Mitigation Recommendation Report

Environmental Study of the Lancang-Mekong Development Plan

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This report is one of four in this set on the *Environmental Study of the Lancang-Mekong Development Plan:*

1. Introduction Report
2. Baseline Assessment Report
3. Impact Assessment Report
4. **Mitigation Recommendations Report**

The report covered in this volume is bold.

DISCLAIMER

This document was prepared by a consultant team engaged to undertake the Environmental Study of the Lancang-Mekong Development Plan. The project is funded by the Critical Ecosystem Partnership Fund (CEPF), a joint initiative of l'Agence Française de Développement, Conservation International, the European Union, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank. A fundamental goal is to ensure civil society is engaged in biodiversity conservation. The views, conclusions and recommendations in the document are not to be taken to represent the views of CEPF.

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ABBREVIATIONS

CEPF	Critical Ecosystems Partnership Fund
DWT	Deadweight ton
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
ES	Environmental Study
GMS	Greater Mekong Subregion
HPP	Hydropower project
IUCN	International Union for Conservation of Nature and Natural resources (IUCN)
JCCCN	the Joint Committee on Coordination of Commercial Navigation on the Lancang-Mekong River
LMB	Lower Mekong Basin
LMDP	'*Development Plan of International Navigation on the Lancang-Mekong River 2015-2025*'
LNMC	Lao National Mekong Committee
MRC	Mekong River Commission
NGO	Non-governmental organisation
PAT	Port Authority of Thailand
PCD	Pollution Control Department
SEI	Stockholm Environment Institute
TFT	Tortoise and freshwater turtle
TMD	Thailand Marine Department
TNMC	Thailand National Mekong Committee
WWF	World Wildlife Fund

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1 INTRODUCTION

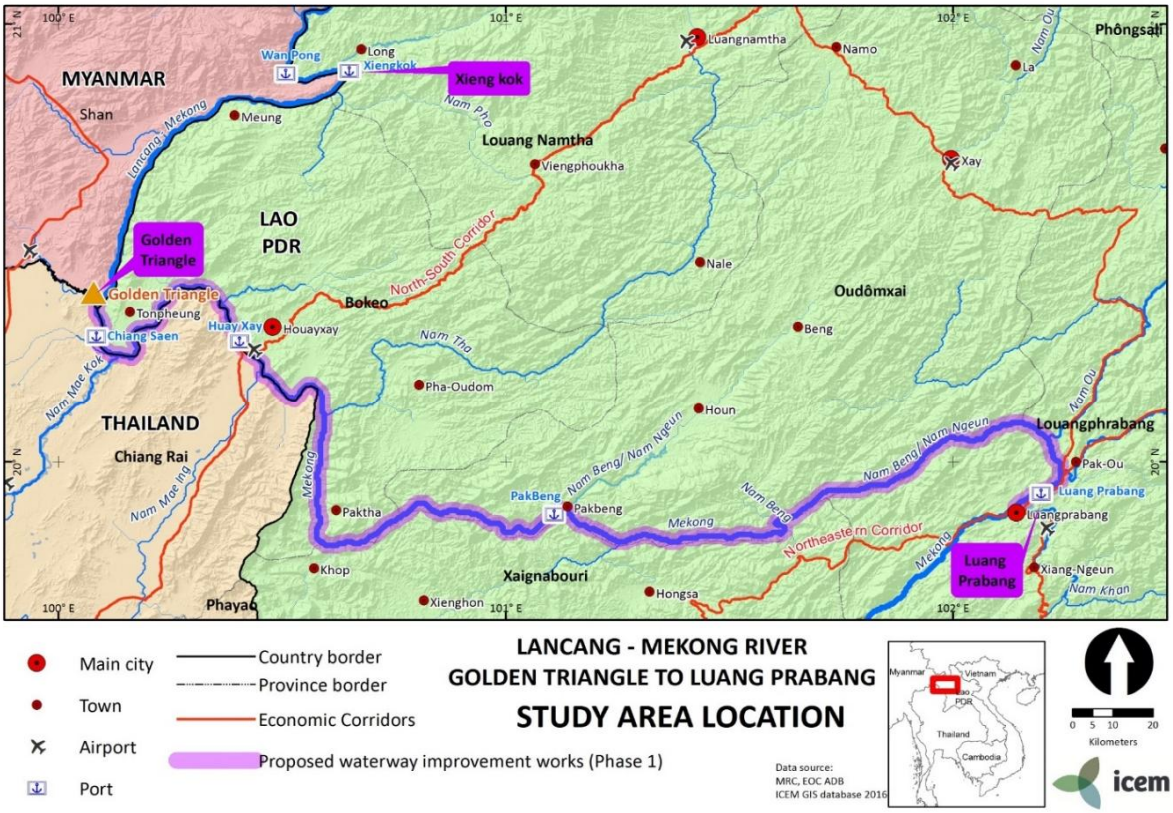
This volume provides a set of recommendations for mitigating the negative impacts and enhancing social and environmental outcomes of the Lancang-Mekong Development Plan (LMDP) and Pak Beng Hydropower Project (HPP) on a 368 km stretch of the Lancang-Mekong River between the Golden Triangle and Luang Prabang. The volume starts with a brief reminder of the study rationale followed by a summary of the key impacts of the LMDP and Pak Beng HPP and the mitigation assessment approach. It then details the recommended mitigation strategies for each of the proposed developments separated into two chapters.

The development of mitigation recommendations is the fourth and final phase in the Environmental Study of the Lancang-Mekong Development Plan (LMDP), following the scoping phase, baseline assessment phase and impact assessment phase.

1.1 ENVIRONMENTAL STUDY RATIONALE

There may be significant long-term and irreversible social and environmental impacts of the LMDP from port construction, increased waterway use and partially removing 146 rapids and shoals to improve navigation. The environmental and social impacts need to be fully assessed. As the LMDP does not currently include a comprehensive environmental management plan, the Critical Ecosystems Partnership Fund (CEPF) allocated grant funding to ICEM to conduct an Environmental Study (ES) of the LMDP from the Golden Triangle to Luang Prabang (Figure 1.1). The ES set priorities for an environmental management plan with a special focus on biodiversity to be integrated within the LMDP should the plan proceed. The LMDP would be the most significant development of the Mekong River since the proposed mainstream hydropower projects in Lao PDR and Cambodia. As the Pak Beng Hydropower Project (HPP) also falls within the study reach it has been included in the assessment. The study assumes that both the LMDP and Pak Beng HPP will proceed and only sought to formulate recommendations to improve environmental outcomes of both proposed developments.

Figure 1.1: Study area for the ES of the LMDP



The ES supports the findings of the '*CEPF Status and Distribution of Freshwater Biodiversity in Indo-Burma*' that calls for targeted ecological studies of fresh-water species in the upper mainstream Mekong River to determine the impacts of navigation development. The ES also supports CEPF recommendations to integrate aquatic biodiversity and biodiversity surveys into the SEA/environmental impact assessment (EIA) processes in the Mekong region. This ES responds to concerns raised by Mekong River Commission (MRC) member countries, donors and development partners that the cumulative and trans-boundary impacts of the LMDP and Pak Beng HPP require comprehensive environmental assessment. The MRC Navigation Programme (NAP) 'Master Plan on Regional Navigation 2015' recommended that an independent strategic environmental assessment of the LMDP be completed.

ICEM ensured that these concerns were taken into consideration in the ES including conducting a rapid integrated field survey in the development corridor between the Golden Triangle and Luang Prabang to inform strategic planning and sustainable decision-making.

2 SUMMARY OF ASSESSMENT ZONES AND LMDP AND PAK BENG HPP IMPACTS

2.1 SUMMARY OF PROPOSED WORKS AND ASSESSMENT ZONES

Two major developments are proposed for the study reach:

- **LMDP** - Improving the river for navigation by up to 500 tonnes boats including clearing "dangerous areas" and constructing ports; and
- **Pak Beng HPP** - Development of the run-of-river Pak Beng hydropower scheme which will involve construction of a dam and reservoir backing up from Pak Beng to the border with Thailand.

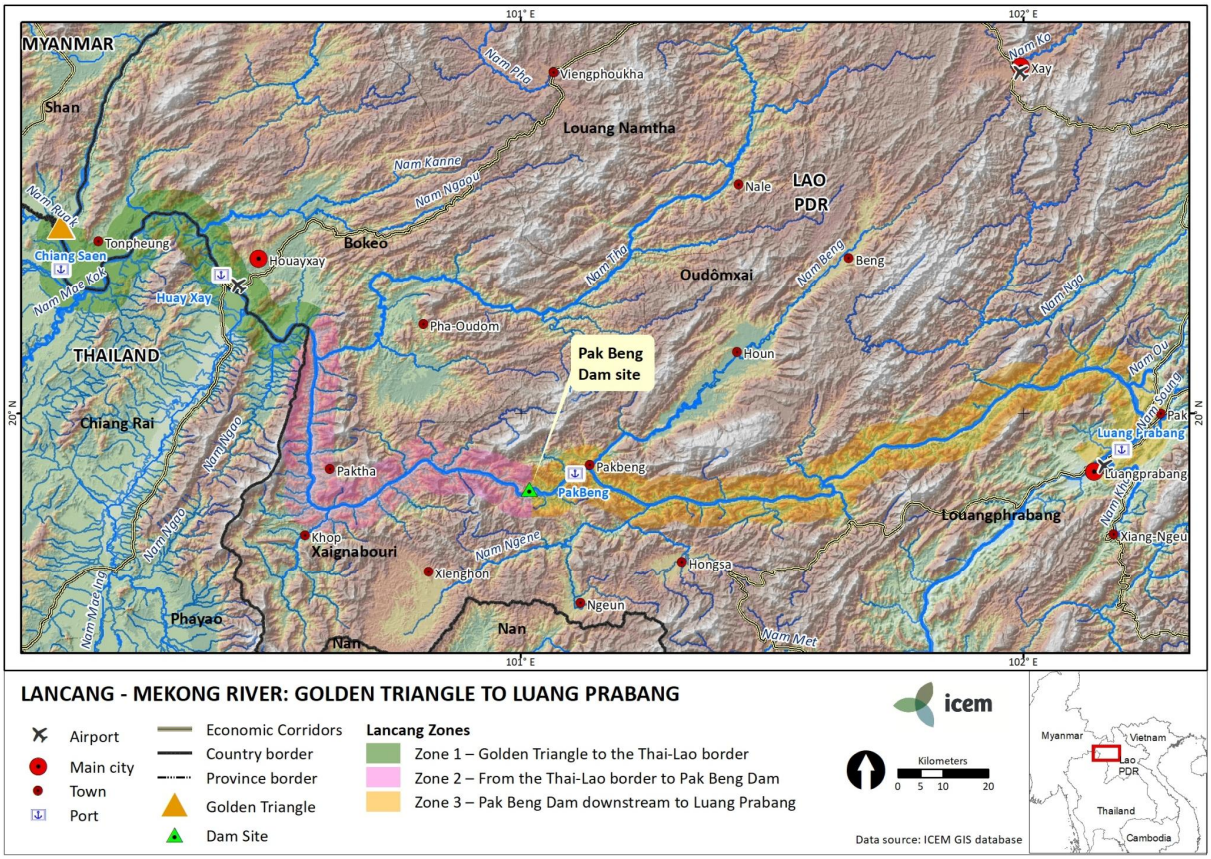
Due to the differing impacts that can be expected by the proposed developments, the study reach has been divided into three zones representing the areas of influence of the developments and distinctive biophysical features (Figure 2.1).

ZONE 1 - Golden triangle to the Thai-Lao border (approx. 98 km): This region has four MRC surveyed dangerous areas for navigation, where obstruction removal and channel dredging under the LMDP is likely. Construction of the Houay Xay and Chiang Khong ports as part of the LMDP will also occur in this zone.

ZONE 2 - Thai-Lao border to Pak Beng dam site (approx. 94 km): The impoundment reservoir of the Pak Beng HPP is expected to reach as far as the Thai-Lao border. This region has seven dangerous areas likely to be subject to obstruction removal and channel dredging under the LMDP. However, with construction of Pak Beng HPP, this whole section will become a reservoir and it is expected that the navigation improvement works under the LMDP would only be needed in the upper parts of the reservoir.

ZONE 3 - Pak Beng dam site to Luang Prabang (approx. 176 km): This stretch is located downstream of the proposed Pak Beng HPP dam and has twelve surveys dangerous areas where river improvement works under the LMDP are expected. Impacts in this stretch of the river include: removal of obstructions, dredging and port construction (at Pak Beng and Luang Prabang) associated with river improvement works; and impacts from the upstream Pak Beng HPP dam, reservoir and operations.

