37 Annex A, but needs to be detailed before construction.
- All mechanical and electrical control equipment shall be backed/doubled up to ensure a high level of capacity in case of emergency. This shall be described in a specific document or chapter of the description of the equipment, mainly for the spillway, and even the powerhouse equipment shall also be fully equipped for cases of emergency.
- Opening gates pattern shall be provided in the feasibility study to check the capacity of the spillway. They should be adapted with regards to scouring tests on a physical model.
- Great care will be needed when setting operational procedures for the cleaning boat manoeuvring just upstream of the dam in order to secure these operations.
- The design of coffer-dams shall be completed with seepage assessment as curtain grouting is just in contact with impervious layers as well as a with a suitable monitoring system for watering and dewatering procedures.
- The material used for river closure is not specified. Its stability shall be controlled.
- There is no emergency bulkhead for filling and emptying the system of the navigation lock.
- Hourly limits to upstream and downstream water level fluctuations should be set and used in operation policies, as they are relevant for both bank stability and riparian populations.

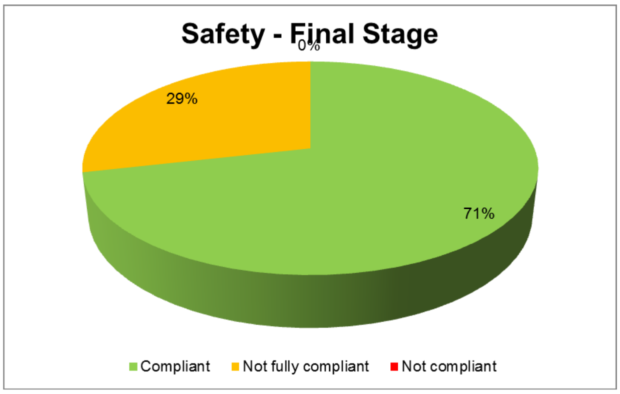



**Figure 14:** PKHPP level of PDG compliancy on dam safety.

*Sediment transport and river morphology*

- Current design, with 11 surface spillways (220 m), three middle level spillways (212 m), and two bottom outlets (205 m) is a relevant foundation of a run-of-river scheme on the Mekong River.
- This design, with middle level and bottom outlets, potentially has the capacity to pass suspended to bed-load in a way that most closely mimics the natural timing of sediment transport in the river.
- The developer shall continue data collection as well as hydrological and sediment measurements in the future.
- The current on-site measurements of sediments are now relevant to increase the knowledge on this part of the Mekong River. This has allowed the developer to provide relevant studies of sedimentation impacts. However, additional information and simulations are still required to ensure the compliancy of the project and control its adverse impacts.
- As a consequence of the new design, a new version of the reservoir operating pattern allows for potentially mimicking the seasonal distribution of sediment transport. The developer must study specific operating conditions in more detail and liaise with the sediment strategy plan. Several modes of operating the reservoir are now possible, from high flows when flood occurs, to low flows when seasonal drawdown of the reservoir water level is implemented, to facilitate sediment transport.
- All sediment management measures can be optimised by sedimentation studies, like releasing operations for each modes of transport by seasonal drawdown for instance, in coordination with upstream and downstream hydropower project operators. Adaptive measures can be evaluated at the feasibility stage, and if necessary and consistent, the reservoir operating pattern could be adjusted in the future.

*Navigation*

- The issues relative to lock design and navigation conditions have been improved. Most of the MRC guidelines have been fulfilled, even if there are still some points to be completed.
- The lock design has been well studied due to a physical model (1:20) and is suitable for the PLHPP, even if the following issues can be highlighted:
    - Operating conditions need to be adapted with respect to high velocities.
    - The physical model study report is missing and would have brought valuable information for a better understanding of the results obtained during the tests.
- Lock equipment is compliant. Operation and maintenance policies have been described in greater detail, even if some points still need to be detailed.
- The flow conditions in approach channels have been studied on a 1:100 physical model:
    - The upstream lock approach seems to be safe, even if velocities higher than 0.8

m/s (threshold value in the Chinese guideline[1]) can occur for discharge higher than 13,500 $m^3/s$.
    - The downstream lock approach seems to be very disturbed (cross-current and backflow) and may raise problems for vessels.
    - The physical model study report is missing and would have brought valuable information for a better understanding of the results obtained during the test.
- The sediment issue is shortly addressed through a two-dimensional numerical modelling study. It is strongly advocated to survey regularly (at least each year) the approach channel areas in order to implement dredging operations if necessary.