Figure 2.1: Study assessment zones



The impact assessment is split into:

i) Assessing the impacts of the LMDP river improvement works, ports and operation of larger boats in Zones 1, 2 and 3; and

ii) Assessing the impacts of Pak Beng in Zones 2 and 3. The impact assessment in Zone 2 focusses on changing the river to a reservoir. The impact assessment of Pak Beng in Zone 3 focusses on altered flow and sediment regimes from the dam construction and scheme operation.

2.2 SUMMARY OF LMDP IMPACTS

2.2.1 Zone 1 Golden Triangle to Thai-Lao PDR Border

Four dangerous areas are likely to be partially cleared for navigation as part of the LMDP in Zone 1. This will likely involve mainly dredging with some rock removal in the rockier dangerous areas in the downstream section. Two ports will also be constructed within Zone 1 as part of the LMDP in later phases – at Huay Xay and Chaing Khong.

2.2.1.1 Summary impacts

Much depends on the quality of the work – past clearing has been poorly supervised and completed in an uncontrolled manner with little regard for environmental and social consequences. If work is done to international good practice, impacts can be minimised.

Hydrology and Sediment

Highest risk impacts in Zone 1 are dredging of sand from bed, banks and islands for navigation improvement that will cause downstream bed and bank erosion; clearing of sediment for port construction, and increased large boat traffic causing bank erosion through wave action.

Table 2.1: Summary of high risk hydrological and sediment impacts in Zone 1

Impact description	Construction/ long term	Likelihood	Consequence	Risk
Sediment impacts				
Sand from bed, banks and islands removed through dredging	Construction	Almost certain	Moderate	High
Port construction clearing and dredging releases materials into the river	Construction	Almost certain	Moderate	High
Increasing large boat traffic causes bank erosion and pollution	Long	Almost certain	Moderate	High
Dredging changes downstream sediment dynamics	Long	Almost certain	Moderate	High

Aquatic ecology and biodiversity

In general, the LMDP navigation improvement works have low to very low impacts on geomorphology, wetland habitats, aquatic vegetation and macroinvertebrates in Zone 1. However, the increase in large boat traffic will lead to declines in water quality, increased risk of spills and potential for bank erosion through wave action.

The LMDP is expected to cause some direct loss of habitat for amphibians and reptiles, although this is likely to be small. However, the port construction and increase in boat traffic and people moving up and down the river may facilitate human access into remote portions of the survey areas, which in turn may facilitate overharvesting of turtles, large lizards and large snakes for consumption and trade, particularly illegal wildlife trade to China.

In terms of the LMDP impacts on fish, the construction phase is likely to have the following impacts:

- blasting (mortality) and dredging (reducing food sources, mortality in larvae); and
- partial filling of deep pools (reduced habitat for some species such as the Mekong Giant Catfish).

However, these impacts are not expected to cause a permanent decline in fish populations or loss of species if they are adequately managed. The operational LMDP phase will impact fish through:

- increased wave action from boat traffic (mortality of small fish);
- boat shear stress (mortality of fish eggs);
- oil/grease spills (affects food sources); and
- any LMDP associated river bank stabilisation for navigation purposes (may reduce habitat but depends on the species).

Again, these impacts are not expected to cause a permanent decline in fish populations or loss of species if they are adequately managed.

The LMDP impacts with the most potential to have a significant negative impact on birds in Zone 1 are:

- Increased dry-season sediment flow (during construction phase) – which may lead to a short-term reduction in bird feeding and subsequent breeding output for some species; and
- Water pollution from boats and associated infrastructure (during operation phase) – reducing water quality and food availability for birds.

However, none of the potential LMDP impacts on birds are likely to result in a significantly different future situation for birds in the study stretch than the future without implementation of the LMDP. This is mainly due to the small proportion of seasonally exposed habitat that will be removed and the fact that other non-LMDP factors impacting birds are likely to continue and overshadow any LMDP impacts.

Socio-economics

The most probable (likely, very likely or definite to occur) LMDP socio-economic impacts in Zone 1 are:

- If riparian farmers are poor or near poor, the loss of farmland through bank erosion is likely to undermine household food security.
- If those who harvest freshwater algae (kai) are poor or near poor, a short term loss of harvestable kai (from sediment pollution) is likely to undermine household food security.
- Water pollution (from boats and ports) is likely to lead to increased instances of water- and food-borne diseases in the vicinity of the towns where the new ports are located.
- Increased water pollution is also likely to have a negative impact on the desirability of this stretch of the Mekong River as a tourist destination.
- Road upgrades associated with port development are also likely to lead to more injuries and fatalities from traffic accidents, because traffic can travel faster.
- It is likely that more 'outsiders' (construction workers, traders, boat crews) will come to towns and villages in the area (due to port construction and subsequent increase in trade), which will mean that:
  - There is likely to be more gambling, and more alcohol/substance abuse
  - It is likely that levels of violence/civil disturbances will increase
  - It is likely that gangs will form
  - It is likely that there will be a growth in prostitution
  - It is likely that there will be increased rates of sexually transmitted diseases
- It is likely that there will be increased instances of respiratory illnesses because of dust due to construction from increased trade and building construction following port development
- There is likely to be an increase in vector-borne disease rates (predominantly dengue in more urban areas, and predominantly malaria in more forested areas) due to increases in building construction following port development
- There is likely to be an increase in water- and food-borne diseases if development is not planned and managed effectively (because of factors such as inadequate household or municipal sanitation facilities and poor living conditions for new arrivals) due to increases in building construction following port development
- There are likely to be new tour operator business opportunities
- There are likely to be new employment opportunities for tour guides (knowledge of foreign language(s) such as Chinese, Vietnamese, Thai or English will be a distinct advantage for this type of employment)

- There are likely to be new employment opportunities in construction and hotels and guesthouses

2.2.2 Zone 2 - Thai-Lao Border to Pak Beng HPP Dam

Seven dangerous areas are likely to be partially cleared for navigation as part of the LMDP in Zone 2. This will involve rock removal and dredging. No ports are planned for Zone 2.

2.2.2.1 Summary impacts

Again, much depends on the quality of the work. If work navigation improvement work is done to international good practice, impacts can be minimised.

Hydrology and Sediment

The highest risk LMDP impacts for hydrology and sediment in Zone 2 are the same as in Zone 1, however, there are no ports planned in Zone 2 and therefore the impact of port construction clearing and dredging releasing materials into the river won't occur.

Aquatic ecology and biodiversity

The impacts of the LMDP on ecology in Zone 2 are the same as in Zone 1. However, they may be slightly higher due to the greater number of MRC surveyed dangerous areas for navigation (4 vs 7) and thus potential barriers to navigation to be cleared under the LMDP. Zone 2 is also less developed than Zone 1 and therefore may have less disturbed habitats and higher biodiversity resulting in greater impacts.

Socio-economics

The socio-economic impacts of the LMDP in Zone 2 will be less numerous and severe than those in Zone 1 due to the fact that there are no ports planned for Zone 2. However there are more dangerous areas and key impacts from expected LMDP clearing of these and increased boat traffic will include:

- If riparian farmers are poor or near poor, the loss of farmland through bank erosion is likely to undermine household food security.
- If those who harvest freshwater algae (kai) are poor or near poor, a short term loss of harvestable kai (from improvement works sediment pollution) is likely to undermine household food security.
- Increased water pollution is also likely to have a negative impact on the desirability of this stretch of the Mekong River as a tourist destination.

2.2.3 Zone 3 - Pak Beng HPP Dam to Luang Prabang

Twelve dangerous areas are likely to be partially cleared for navigation as part of the LMDP in Zone 3. This will involve rock removal and dredging. Two ports are planned to be developed in Zone 3 – one at Pak Beng and one at Luang Prabang.

2.2.3.1 Summary impacts

Again, much depends on the quality of the work. If work navigation improvement work is done to international good practice, impacts can be minimised.

Hydrology and Sediment

Highest risk impacts in Zone 3 are sediment impacts through dredging of bed and banks and port construction, and increased large boat traffic causing bed and bank erosion and pollution.

Table 2.2: Summary of high risk hydrological and sediment impacts in Zone 3

Impact description	Construction/ long term	Likelihood	Consequence	Risk
Sand from bed, banks and islands removed through dredging	Construction	Almost certain	Moderate	High
Port construction clearing and dredging releases materials into the river	Construction	Almost certain	Moderate	High
Dredging of the bed and banks to maintain the channel for navigation	Long	Almost certain	Moderate	High
Increased large boat traffic causes bank erosion and pollution	Long	Almost certain	Moderate	High

Aquatic ecology and biodiversity

The types of impacts the LMDP is likely to have on ecology in Zone 3 are the same as in Zone 1 and Zone 2. However, the magnitude of the impacts may be slightly higher due to the greater number of MRC surveyed dangerous areas for navigation (12 vs 7 and 4, respectively) and thus potential barriers to navigation to be cleared under the LMDP. Zone 3 is also significantly longer than Zone 1 and 2 (by about 80 km) and less developed than Zone 1, further increasing the potential overall level of impact.

Socio-economics

The range and severity of socio-economic impact in Zone 3 are the same as those in Zone 1 – including from port development, navigation improvement works and increase in boat traffic.

2.2.4 Summary of LMDP impacts in the study reach

Hydrology and sediment: The LMDP dredging of sand from bed, banks and islands for navigation improvement will cause downstream bed and bank erosion. The clearing of sediment for port construction, and increased large boat traffic will also cause bank erosion through wave action. Both impacts will have moderate consequences but are nonetheless considered high risk due to their likelihood and need to be adequately managed.

Aquatic ecology and biodiversity: the assessments of impacts on the aquatic ecology show that generally the navigation improvement works have a low impact, especially when the works have been completed and the river ecology has been given time to recover and stabilise after the localised and short time period of the works. However, there are certain features which may be more sensitive to these works, especially the more labile sand and pebble flats. On the operational side, the increase in large boat traffic will contribute to the gradually declining water quality in this stretch of the river and the risks of accidents and spillages will also increase. Also, the need for annual dredging of some stretches and dumping of dredge spoils could lead to diminished habitat diversity if not carefully managed.

The LMDP is likely to impact fish, amphibians and reptiles and bird populations through some habitat loss or alteration, reducing food sources and availability, facilitating increased hunting, reducing water quality and direct mortality. The operational phase impacts on water quality and water disturbance are likely to be more significant than the construction phase impacts. However, if adequately managed, none of the LMDP impacts are considered likely to cause permanent reductions in population or loss of species in these groups. Nevertheless, more detailed studies of the specific habitat requirements of species using the rapids is required. In particular, the dependency of fish species on flows and sediment types, either for spawning or via foraging on benthos – and the expected changes in these parameters from the improvement works.

Socio-economics: The assessment used the biophysical impacts from other sections of the environmental study as a base, and also made projections about potential socio-economic impacts based on projected alterations in the river use as well as changes because of major developments such as port facilities. The LMDP is likely to cause some direct negative impacts, particularly on poor or near poor rural people who depend on river bank gardens, fishing or harvesting of kai for income or sustenance through erosion of river banks and sediment pollution. Increases in water pollution raise the likelihood of health impacts. There are also several indirect impacts associated with the increase in passengers, workers, trade and construction following and surrounding port development including increases in social and health problems.

Undoubtedly, there will be positive socio-economic changes associated with the implementation of the LMDP. Improved navigation is likely to enhance tourism potential in the area, and so there will be employment for tour operators, guides, transport operators (both on and off the river), as well as potential for increased accommodation facilities along the river. However, in the study area, it is generally the more affluent who will be able to take advantage of tourism opportunities to become tour operators and hoteliers, and even guides will need to be able to speak foreign languages such as Chinese, Thai, Vietnamese or English in order to communicate with foreign tourists.

2.3 SUMMARY OF PAK BENG HPP IMPACTS

2.3.1 Zone 2 - Thai-Lao Border to Pak Beng Dam

This zone contains the reservoir of Pak Beng HPP from the dam site upstream of Pak Beng town to the Thai-Lao PDR border upstream of Pak Tha.

2.3.1.1 Summary impacts

Environmental impacts of the Pak Beng HPP reservoir and dam operations will be significant and irreversible.

Hydrology and sediment

Highest risk impacts in Zone 2 are increased water levels and flooding of existing habitats; decreased flow velocities; changes in water chemistry; blocking of sediment by the dam wall; reduction in sediment transport will reduce due to lower velocities; and new deltas forming at the bottom of the tributaries.

Table 2.3: Summary of high risk hydrological and sediment impacts in Zone 2

Impact description	Construction/ long term	Likelihood	Consequence	Risk
Hydrological impacts				
Temporary constriction of river for construction causes high velocities in immediate area of the construction	Construction	Likely	Moderate	High
Increased water levels and flooding of existing habitats	Long	Almost certain	Significant	Very high
Decreased flow velocities	Long	Almost certain	Extensive	Very high
Changes in water chemistry	Long	Almost certain	Moderate	High
Sediment impacts				
Reservoir traps sediment	Long	Almost certain	Significant	Very high
New deltas form at the bottom of tributaries	Long	Almost certain	Extensive	Very high

Aquatic ecology and biodiversity

The Pak Beng HPP reservoir in Zone 2 will cause high and permanent impacts on geomorphology, wetland habitats, aquatic vegetation and macroinvertebrates due to the inundation of habitats and change in aquatic ecology. Five deep pools, several rocky outcrops and sand bars and six MRC surveyed dangerous areas for navigation will be permanently lost.

The dam wall will also block the migration of fish; and alter fish assemblages, reduce oxygen and fish productivity in the deeper water through the change from a riverine to lacustrine environment. There may also be a loss of tributary connectivity to the mainstream through slowing of flow and delta formation/sedimentation.

The Pak Beng HPP will have a locally devastating effect on river bird communities in its reservoir; with the reservoir on current plans extending about 100 km upstream of the dam, the length affected and its likely current regional significance for river birds (based on information from 1999–2000) could potentially stimulate declines significant at the Mekong basin-level in some species of conservation concern.

The Pak Beng HPP reservoir is expected to cause significant direct loss of habitat for amphibians and reptiles through inundation. In addition, the influx of construction workers will likely increase hunting pressure and development of access roads and transmission lines will facilitate human access into previously inaccessible areas, leading to further and ongoing overharvesting of turtles, large lizards and large snakes for consumption and trade, particularly illegal wildlife trade to China.

Socio-economics

The primary construction phase negative impacts are:

- Job seekers who are unsuccessful in securing employment may turn to crime, causing social disruption.
- Health-related impacts including workplace accidents, unsafe water leading to water- and vector-borne disease and respiratory diseases relating to dust and air pollution.
- Displacement and livelihood related impacts for those who live in the seven villages that require re-location or resettlement.

- Reduced fish stocks while the reservoir fills.
- Vulnerable groups being impacted by land loss.

During the operation phase of the dam, there are six main separate impacts. Three of these impacts are only positive: 1) Impacts on health and education, 2) Impacts on tourism, and 3) Impacts on land transportation. Two of the impacts have both positive and negative components: 4) Impacts on fishing, and 5) Impacts on navigation. And the final impact is only rated as being negative: 6) Impacts on livelihood restoration.

In addition, there are several indirect impacts that were not covered in the SIA including: 1) Changes in boat traffic (as indicated by the plans for the ship lock), 2) Infrastructure upgrades that are likely to occur because of the dam construction, and 3) Social dynamics leading to additional changes.

2.3.2 Zone 3 - Pak Beng Dam to Luang Prabang

This zone stretches from the base of Pak Beng HPP to Luang Prabang and is the immediate area of downstream impact from the dam operations.

2.3.2.1 Summary impacts

Hydrology and sediment

Highest risk impacts in Zone 3 are flow regime altered due to operation of Pak Beng dam and reduced sediment load and increased water level variability causing bed and bank erosion.

Table 2.4. Summary of high risk hydrological and sediment impacts in Zone 3

Impact description	Construction/ long term	Likelihood	Consequence	Risk
Hydrological impacts				
Changes in the flow regime due to dam operations	Long	Almost certain	Negligible*	High
Sediment impacts				
Decrease in sediment load leading to bed and bank erosion	Long	Almost certain	Moderate	High

Aquatic ecology and biodiversity

The downstream impacts of Pak Beng HPP in Zone 3 are likely to negatively affect aquatic ecology in several ways including potential scouring and erosion of sensitive habitats such as sand and pebble bars during operation and filling of deep pools during construction. Flow regime and water quality changes are also likely to impact fish behaviour related to flow (particularly reproduction), increase fish mortality (due to release of cold and/or oxygen depleted water) and lead to changes to dry season refuges for fish.

The coating of a high proportion of the river bed with small sediments may devastate aquatic invertebrate communities and in extreme cases fish too (e.g. through blocking of gills). Thus, for a while, severely reduced bird breeding output is quite conceivable. It is plausible that most of the enhanced sediment load will be redistributed non-threateningly during the following wet season. Fluctuations in water level from dam releases also has the potential to significantly impact downstream bird nesting habitat e.g. sudden releases inundating seasonally exposed nest sites.

The severity of downstream Pak Beng HPP impacts will depend on the way the dam is operated and releases water and sediment downstream.

Socio-economics

Key negative impacts include: 1) Impacts on water quality, and 2) Impacts on fishing. Positive impacts include: 3) Impacts relating to employment, 4) Impacts on household investment, and 5) Impacts on food supply.

There will be long-term negative impacts relating to water variation, fishing and livelihoods. In addition, there are several indirect impacts including: 1) Changes in boat traffic (as indicated by the plans for the ship lock), 2) Infrastructure upgrades that are likely to occur because of the dam construction, and 3) Social dynamics leading to additional changes.

2.3.3 Summary of Pak Beng HPP impacts in the study reach

Hydrology and sediment: the Pak Beng HPP reservoir will cause increased water levels and flooding of existing habitats; decreased flow velocities; changes in water chemistry; blocking of sediment by the dam wall; reduction in sediment transport due to lower velocities; and new deltas forming at the bottom of tributaries. The downstream impacts of Pak Beng HPP are the alteration of the flow regime; reduced water quality of water released from the reservoir; change in the sediment size distribution of the channel bed due to change in velocities; reduced sediment load and increased water level variability causing bed and bank erosion.

Aquatic ecology and biodiversity: The long term impacts over the whole reservoir area are Very High and reflect a complete change in the aquatic ecology in the reservoir – inundating habitats for invertebrates, birds, fish and amphibians and reptiles. There are also to be expected impacts on the aquatic ecology downstream in Zone 3, but the intensity of these impacts may depend upon the way in which the Pak Beng dam is operated. The blockage of fish migration by the dam wall will have a major impact on migratory fish species even with the proposed fish passage. If the fish corridor role of the study section is confirmed by additional analyses, altering the section and making it harder for fish to pass may have a disproportionately important negative impact on fish diversity in adjacent sub-basins. This impact would result from the interruption or perturbation of migration routes not only among white fish migrating over 100-1000 km between the Lower and the Upper Mekong, but also on grey fish migrating over 10-100 km between habitats located in neighbouring watersheds. The influx of construction workers and long term increased accessibility of habitats from Pak Beng HPP are likely to have significant impacts on hunting pressure, particularly for amphibians and reptile and to a lesser extent on birds, which already have high existing pressure.

Socio-economics: Improved roads and ports are likely to put poor subsistence farming households in a wide area at risk of being pressured to give up their customary lands and subsistence activities. Other likely impacts related to the increased size and number of boats that will be on the river, and which have the potential to cause bank erosion, and the loss of farmland and food security. In the towns near the dam site, population growth will create some positive changes, such as opportunities to establish restaurant and accommodation facilities. However, population growth is also likely to be associated with negative effects such as increased alcoholism, gambling, violence and prostitution.

3 MITIGATION APPROACH

3.1 INTRODUCTION

This section outlines the study approach to developing mitigation recommendations to address the main impacts of the LMDP and Pak Beng HPP, which fall into one of the mitigation stages below (Figure 3.1).

Figure 3.1: Mitigation stages

Key steps included:

- Identifying areas where understanding of current environmental and social conditions in the affected areas needs to be improved;
- Outlining measures that should be included in environmental and social management plans to address the main construction and operational impacts;
- Defining areas requiring special conservation management and the roles and responsibilities of the MRC, member countries, the private sector and communities;
- Outlining how the rights of ethnic minority and other vulnerable groups can be taken into account in development planning and project management; and
- Laying the groundwork for establishing environmental and social management and monitoring plans.

The design of the avoidance, mitigation and enhancement measures including the framework environmental and social management plans and guidelines for environmental monitoring and further study provides governments, provincial departments, civil society, private sector and local communities with a road map for avoiding biodiversity losses and managing the impacts of inland navigation development in the Mekong mainstream. The process of implementing the study recommendations will also enhance coordination between key actors at the national and provincial level and provide opportunities for an increased ownership of environmental protection, trans-boundary cooperation and management.

3.2 OVERARCHING STRATEGIC RECOMMENDATIONS

Six overarching strategic recommendations are made to avoid, minimise, remedy or offset the most serious negative impacts of the LMDP and Pak Beng HPP on biodiversity and livelihoods. These are:

1. Establish an **enhanced baseline**: additional detailed biodiversity and livelihoods baseline studies (to better understand their current status and spatial distribution for improved impact assessment and management of proposed developments);
2. Develop an **alternative layout and design for Pak Beng HPP** dam (to avoid or minimise impacts on biodiversity and livelihoods);
3. Embrace **best practice design, construction and operation** requirements for the LMDP and Pak Beng HPP (to avoid or minimise impacts on biodiversity and livelihoods);
4. Establish a **transboundary Mekong mainstream conservation area network** (to remedy or offset biodiversity and livelihoods impacts through habitat restoration and enhancement);
5. Conduct **ongoing monitoring** of biophysical and socio-economic conditions and impacts of the LMDP and Pak Beng HPP (to ensure ongoing management is effective).
6. Provide **livelihood support and ensure the rights of ethnic minority and other vulnerable groups are respected** (to avoid, minimise or mitigate against unintended negative impacts on vulnerable groups).

All of the strategies except the second strategy apply to both the LMDP and Pak Beng HPP and are described under recommendations for each proposed development below. The second strategy applies only to the Pak Beng HPP and so is only covered under the Pak Beng HPP recommendations section.

4 LMDP RECOMMENDATIONS

Five of the key strategic recommendations (1 and 3 to 6) proposed to address the most significant impacts of the LMDP. Prior to implementing the LMDP, it will be necessary to conduct further detailed physical, biological and livelihoods baseline studies in the impacted areas (Strategic Recommendation 1) to fill gaps in knowledge and ensure all impacts have been identified and are appropriately mitigated. Best practice design, construction and operation requirements for the LMDP (Strategic Recommendation 3) aims to avoid or minimise impacts of the navigation improvement works. The aim of the transboundary Mekong mainstream conservation area network (Strategic Recommendation 4) is to rehabilitate, restore or offset LMDP impacts on biodiversity and livelihoods through conservation management of selected important biodiversity areas. Ongoing monitoring of biophysical and socio-economic conditions and impacts of the LMDP will ensure that management actions are working, adjusted as necessary and any unforeseen impacts are dealt with. It will also be important to put in place measures to ensure livelihoods and the rights of ethnic minority groups and other vulnerable groups are protected in rolling out the LMDP. The development and application of each of these strategies is described in detail below.

A summary of measures under strategic recommendations 1, 3 and 5 and how they relate to hydrology and sediment, biodiversity and socio-economics, is provided in Annex 1.

4.1 STRATEGIC RECOMMENDATION 1: ADDITIONAL DETAILED BIODIVERSITY AND LIVELIHOODS BASELINE STUDIES

Hydrology and sediment

Before the works are started it is essential to establish an improved understanding of the baseline condition of hydrology and sediment. In the study reaches this requires additional discharge monitoring, particularly of tributaries, and a better understanding of sediment loads and dynamics.

Hydrology and sediment transport throughout the whole study reach is not well understood and needs to be further explored and documented. For example, hydrological data is not available for many of the tributaries and sediment monitoring has been limited. A comprehensive hydrology, sediment transport and geomorphology study of the area is needed to build a better baseline understanding of the area, so that assessments of the potential impact and mitigation of dam and sediment transport works can be based on a comprehensive scientific understanding of the context.

As part of this comprehensive study, improved monitoring of sediment will be essential. This should include monitoring of concentrations and grain size of suspended sediment concentrations for several years and across all seasons, with a particular focus on the wet season when a large proportion of the annual sediment movement will be occurring. Comprehensive monitoring results for several years will enable development of a sediment rating relationship, computation of long – term sediment yields and an understanding of the seasonal and annual variability in sediment loads and grain sizes. In addition, to enable improved estimates of bed load transport, the bed material grain size should be documented by sampling at several locations along the river at low flow, including documentary photographs and global positioning system coordinates.