CNR concluded that PLHPP is nearly fully compliant with MRC guidelines and international standards. CNR noted that remaining issues should be easily addressed during the next stage of the project. The final design of PKHPP, featuring spillway, middle level gates and LLOs (Low Lever Outlet), should allow for efficiently mimicking the impact of sedimentation upstream of the dam site. Furthermore, the design is very flexible and will ease operation whatever the inflow is.

### 4.3.2 Feasibility study review report by Brazilian fishing engineering experts on the fish passage as well as on water quality and aquatic ecology

*Fish passage*

The review report concludes that the information available on the fish pass facilities are insufficient for a conclusive assessment. The review report provides the following recommendations:

- Conduct more fish sampling as additional baseline data in the Pak Lay area to assess fish diversity and fishery resources—the current baseline data are not sufficient;
- Include sampling of drifting fish eggs and larvae to determine spawning and nursery habitats;
- Provide more information about fish species occurring in the project area (black, grey, and white species) and discerning target species;
- Clarify whether there are critical habitats (spawning, growth, food) above or below the dam and what the actual risks to populations of migratory fish are;
- Clarify if the habitats of migratory species will be affected or lost with dam construction, especially the deep pools;
- Provide a better description of migratory fish species, which must mention which species are long-distance migratory in the project impact area and how they will be affected;

[1] The title of the Chinese guideline or its mentioned standard is not available in this moment. A request will be made to the Lao Government to supplement the document for reference.

- Provide more information on biological and hydrological requirements for fish species concerned, flow of operation in the fishway during seasons, adequate flow to attract fish at the entrance, and spillway designed to minimise fish injury and entrapment;
- Provide more information and details on fish-friendly turbines;
- Consider provision of training in new fisheries techniques, annual stocking of reservoir, and tributary fisheries.

Further, the review recommended inserting information in the feasibility study report, under Chapter 5 on project layout and main structure, to address the issues below:

- Project site hydraulic conditions for the construction of the fishway;
- Design of the fish passages;
- Consider the construction of fishways on both banks of the river;
- Consider the design of the fishways with wider width and depths to provide dimensions suitable for the large species;
- Avoid level differences in the entrance of fish pass; it must be able to attract fish on the bottom—large catfish swims on the bottom;
- Considerations of fish movements—both upstream and downstream of the dam;
- Biological and ecological aspects;
- Information on hydrology, simulation of hydraulic conditions, and operations (flow velocity and discharge, slope, depth, etc.);
- Development of a reduced model of the fishway and swimming performance tests of the target fish species could be of great value;
- Design of an ecohydraulics and hydrobiology laboratory may be one of the keys to success for the fish passage projects;
- Proposal for evaluation and monitoring of the fishway regarding hydrological and biological aspects (attractiveness and efficiency of fishway as well as fish swimming behaviour and swimming capacity);
- Consider a monitoring programme during the concession period;
- Consider the use of international experts and professionals with skills in biology and fish ecology to assist in the design and implementation of the monitoring programme.

*Water quality and aquatic ecology*

The review noted that in a run-of-river hydropower project, reservoir inflows and outflows are similar, but that the timing of flood pulses may be affected, which will impact the aquatic ecosystem. At the same time, the regulation of the water level by dams affects the downstream ecosystem.

The review report concludes that the cumulative effects from the PLHPP, as well as of other hydropower projects along the Mekong River, will be felt downstream in Cambodia, down to the Tonle Sap and even down to the delta in Viet Nam. Migratory fish have been shown to come from both of these parts of the river in to the upper Mekong system.

The review recommends that monitoring of water quality should cover not only the physical and chemical parameters, but also some biological parameters such as macroinvertebrates, phytoplankton, zooplankton, macrophytes, and fish, in order to fully attend the issues of the MRC PDG. The review report concluded with a proposed basic scope for a water quality monitoring programme and a description of environmental flows and management.

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