A full geomorphology study of the reach is needed to better understand the creation, transport and deposition of sediment in the study reach. In addition to the sediment load monitoring described

above, this study should include repeat cross-section surveys, temporal analysis of satellite imagery and field studies. A more detailed and accurate understanding of the existing geomorphology dynamics will enable a better assessment of the potential changes due to navigation improvement (or reservoir construction works).

Biodiversity

More detailed biodiversity surveys of the project stretch are required to provide a more up-to-date and complete picture of important habitats and species potentially affected by the LMDP. This includes comprehensive surveys on fish, herpetofauna and birds.

Birds: An important priority is for a proper assessment of the current avifauna of the project stretch and the current threats operating on it, so that future recommendations can move from the realm of armchair speculation as of now, to specific, justified, precise recommendations that, if implemented, are likely to succeed.

Implement a comprehensive baseline survey of the pre-project avifauna and its threats, which serves as the basis to a long-term monitoring programme: this would be invaluable in adaptive management for the maintenance and potential enhancement of the project stretch's bird conservation values. This needs to be undertaken by external specialists. Bird identification is often very difficult yet critical to get right: for example, the management implications of finding regular use of a part of the study stretch by the globally threatened White-browed Reed Warbler are colossal, but if the species involved is actually Black-browed Reed Warbler *Acrocephalus bistrigiceps* they are trivial; it is common in Lao wetlands and globally abundant. These two species are highly challenging to tell apart even for generally experienced bird surveyors, if they are not already familiar with both the species.

Most important is a survey along the river channel in the style of that by Duckworth & Timmins (2013) for the Louang Prabang – Vientiane stretch. This should use a boat as a survey base, spend the nights in the channel in the best sites for project species that call by night (e.g. nightjars, fish owls and thick-knees) and by day walk extensively in all areas of mosaic and large sandbanks to detect birds unlikely to be found from the boat. This should take about 3 weeks in each of the cold dry season (to understand the status of winter visitors), the hot dry season (to understand the breeding community; some cryptic breeding species do not start singing until after many winter visitors have left) and one week in the wet (with much less exposed land in the channel at this season than in the dry, effective survey is much quicker). This would allow comparison with the 1999–2000 information for conspicuous species, expansion of the number of species for which credible survey has occurred in this stretch after 1940, the first understanding of wet-season status and threats, and the determination of exactly which parts of the project stretch retain the most importance for the avifauna and therefore warrant the most consideration in management.

If it be considered important to improve the precision and perhaps accuracy of the speculations concerning the study stretch's likely importance to globally threatened species, surveys are needed for Yellow-breasted Bunting (late March to late May, and October to November) in the river channel; White-browed Reed Warbler (May and autumn) in large stands of tall graminoids; Wood Snipe (October – March); and White-eyed River Martin (all seasons, all habitats but particularly the channel where habitat differs strongly from that around the parts of Chiang Saen visited heavily by leisure bird-watchers, on the grounds that if it used the habitats there, it presumably would have been found there already). It is quite plausible that all this effort would give no useful information on these species other than that the stretch is simply not very important to them.

Even with such a survey there is still the issue that untangling the precise mechanisms underlying the long-term declines of channel birds is extremely challenging, yet essential if recommended management interventions are going to be precise and successful other than by good luck. Without a lengthy and expensive research programme, recommendations need to be broad enough to cater for all realistic possibilities.

Amphibians and reptiles: The conservation value for amphibians and reptiles in the survey area probably lies in forested portions of the mainstream Mekong and its tributaries. Surveys of amphibians and reptiles in those areas are urgently needed.

Fish: The high number of native and endemic species in the limited mainstream section considered probably indicates an ecological corridor role between adjacent sub-basins. It is essential to document further that corridor role before considering major flows and habitat alteration, since a local river modification could have a large-scale impact in several watersheds of global biodiversity significance. This information is also of relevance to the definition of Key Biodiversity Areas and the Wildlife Corridor approach. The proposed study can build on existing literature complemented with local ecological knowledge surveys, in order to assess in more detail: i) species similarities and connections between the mainstream section and adjacent tributaries; ii) migratory patterns among the species listed; and iii) requirements of endemic or endangered species for specific aquatic habitats, to be coupled with a GIS identification of such habitats in adjacent sub- basins.

Existing information about Mekong fish ecology does not include enough knowledge of fish species swimming capabilities and flow range requirements in order to be able to pass critical obstacles during their migrations. Such knowledge is essential for the development of fine-tuned blasting in which small corridors of suitable current speed would be left available or created for fish to remain able to pass despite the overall channel modification.

It can be noted that fish swimming capability studies have been developed at Xayaburi and Don Sahong dam sites, and information sharing facilitated by national authorities would definitely benefit fish resource protection in a rapid river development context. This would in particular underpin the development of nature-like fish passes recommended at Pak Beng HPP but also relevant to multiple other dam sites.

Based on existing literature, the present study has underlined that about 20 species will be particularly impacted by the planned developments, because they are specifically reliant on certain sediment types or habitats strongly influenced by current speed. However, the area is home of 199 fish species in total, and ecological requirements remain undocumented for most of these species. Thus, the present study could be deepened by a thorough survey of local ecological knowledge aimed at systematically assessing the dependency of species on flows and sediment types, either for spawning or via foraging on benthos.

There is a need for a joint definition of how much blasting is desirable or acceptable from multiple perspectives (described further below under Strategic Recommendation 3). Such coordination would require substantial new inputs from fish scientists, in particular an identification of the sites where blasting of rapids would create channelization and new flow conditions *not passable by fish any more*. This would lead to a ranking of sites whose blasting is acceptable or not from a fish resource protection perspective, and a prioritized list for intervention, up to the number of blasting jointly agreed.

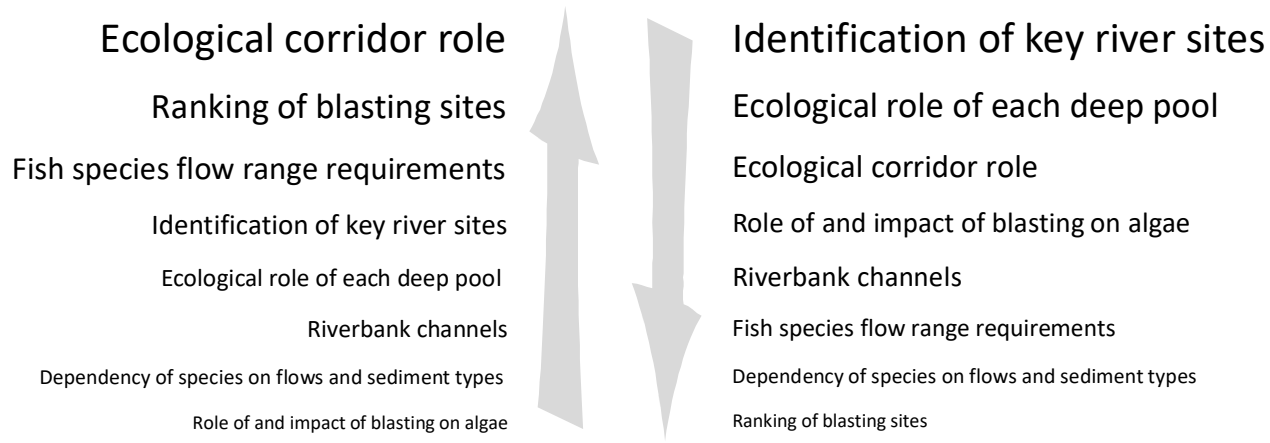
The study has highlighted the concentration of deep and very deep pools in the Pak Beng – Luang Prabang section of the river. The ecological role of these deep pools is well recognized in the regional scientific literature, but the specific role of each of these 16 pools has not been assessed – which hampers the recommendation to set some of them as protected areas. Such knowledge gap could be filled through a survey of fishers' ecological knowledge about the ecological role of each deep pool in that river stretch, as illustrated by similar studies along the Mekong or the Ayeyarwady Rivers. Given the ecological significance of this area, the study could be extended to the whole river stretch between Chiang Saen and Luang Prabang (29 deep pools, Halls et al. 2013).

Surveys along the study zone have confirmed, like elsewhere in Laos and Thailand, that "Tao" and "Kai" algae (*Cladophora sp.*, *Microspora* sp. and *Spirogyra sp*.) play an important role for fish and people as a nutriment, in particular in the dry season (Roberts and Warren 1994, Bunyang Chumsi and Charin Chaemchit. 1999, Baird and Shoemaker 2008, Yana and Peerapornpisal 2009). Since the presence and development of these algae are correlated with slow water currents, there is a need to assess the impact of a change in river hydrology on algae, a local aquatic resource whose nutritional input can be significant important (Moat War Dine Naw and Soe Soe Win 2011).

Among other specific sites, the Khone Phi Long area has been highlighted by local residents as an ecologically important zone; other sites have been incidentally mentioned too during the team's rapid visit. This calls for a thorough assessment of sites considered as ecologically important by local villagers, in order to help identify priority conservation zones.

The various knowledge gaps and proposed studies mentioned above are different in terms of importance to management and immediate feasibility, as illustrated in Figure 4.1.

Figure 4.1: Importance of recommended studies from a management and feasibility viewpoint



Socio-economics

Before the LMDP implementation begins, stronger socio-economic baseline data is required to better target mitigation measures. In particular, a field study to provide finer detail about, for example, where ethnic minority communities are living, the communities living near the dangerous areas, and the socio-economic status of those with farms on the riverbank.

A management plan is only as good as the information that feeds it, and in this case more detailed data could be gathered through fieldwork surveys and consultations with community members and local government officials in order to improve on the mitigation options provided. For example, the socio economic section of the Baseline Assessment Report highlights that 18 of the 23 dangerous areas that have been surveyed in the study area have communities living in nearby areas. As a priority, the following three actions should be taken:

1. Field surveys should be conducted in the communities proximate to the dangerous areas to assess their ethnic compositions, to quantify areas of riparian farmland that may be at risk of erosion, to assess the financial and overall well-being of community members, and to determine community needs and aspirations with regard to improving or maintaining their livelihoods.
2. These surveys will then be used to sustain people's livelihoods, including by prioritising assistance for those who are at risk of losing farmland and those who harvest kai for a living, and to target support for those who live near to rocky dangerous areas that will be blasted.
3. Quantitatively model the likely urban growth of Houay Xai, Chiang Khong, Pak Beng and Luang Prabang, and provide support to the local administrations for town planning in advance of port development.

The key socio-economic impacts and recommended mitigation options are listed in Table 4.1 below.

Table 4.1: Key socio-economic impacts and recommended mitigation options

Impact Grouping (negative)	Mitigation/Enhancement Options
Loss of riparian farmland due to riverbank erosion (direct)	Conduct of field surveys to establish the socio-economic situations for those who will be exposed to negative impacts associated with the LMDP. This will support prioritisation of effort in mitigating negative impacts. Socio-economic field surveys of communities living near planned dredging and blasting areas for their socio-economic conditions. (Note: A broad overview of communities living near 'dangerous areas' of the river is included in the Baseline Report).
Expanding towns will lead to increased urban run-off, including untreated or semi-treated domestic waste-water (indirect)	Full EIAs, SIAs and HIAs should be conducted for each port development proposed in the LMDP, prior to work on those port developments commencing. Survey of vessels on the river, and for the vessels planned to be used following the implementation of the LMDP, for how waste disposed of (human waste, food waste, rubbish).
Grease and oil, loss of riparian vegetation, and disturbed sediment polluting waters near to port development areas (direct)	Full EIA, SIA and HIAs should be conducted for each port development proposed in the LMDP, prior to work on those port developments commencing. Conduct socio-economic field surveys of those who harvest and sell kai (including an assessment of the total value of kai traded compared to agricultural crops and other produce, and the length of the river in which it grows). Modelling of urban growth in towns where ports will be developed. Modelling of likely additional urban run-off that will result (both domestic waste-water and mineral contaminants).

4.2 STRATEGIC RECOMMENDATION 3: BEST PRACTICE DESIGN, CONSTRUCTION AND OPERATION REQUIREMENTS FOR THE LMDP

Ensuring the design, construction and operation of the LMDP are implemented in line with environmental best practices, means that all reasonable measures are taken to reduce the impact on the environment and people. This can be achieved through direct changes to the design and operation, as well as setting of policies and regulations and the development of cooperative institutional arrangements to agree on and oversee the design and implementation of works. Further detail on relevant best practice measures are provided in more detail in the following sections.

Hydrology and sediment

The highest risk impacts are related to dredging of sand from the riverbed and islands that may cause downstream bed and bank erosion; clearing of sediment for port construction; and increased large boat traffic causing bank erosion through wave action. The first two impacts need to be mitigated by ensuring best practices are followed in sand and silt removal, the second needs to be mitigated by bank protection works and limits on boat size and speed.

Best practice sand and silt removal ensures that:

- The volume of sand and silt removed is minimised
- The area of affected riverbank and riverbed is minimised

- Dredged sand and silt is placed in a location that minimises the potential downstream impacts (e.g. is spread downstream so the downstream section does not become sediment starved, and does not cover existing habitats)
- Sand and silt mobilised during the dredging process is contained into a small area and does not smother nearby or downstream habitats

To minimize the increased bank erosion that may be caused by larger and increased numbers of boat traffic, it is important that navigation rules are set for boat traffic. This should include:

- Setting a limit to the size and weight of boats trafficking the river
- Ensuring that boat traffic maintains a certain distance from the river banks where possible
- Setting speed limits for boats trafficking the river

In addition to the above measures, it is recommended that a monitoring program is undertaken to identify and rectify any bank erosion issues as soon as possible. Approaches for bank erosion should use bio-engineering where possible.

Biodiversity

Design

With no or limited access to project plans and documents, it is difficult to develop a detailed avoidance plan by proposing, for instance, changes in the location of interventions or adjustments to some construction measures. However, a first avoidance measure would consist in reconsidering the number and magnitude of interventions by integrating multiple perspectives in the intervention design.

We understand that in the case of river navigation improvement under the LMDP, the 146 rapids and shoals identified for blasting have been identified from the sole perspective of boat traffic. However, navigation could be greatly improved with the blasting of only a fraction of these 146 sites, the most dangerous ones, without aiming for maximal traffic fluidity alone. Similarly, the amount of blasting required reflects the size (tonnage) of boats whose passage is to be facilitated, but it does not seem that this tonnage has been defined while considering multiple perspectives such as environmental conservation and sustained livelihoods of riparian communities.

We recommend the re-definition, by a multi-disciplinary and multi-stakeholder team, of:

- How much blasting is acceptable by all parties, so that a compromise between multiple perspectives is reached; for instance, whether the blasting of 50 sites only is acceptable from a navigation perspective if that allows protecting 5 critically endangered species.
- Consideration of the tonnage of the boats whose passage is to be facilitated, so that the trade facilitation perspective is blended with several other objectives.
- A prioritization of the sites to be blasted, based on a multiple-objective analysis. The biodiversity resource protection perspective requires in particular: i) a greater diversity of channels and flows permitting sustained fish migrations by species of various sizes; ii) maintenance of flow velocity diversity in order to sustain micro-habitat diversity for breeding or feeding of aquatic organisms; iii) maintenance of macro-habitats (islands, dry-season wetlands, etc.) from a habitat conservation and biodiversity conservation perspective. The fishery conservation perspective also calls for sustained access of riparian villages to sites that can be harvested and remain productive enough for sustained livelihoods.

Overall, from an avoidance perspective we recommend that the current LMDP development plan is reconsidered and revised before intervention, in order to also integrate fish and habitat protection perspectives, but also sustained livelihoods of riparian communities.

Construction

In addition to controlling hydrological and sediment impacts during construction, the management of noise during rock blasting must be considered. Very loud sound vibrations, such as those generated by rock blasting, can harm and impair fish and other aquatic organisms in the vicinity of intervention areas. Mitigation measures should be applied to limit the impact of blasting such as restricting the timing of blasting to avoid migration and spawning seasons, the size of each blast or avoid blasting altogether by using chiseling methods.

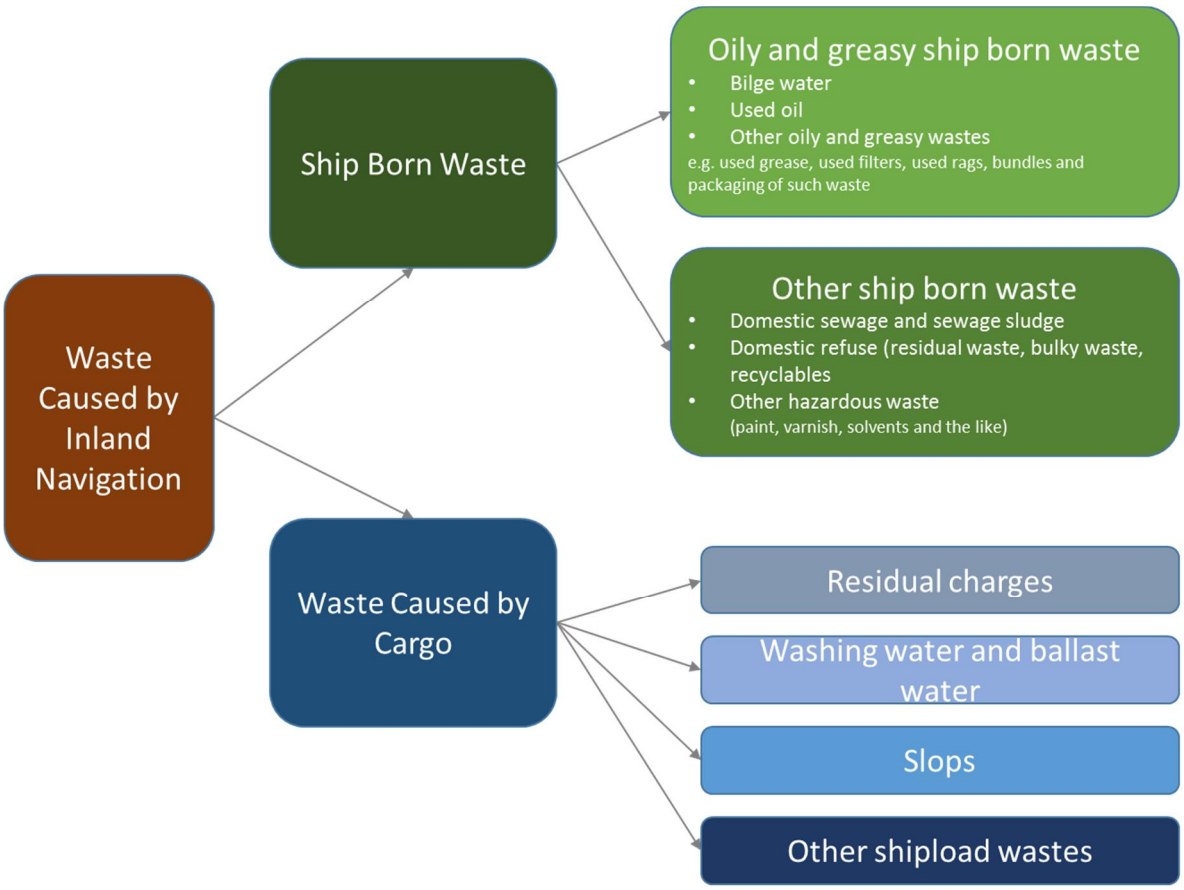
To protect water quality, dredgers need to be restricted from discharge of wastes such as fuel and lubricants into the river during dredging operations (USACE, 2009). Halting dredging during the fish spawning season is also recommended (Gupta et al., 2005)

Operation

To minimise pollution produced by boats and ports entering the waterway, providing facilities for collection and disposal of waste oil and any other wastes such as garbage is essential. Moreover, any hazardous wastes should be separately collected and disposed at appropriate facilities (Gupta et al., 2005).

Waste onboard vessels is typically generated by three main sources (Figure 4.2): the operation of the vessel, the people staying onboard and waste related to the cargo. Each of these three main waste groups vary in terms of characteristics and amounts produced. However, in general, increasing traffic volumes also leads to growing amounts of ship waste. Ship borne waste results from the operation of the vessels (oily and greasy ship borne wastes, paints, solvents) and is also generated by the crew and passengers (e.g. domestic sewage, wastewater, sewage sludge). Cargo wastes contain residual charges, washing and ballast water as well as slops and other shipload wastes.

Figure 4.2: Waste caused by Inland Navigation (modified from AWC, 2012)

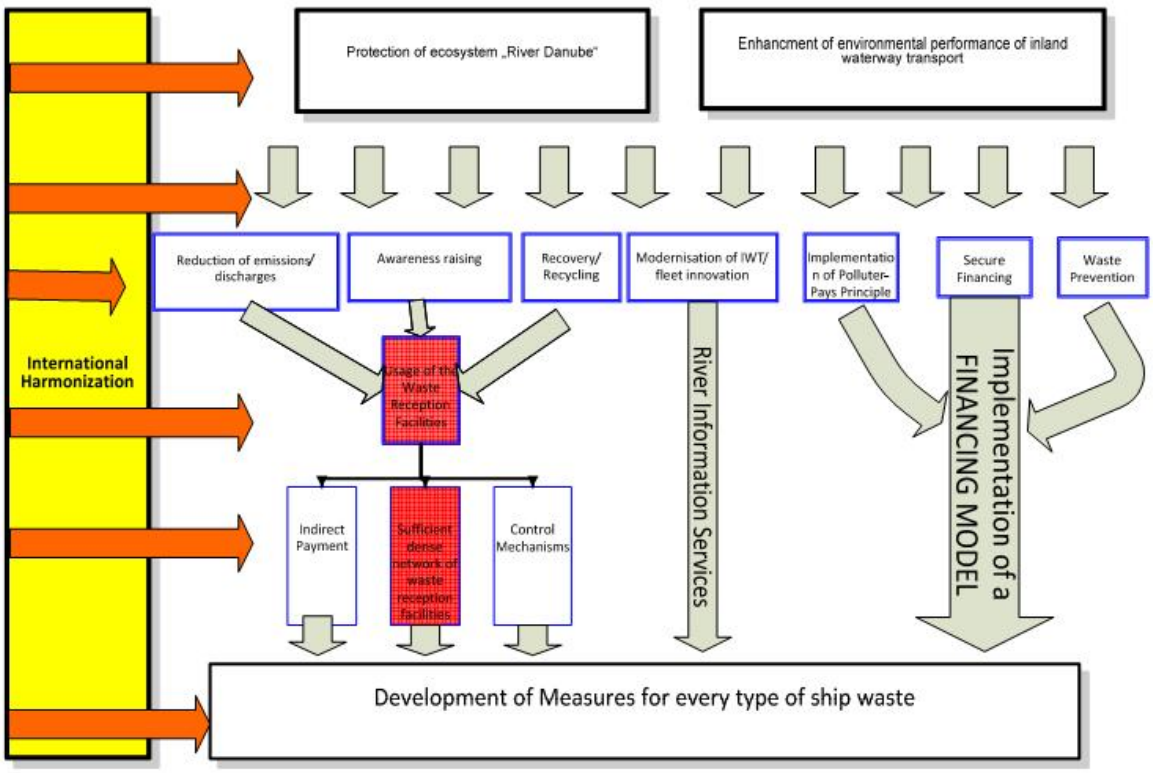


One initiative that has been implemented for the Danube and other rivers in Europe is the deployment of mobile waste reception facilities or floating barges that collect bilge, oil and grease and solid wastes from cargo and passenger ships. There is also restrictions placed on discharge of bilge waters, carriage of dangerous or toxic substances and facilities provided at ports for disposal of wastes. An overall set of objectives and mechanisms for developing appropriate measures for managing every type of waste from inland navigation in Austria have been developed and are summarised in Figure 4.3.

These objectives and mechanisms for managing waste from navigation should also be considered in developing appropriate waste management arrangements and measures for the Lancang-Mekong in dealing with the impacts of current and future increase in navigation waste under the LMDP.

In addition to waste management, while cruising, along the navigation route, the engine speed of boats should be minimized to avoid the disturbance, both by noise and waves, produced by the engine that can have negative impacts on fish and other aquatic organisms. Underwater noises of long duration, such as those produced by boats, could potentially impact fish across large areas and involve large numbers of fish (Slabbekoorn et al. 2010). Reducing vessel speed (to reduce noise and wave intensity), regulation of the number of boats operating at certain times (such as spawning or migration seasons), and increasing the passing distance of vessels to the shore (Gabel et al., 2017) are all important measures to reduce direct and indirect impacts on fisheries and other aquatic biodiversity.

Figure 4.3: Pathways for ship waste management in Austria – simplified version (taken from AWC, 2012)



Socio-economics

By reducing the environmental impact of the navigation channel and port facility works, the immediate impacts on peoples' livelihoods will be commensurately reduced, such as by reusing spoil in construction activities rather than dumping it in deep pools. Key construction and operation impacts of the LMDP on socio-economics and suggested mitigation measures are shown in Table 4.2 below.

Table 4.2: Key construction and operation impacts of the LMDP on socio-economics and suggested mitigation measures

Impact Grouping (negative)	Mitigation/Enhancement Options
Loss of riparian farmland due to riverbank erosion (direct)	Introduce and enforce speed limits for vessels with displacement hull characteristics.
Expanding towns will lead to increased urban run-off, including untreated or semi-treated domestic waste-water (indirect)	Develop regulations for the disposal of waste from boats, including inspections, and sanctions if regulations are ignored. Plan waste disposal facilities at ports.
Grease and oil, loss of riparian vegetation, and disturbed sediment polluting waters near to port development areas (indirect)	Develop facilities for receiving and treating petroleum based waste products at the new ports. In order to protect fish habitats/breeding sites, protect deep holes from dumping of dredge spoil. Require spoil from dredging and port construction to be transported for reuse.

4.3 STRATEGIC RECOMMENDATION 4: ESTABLISH A TRANSBOUNDARY MEKONG MAINSTREAM CONSERVATION AREA NETWORK

4.3.1 Introduction

A transboundary Mekong mainstream conservation area network is proposed in study area to address impacts of the LMDP maintain important biodiversity and livelihood values. It is intended that the strategy is implemented initially as a pilot and demonstration phase with a vision for network extension along the entire Mekong mainstream.

The strategy could be implemented as a win-win with the LMDP - and be an important initiative whether or not Pak Beng HPP proceeds. The network is not competing with development but is an essential part of the development strategy – allowing improved navigation, trade and economic development, whilst also maintaining important biodiversity and local traditional livelihoods reliant on biodiversity.

It will be essential that the Mekong River Commission Secretariat (MRCS) have a key role in facilitation, management, guidance and monitoring and evaluation of the network. It will be important to integrate the outcomes into the MRCS future program of work as a "transboundary project" managed by MRC with Thailand and Laos. Eventually, the network should extend down the entire length of the Mekong River and bring Cambodia and Vietnam into the planning and management process with MRC facilitation.

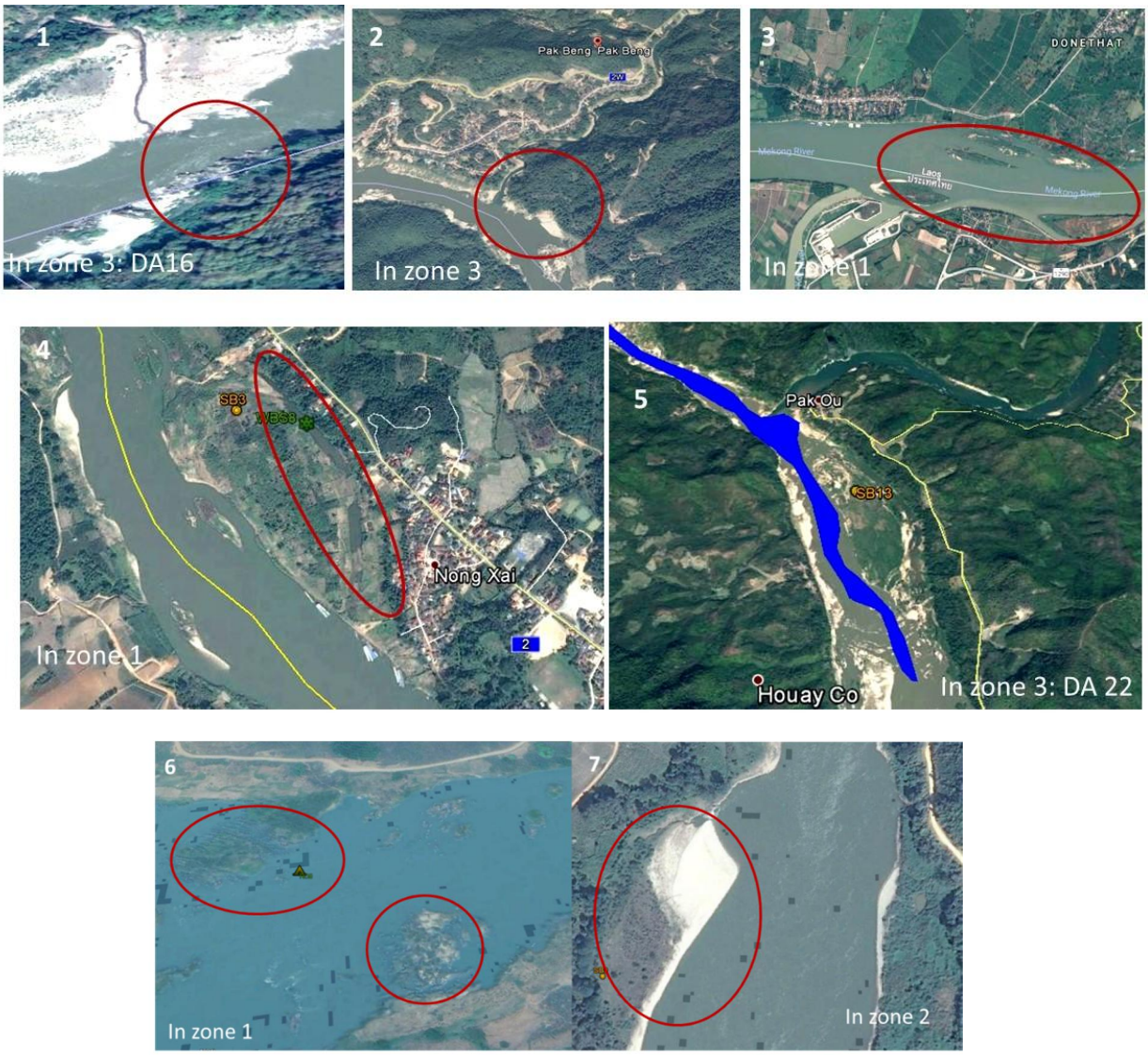
4.3.2 Identification of conservation sites

First, almost the entire length of the study area is classified as an IBA, so is an internationally recognised bird and biodiversity area. However, it is also possible to identify individual habitat features and habitat clusters or mosaics that are likely to be relatively more significant for biodiversity than other parts of the study area. Several important habitat features can be identified along the study area including:

1. Rapids/shoals
2. Tributaries/deltas
3. Vegetated islands
4. Off-main channel wetlands
5. Deep pools
6. Rocky outcrops
7. Sandbanks

Examples of these habitat features area shown below (Figure 4.4).

Figure 4.4: Habitat feature types in the study stretch



The number of each of these features were counted in each zone. This helped to quantify important habitats and characterize each of the three zones based on distinguishing biophysical features. For example, Zone 1 has more vegetated islands and wetlands than the other two zones due to its flatter topography, wider channel and finer grained sediments.

Table 4.3: Identified environmentally sensitive habitats in each assessment zone within the study reach

Environmentally sensitive habitats			
Habitat	**Zone 1**	**Zone 2**	**Zone 3**
Vegetated Islands	18	1	10
Deep pool	4	5	10
Very deep pool	3	0	7
Rapid	15	8	10
Rocky outcrop	10	11	18
Sandbank	19	3	6
Tributary/ Delta	23	33	33
Off-main channel wetland	12	2	2

However, these features are too numerous and at too fine a scale to be used as individual conservation sites. Therefore, an aggregating approach using these features as a basis was taken. An ideal approach based on habitat and species biodiversity significance criteria is also proposed for the future requiring more detailed study and information. Both are described below.

4.3.2.1 Site selection criteria

In order to select a manageable number of conservation sites within the study area that could be used as a basis for the first phase in piloting this strategy, a reduced and simplified set of criteria to emphasise habitat diversity and representativeness was taken.

The criteria for selection, though ideally based on unique and threatened biodiversity (Box 1), was not practicable because the granularity of information to distinguish between the sites was not available.

Therefore, at this stage, sites were distinguished by identifying areas of important habitat features, ensuring that they were representative.

The selection took into account:

1. Representativeness of the different habitat types including, wetlands (in channel and on the banks or in floodplain areas), sandbanks, rocky outcrops and rapids, vegetated islands, deep pools, tributary confluences and dangerous areas.
2. Uniqueness of the habitat, e.g. the small wetland area on the Lao bank in Zone 1.
3. Geology - especially limestone areas e.g. from the Pak Ou upstream by 10 km.

Box 1: Ideal future criteria

As more information is gathered at these sites, progressive application of the following more comprehensive set of criteria will allow for: (i) a more detailed justification for protection, (ii) a greater precision in boundaries and (iii) a thorough framework for monitoring and management.

Habitat:

1. contains unique and rare habitats;
2. includes fragile and sensitive habitats;
3. important for ecological integrity;
4. representative of a Mekong River habitat type.

Species:

5. presence of species of conservation concern;
6. occurrence of restricted range species;
7. species richness;
8. importance for species life history stages.

The following social and management criteria to be used in setting priorities or ranking important sites for management:

9. Is in close proximity to a community/settlement (that could be involved in co-management);
10. An important site for local livelihoods;
11. An important site for cultural significance and recreation.

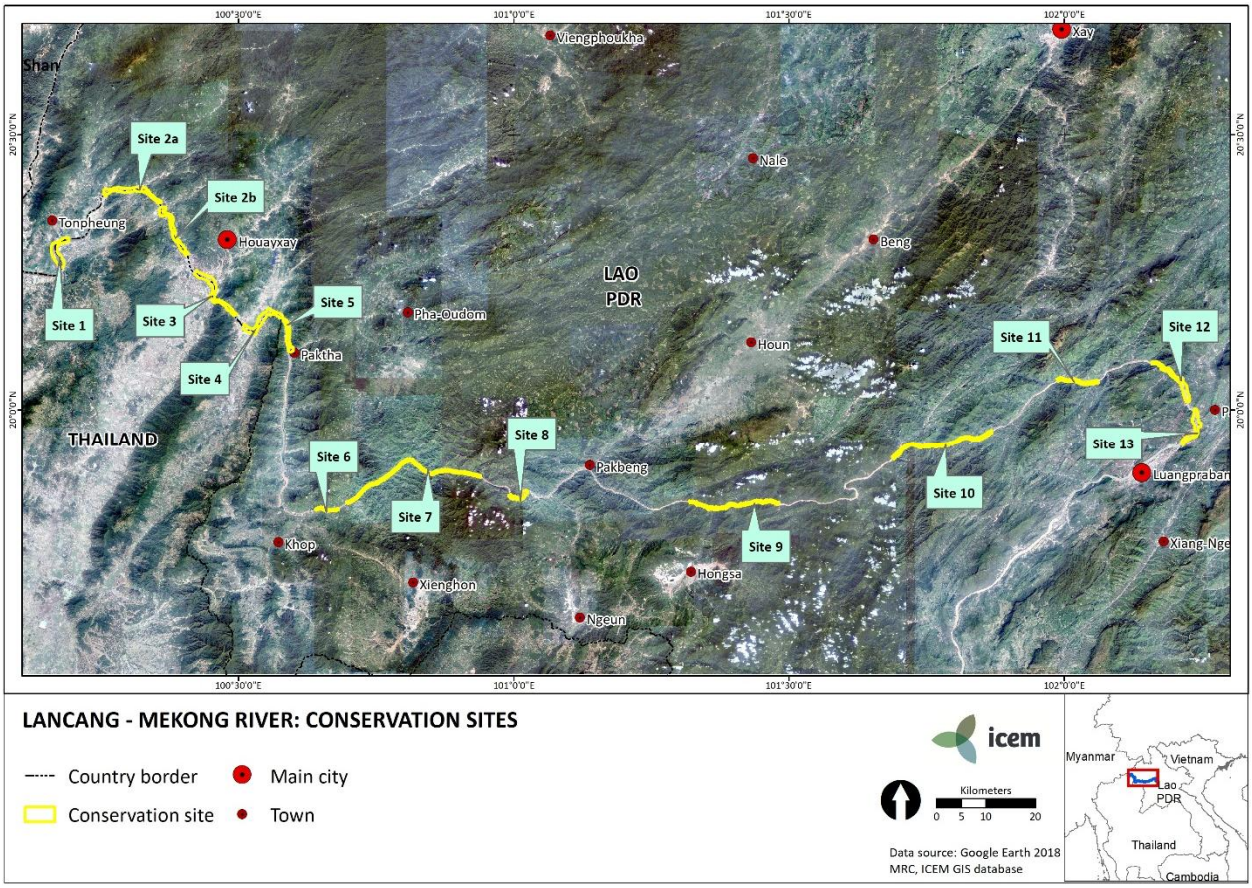
4. Threat e.g. sandbanks are probably beginning to diminish in size because less sediment is coming down the river, areas near settlements may be more disturbed than others, especially streams and tributaries where settlements are often located.

An aggregating approach was taken, so that rather than identifying small patches of habitat, larger lengths of river on both banks, which may have several important habitat features, were identified.

4.3.2.2 Selected sites

A series of maps showing the prospective high biodiversity value sites in each zone, which would make up the initial network for further more detailed study, are presented in Annex 2. The selection identifies 14 sites in total (Figure 4.5) – 5 in Zone1, 4 in Zone 2 and 5 in Zone 3. They ensure representativeness of habitats, coverage of unique and threatened habitats and limestone areas. Some are up-to 30 km long but the average length is 13km – with an overall combined length of 181 km for all 14 sites – about half the length of the entire study stretch. They also align closely with some of the dangerous area sites identified by the earlier MRC dangerous areas survey by the Navigation Program – which are also likely to be areas targeted for partial clearing under the LMDP.

Figure 4.5: Selected conservation sites



4.3.3 Key implementing actions

This section sets out the key actions that need to be taken for implementing the proposed transboundary conservation network. In order for the proposed conservation area network to be implemented effectively, these actions and overall management will need to be led by the MRC with national and locally responsible Thailand and Lao PDR navigation and environmental management agencies as core partners.

Thorough survey and boundary definition of currently proposed sites is an immediate priority in order to more clearly define the biodiversity values and spatial boundaries of each site, and the justification for protection. The current site definition is largely based on a visual assessment of potentially high biodiversity value habitats without detailed information on the habitat and species values at each site.

Each identified site requires a detailed biodiversity survey to properly assess its biodiversity importance with the application of the comprehensive biodiversity criteria outlined in Box 1 above. In particular, a comprehensive bird and fish survey would be required as habitats in the stretch of the river containing the proposed sites is known to be significant for both groups. A general flora and fauna survey should also be included covering plants, mammals, amphibians, reptiles and invertebrates – the latter particularly in potential karst habitat areas around the Nam Ou and Nam Suong tributaries in sites 12 and 13. Detailed justification, boundary definition and management and monitoring plans can then be prepared for each site.

Formal designation of the conservation network should be undertaken following further site studies and justification to ensure the sites are protected under a legally binding framework that sets out management objectives and requirements, roles and responsibilities. For the five transboundary sites in Zone 1, a Lao-Thai agreement will be required, establishing the sites under each country's protected area system and setting out joint and respective country roles and responsibilities. The remaining eighteen sites in Zone 2 and Zone 3 will fall under the responsibility of Lao PDR and require their own designation under the Lao PDR protected area system. This is perhaps clearer in terms of setting up institutional management responsibilities and arrangements. However it is also more burdensome in terms of resources and capacity for the relatively less developed and well-resourced Lao PDR. It is particularly important for Lao PDR, therefore, that mechanisms for obtaining private sector financing for implementing the conservation network are established. This is also important for Thailand and the successful implementation of the network overall.

Establishing mechanisms for private sector financing of the proposed conservation network is critical for ensuing there are adequate resources for it to be established and maintained. This could include through implementing one or more of the following funding mechanisms:

i) requiring the LMDP developer to pay for establishment, maintenance, enhancement and monitoring of the network (or selected sites) as a biodiversity offset requirement under the Thai and Lao development approvals process;
ii) payment for ecosystems service (PES) schemes by users of the enhanced navigation facilities; and
iii) imposing levies on waterway users or beneficiaries of the LMDP (such as large vessels).

Biodiversity offsets could be applied to offset any losses in biodiversity caused by the implementation of the LMDP that cannot be avoided or mitigated – paid for by the LMDP developer. Most of the 23 MRC surveyed dangerous areas for navigation likely to be partially cleared under the LMDP will contain natural habitat and some may contain critical habitat. If the LMDP navigation improvement works are done to best practice, the losses in habitat would be relatively small.

However, there may still be some residual adverse impacts on biodiversity after all avoidance and mitigation measures have been applied to the impacts of the clearing and increased boat traffic from the LMDP. These residual impacts could be bundled into a biodiversity offset that could be applied to rehabilitate other similar rapid or obstruction habitat areas that are degraded and do not need to be cleared under the LMDP, and are within the proposed conservation area network. An assessment of residual impacts that need to be offset and identification of potential candidate sites will need to be undertaken as part of country-level ESIAs for the LMDP. It will also be necessary to identify suitable offset sites within the proposed conservation network. These will need to be able to achieve a net gain in biodiversity through long-term conservation management.

Due to the close proximity or overlap of the conservation sites and sites to be cleared under the LMDP, finding suitable offset sites within the proposed network could prove challenging i.e. most of the proposed conservation network sites contain dangerous areas for navigation that are likely to be targeted under the LMDP.

As for the option of setting up a PES scheme to pay for the establishment and management of the network, there would need to be, among other requirements, a clear link between the generation of ecosystem services by the proposed network and users or recipients that would be willing to pay for one or more of those services. The proposed network will maintain or improve several regulating and provisioning ecosystem services through natural habitat and biodiversity conservation and enhancement. However, a clear link between these services and direct users or beneficiaries that would be willing to pay for them is not immediately apparent. The ecosystem service benefits generated by the network are diffuse and mainly accrue to poor local communities scattered along the river who would not have the ability to pay (and the transaction costs would be too high). It is possible that eco-tourists through eco-tour boat operators may be willing to pay for enhanced cultural services i.e. biodiversity sightseeing and recreational opportunities. However the scale of eco-tourism is likely too low at present for this to be a viable PES option.

Box 2: The Australian Protection of the Sea Levy

Protection of the sea levy. The protection of the sea levy helps to fund the response to any environmental incidents through requiring potential polluters to pay a levy.

Who pays the levy. Any vessel of 24 metres or more in length carrying 10 tonne or more of oil on board at any time during a calendar quarter will need to pay the protection of the sea levy. This may include some fishing vessels which are exempt from the marine navigation levy and the marine navigation (regulatory functions) levy. If vessels already pay the marine navigation levy and the marine navigation (regulatory functions) levy, they will also need to pay the protection of the sea levy.

Exemptions. Vessels which enter ports to load fuel, provisions and water to complete a voyage, undertake crew changes or for repairs only do not pay the levy.

When to pay the levy. Vessels must pay the levy at the same time vessels are required to pay the marine navigation levy and the marine navigation (regulatory functions) levy. If vessels are exempt from paying the marine navigation levy and the marine navigation (regulatory functions) levy, vessels must pay the levy each quarter if they are a coastal vessel. Overseas vessels must pay upon arrival at an Australian port. Vessels will receive a receipt when you pay the levy and this receipt will be valid for three months.

Levy charges. The levy is calculated at 11.25 cents per net ton per quarter, with a minimum of AUD$10 per quarter. The levy is reviewed annually.

Funding clean-up costs. The levy funds the National Plan for Maritime Environmental Emergencies and clean-up costs which cannot be attributed to a known polluter.

Alternatively, a fee (or special purpose levy) could be levied on the passage of large cargo vessels to support the protection of the conservation areas. Every voyage, cargo vessel or tanker would pay a fee to maintain the waterways (for navigation) and conservation areas (for biodiversity). In Australia, for example, a levy is applied on marine commercial shipping to cover the cost of marine aids to navigation systems[1]. A protection of the sea levy[2] is also imposed (Box 2).

[1] https://www.amsa.gov.au/about-us/fees-levies-and-payments/marine-navigation-levy

[2] https://www.amsa.gov.au/about-us/fees-levies-and-payments/protection-sea-levy

In general, a special purpose levy is justified when continuous funding is required for a particular service, and it is more efficient for payments for that service to be spread across the community – or that part of the community which benefits directly from the service (Fingleton, 2005)[3].

The following eight aspects need to be considered when deciding how to provide for special purpose levies (taken from Fingleton 2005).

1. There are two main aspects in operating a levy system – (a) how the levy is collected; and (b) how the levy is disbursed.
2. Regarding collection of the levy, the levy can either be – (a) paid into consolidated revenue; or (b) paid into a special fund.
3. If the levy is paid into consolidated revenue, no further provision is necessary regarding collection of the levy.
4. If the levy is paid into a special fund, further provision may be required for –
    (a) creation of a legal entity which collects the levy, holds the levy fund and disburses payments from the fund;
    (b) the membership (if any), functions and powers of that legal entity;
    (c) how decisions are made by that legal entity;
    (d) its accountability to the stakeholders involved.
5. Legal provision will also be required for –
    (a) who pays the levy;
    (b) how the levy is assessed;
    (c) how the levy is imposed;
    (d) any exemptions or rebates from the levy.
6. Legal provision may be required for financial matters, such as –
    1. how the levy is collected;
    2. issuing of receipts for levy payments;
    3. banking of levy receipts;
    4. debt recovery.
7. Regarding disbursement of the levy, legal provision may be required for –
    1. the purposes for which the levy fund may be disbursed;
    2. how disbursement is carried out;
    3. risk management.
8. Provision will be needed for the management of the levy, including for –
    1. administration, staff appointments and supervision;
    2. record-keeping and reporting;
    3. accountability and transparency;
    4. public awareness and notification of the levy;
    5. possibly decentralised operations.

[3] Jim Fingleton (2005). Funding options for agricultural development: *the case for special purpose levies*. FAO 2005. http://www.fao.org/3/a-bb077e.pdf

In general, the establishment of a special purpose levy on waterway users for the establishment and management of the proposed conservation network (along with maintenance of the waterway for navigation) is considered to be the most promising potential funding mechanism.

Clearly defining the role of the MRC in transboundary network facilitation, studies, management planning and monitoring. The MRC will need to play a key role in setting up and providing support to the management of the proposed conservation network. This would include leading the further establishment steps in conducting additional surveys to better define the areas and helping to facilitate formal designation of the sites by Lao PDR and Thailand, establishment of funding mechanisms and setting-up of Thai-Lao and Lao conservation management units.

The MRC Joint Committee would need to facilitate initial cooperation and planning between the Thai and Lao National Mekong Committees to open dialogue and begin the network establishment process with additional technical support provided by the MRC Secretariat Environmental Management Division and Technical Support Division in conducting detailed site surveys and evaluation of funding mechanism. The MRC would also play an ongoing technical assistance role in assisting with monitoring of the network and helping to plan and carry out any further assessments and management actions.

Establishment of Lancang-Mekong Lao and Thai conservation management units. Permanent Thai and Lao conservation management unit will need to be established for network survey, management planning and ongoing monitoring and management of the sites including rehabilitation and bioengineering works, supported by the MRC. For the five transboundary sites in Zone 1, a joint Thai-Lao sub-unit could be considered to jointly manage these sites – but transboundary institutional arrangements of this kind for protected areas have not been easy to establish in this region.

In terms of defining the institutional arrangements for the management units including under which agency they should be formed, there are two main agencies in each country to consider – relating to protected area management and inland waterways management. In Thailand, protected areas are managed by the Department of National Parks, Wildlife and Plant Conservation (DoNP) under the Ministry of Natural Resources and Environment. Whereas, the Marine Department under the Ministry of Transport (MoT) is responsible for planning, under-taking and controlling, maintenance, improvements and navigation for inland waterways. In Lao PDR, protected areas are managed by the Ministry of Natural Resources and Environment (MoNRE). Whereas, the Department of Waterways under the Ministry of Public Works and Transport (MPWT), is responsible for policy, planning, and managing all inland waterways in the country. This includes port and navigation channel management, flooding and river bank protection, and waterways transport.

As the primary objective of the proposed conservation network and management units is conservation of biodiversity, the establishment of institutional management units should occur under the respective protected area management agencies in each country. However, the units should also closely link with the respective inland waterways management agencies to ensure the conservation management objectives and interventions influence and harmonise with inland waterways and navigation objectives and interventions, many of which are needed to effectively manage many construction and operational impacts of the LMDP, which the network alone does not address. In order to be successful, the management of the proposed network needs to include inland waterways interventions that limit the LMDPs impact on and enhance biodiversity conservation. So active participation of the Thai and Lao inland waterways management agencies within each established network conservation management unit is essential.

Preparation of an overall network management plan (including monitoring and evaluation requirements) will be essential for effective management of the proposed network. This will need to be done undertaken by the network conservation management units, once established, with support from the MRC and donor funding if available. The plan will set out the well-defined network and justification for each site (following the additional surveys), the formal designation arrangements for the network under Lao and Thai protected area management frameworks, the funding mechanism or mechanisms for supporting the network including institutional arrangements, the role of the MRC in supporting the network and the institutional arrangements, mandate and functions of the established conservation management units. It will also provide the overarching management framework for the whole network including:

- Background and justification for the network;
- Vision and plan for extension of the network including criteria for inclusion of additional sites;
- Conservation management objectives for the network;
- Roles and responsibilities for management;
- General guidelines and requirements for managing impacts on the network;
- Management actions linked to objectives including an implementation timeframe and cost;
- Procedures and requirements for developments potentially affecting the network;
- Requirements and guidelines for preparation of individual site management plans; and
- Monitoring and evaluation requirements including reporting.

Preparation of specific site management plans including site zoning and specific management requirements will be necessary to effectively manage each site, which have different needs. All the distinct habitats within each sites will be important to identify and zone within each sites management plan, which will set out specifically targeted site and habitat management actions, restrictions, permitted uses and monitoring requirements. Depending on the site, the management may be merely to protect, study and monitor their condition i.e. to allow no exploitative uses or development induced change. Or it may involve rehabilitation or "construction" actions to enhance biodiversity outcomes. The different habitats need to be demarcated and included in the zoning safeguards and management arrangements.

The site management plans will set out:

i) Background and justification for the site;
ii) Site conservation management objectives;
iii) Community and collaborative management arrangements for each site;
iv) Overall zoning arrangements such as;
    a. Creation of fishing use and conservation zones (examples for fish and birds given below); and
    b. Definition of commercial vessel no go areas.
v) Site-based management actions linked to objectives including an implementation timeframe and cost such as demonstration and piloting technologies for habitat maintenance and creation; and
vi) Site specific monitoring requirements if applicable.

An example of and consideration for setting a zoning requirement for bird habitat

Zone the seasonally exposed channel bed to comprise the maximum proportion that is socially acceptable as no-go areas for people, dogs and domestic bovids during November – May: this is to provide some 'safe havens' within which ground-nesting birds can breed. Safe havens should be positioned on dry-season islands (which remain separated from the mainland until at least the end of April) so that dogs cannot simply walk across from the adjacent land, and in stretches of complex channel mosaic which are already difficult to walk, boat or swim through. Given the current allowance for anyone to go anywhere at any time for any purpose, if the safe-haven approach were implemented effectively over a significant proportion of the seasonally exposed channel bed, it could even reverse declines in some species.

Although the project impact to be addressed by safe havens is transitory (construction phase), the baseline (no project) situation is one of high dry-season channel use, making it highly desirable to institute no-go islands each dry season on an ongoing basis. This recommendation should be achievable with sufficient political will, but could be futile if water-level changes consequent on management activities upstream of the project stretch render the entire area already of low value to ground-nesting project species. It would be completely unworkable without genuine participation of local people, both those resident and those traversing regularly through the project stretch. There is some insight from Cambodia in how to work with local people on the protection of ground-nesting birds of the river channel. But even with this, considerable experimentation and creativity of thought would be required to make 'safe havens' work in the project stretch.

However, locations for safe havens cannot be proposed even provisionally without detailed survey. There are many potential suitably locations and the primary way of selecting among them is for those where local participation would be sufficient to allow a chance of success. There is a modern tendency for environmentally damaging projects to compensate for their negative effects by creating equivalent habitat, or avoiding the otherwise inevitable destruction of extant equivalent habitat. However, it would not be appropriate to take such a habitat-based approach with the Pak Beng HPP. Suitable habitat in the project stretch is, and will remain after the dam, far in excess of what is required to support current project-stretch populations of most of the project species of bird. Populations are currently kept low by human activity and/or inevitable consequences of it, meaning that the effective compensatory activity for the dam's destruction of seasonally exposed, seasonally inundated habitat is not rehabilitation of vegetation or other habitat-based fripperies, but serious attention to spatial patterns of human activity in the parts of the project stretch not affected by changing hydrodynamics.

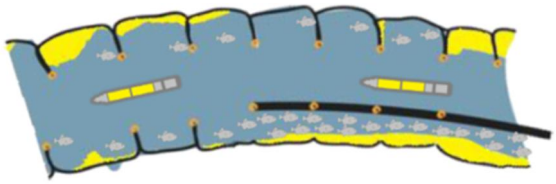
Examples of and consideration for demonstration and piloting technologies for fish habitat maintenance and creation

Most of the small size fishes as well as fish larvae occupy the river bank area and will therefore likely be impacted by waves generated by boats during operation of the LMDP (see fish section in the Impact Assessment Report). A common mitigation approach could be to apply vegetation as a countermeasure to protect the riverbank from wave attacks. Trung et al (2015) showed that the wider and denser the vegetation area, the lower the impact by waves.

The construction of longitudinal training dams (Collas et al., 2018; Figure 4.6) to mitigate the effects of navigation on fishes is also a potential option. This is achieved by maintaining the natural variability of habitat conditions in the littoral zones by reducing the impact of ship passage. The shore channels serve as refugia for juvenile fishes.

Developing longitudinal training dams and creating shore channels to ensure shallow, slow-flow and stable habitats along banks in critical segments of the river stretch to be modified is an option definitely worth considering. Riverbank channels allow facilitating fish passage and breeding without compromising navigation improvement; they have proven necessary and effective in Europe (Brabender et al. 2016, Collas et al. 2018) and are fully relevant here. Such riverbank structural protection in relation to navigation improvement would be a novel and low-cost technology in Asia; once tested and validated, they would be relevant to multiple other sites in the region.

Figure 4.6: The longitudinal training dams (Collas et al., 2018)



In addition, restoration of the pool and riffle ("Pha" and "Kok", in Thai) connection near the Khon Phi Long Rapid area (see fish section of the Baseline Assessment Report) should be considered. This ecosystem is capable of supporting many fish species and is likely to be impacted by the construction blasting and operational navigation impacts of the LMDP.

4.4 STRATEGIC RECOMMENDATION 5: ONGOING MONITORING OF BIOPHYSICAL AND SOCIO-ECONOMIC CONDITIONS AND IMPACTS OF THE LMDP

Hydrology and sediment

Monitor and respond to ongoing impacts: as the works are completed and commissioned, throughout the study reach and downstream. The monitoring should include discharge, sediment load and locations and volume of erosion. Comparison of the baseline and ongoing monitoring should then be used to identify issues that require a response. For example, if erosion is identified as occurring in a section of river bank then remediation works can be installed before the erosion has progressed too far.

Biodiversity

To ensure the implemented LMDP mitigation strategies for biodiversity are working and to adjust them over time in response to changing conditions, monitoring of biodiversity is necessary. This will include short term monitoring of construction phase impacts and longer term monitoring of operation phase impacts. During construction, monitoring of biodiversity around the blasting and dredging sites and ports will need to be undertaken to ensure the mitigation measures are working. This should include: a monitoring program on deep pool fish diversity and abundance; water quality monitoring; monitoring of macroinvertebrate populations; monitoring of identified critical habitats for threatened or endangered species.

Socio-economics

Continuous monitoring and response to impacts: In addition to monitoring the bio-physical impacts, there should be continuous monitoring of changes in the socio-economic conditions with reference to the established baseline and broader trends. This will allow any unanticipated socio-economic impacts and consequences to be identified quickly, and any necessary plans developed to mitigate or otherwise deal with them.

4.5 STRATEGIC RECOMMENDATION 6: LIVELIHOOD SUPPORT AND ENSURING THAT THE RIGHTS OF ETHNIC MINORITY AND OTHER VULNERABLE GROUPS ARE PRIORITISED FOR IMPLEMENTATION OF THE LMDP

Implementation of **Strategic Recommendation 6** includes a range of livelihood support measures for vulnerable groups, including:

- Staged land titling starting with those living or farming within 5km of the river.
- Giving priority to ethnic minority communities in avoiding farmland loss.
- Providing communities located within 2km of blasting areas, whose average income is less than 3 times the poverty line with support and training to ensure that reduced fish stocks will not stop them maintaining livelihoods.
- Providing support to local government authorities to ensure people comply with building standards and WASH related standards to address vector, food and water-borne disease risks.
- Improving access to medical care measures including: developing a plan for universal health coverage; increasing health services at new port developments; implementing public health programs, including STD services; and, increasing public health awareness raising via community nurses.
- Offer re-training where kai harvesters are negatively impacted, so they can be actively employed in port and town construction activities.
- Supporting local governments in town planning prior to implementation of the LMDP, so that likely impacts and mitigation strategies have already been considered by planning officials.
- Enhancing new employment opportunities through: regulations for wage earners (e.g. minimum wage); and providing training in basic construction skills and in tourism-related services.

A very high percentage of the rural Lao population live not far above the poverty line, and are in danger of falling back into poverty. Agricultural and health related shocks have a high probability of leading to those who are less well educated and/or belong to an ethnic minority falling into poverty. Ensuring secure land tenure for land that people farm under customary title, prior to commencing implementation of the LMDP, is one way of prioritising the rights of vulnerable people.

Land titling should be carried out for the riparian communities as well as those living on the road networks that link the towns where port infrastructure will be established. Under the 2003 Land Law this option is available, and with support from international organisations such as GIZ, for example, the government is in the process of ensuring land titling is done across three provinces including Xayabury.

To address the main negative socio-economic impacts of the LMDP, health and livelihood support measures are proposed in Table 4.4.

Table 4.4: Health and livelihood support measures to address the main negative socio-economic impacts of the LMDP

Impact Grouping (negative)	Mitigation/Enhancement Options
Easier access to remote areas of northern Laos (indirect)	To protect the rights of ethnic minority groups, and others who have customary title to their farmland, develop a three tiered land titling arrangement for those living along the Mekong river. This may look something like:

Impact Grouping (negative)	Mitigation/Enhancement Options
	Those living/farming within 5 km of the river should have their lands titled prior to implementation of the LMDP beginning. Those living/farming within 5 km of roads leading out from Houay Xai, Pak Beng and Chiang Khong (up to 100 km out from each town) should have their lands titled prior to the LMDP implementation being finalised. Those living/farming within 20 km of the river, or 20 km of the above mentioned roads, should have their lands titled no later than 3 years after the LMDP implementation is finalised. To reduce the amount of illegal logging and illegal wildlife transport and capture: Increase wildlife and forestry enforcement capacity at new port developments
Loss of riparian farmland due to riverbank erosion (direct)	Survey results to be used to prioritise planting of bank stabilising vegetation in locations where it will limit erosion of land belonging to (under customary title or otherwise) poor households, and to compensate affected families for loss of land. Include collection of information on ethnicity and gender, as well as broader socio-economic conditions. Ethnic minority communities must receive priority for the avoidance of farmland loss. Communities located within 2km of blasting areas, whose average income is less 3 times the poverty line should receive support and training to ensure that reduced fish stocks will not stop them maintaining their livelihoods.
Expanding towns will lead to increased urban run-off, including untreated or semi-treated domestic waste-water (indirect)	To address vector- food- and water-borne disease risks: Support to local government/authorities: • Ensuring people comply with building standards. • Ensuring people comply with WASH related standards. **Improve access to medical care**: • Developing a plan for universal health coverage. • Increase health services at new port developments. • Implement public health programs, including STD services. • Increase public health awareness raising via community nurses.
Grease and oil, loss of riparian vegetation, and disturbed sediment polluting waters near to port development areas (direct)	Where kai harvesters are negatively impacted, offer re-training so they can be actively employed in port and town construction activities. Support to local governments for town planning prior to implementation of the LMDP, so that likely impacts and mitigation strategies have already been considered by planning officials.

- In addition, the following livelihood support options (Table 4.5) are proposed to enhance the potential positive LMDP impacts in increased trade and new employment and business opportunities.

Table 4.5: Livelihood support options are proposed to enhance the potential positive LMDP impacts

Impact Grouping (positive)	Mitigation/Enhancement Options
Increased trade (indirect)	Support to local government/authorities: • Through a chamber of commerce or similar • To local sporting teams and competitions. These may help to mitigate alcohol and substance abuse, as well as gang formation.
Employment opportunities (construction, tourism services). (indirect)	Support to local government/authorities: • Regulations for wage earners (e.g. minimum wage). • Training in basic construction skills and in tourism-related services.
Opportunity for new businesses (indirect)	Support to local governments for town planning prior to implementation of the LMDP, so that likely impacts and mitigation strategies have already been considered by planning officials: • Supporting planning processes for town expansions in Houay Xai, Chiang Khong, Pak Beng: • Planning for green spaces (recreation, and to reduce run-off related to hard surfaces). • Water, Sanitation and Hygiene (WASH) planning, including water treatment. Find out if there is support available at the community level for those who would like to develop small businesses to take advantage of opportunities that arise as a result of the LMDP. • Supporting local business development for tourism and agriculture. • Business skills training.

4.6 MANAGEMENT ARRANGEMENTS FOR IMPLEMENTING THE LMDP STRATEGIC RECOMMENDATIONS

4.6.1 Roles and mechanisms for implementing the LMDP strategic recommendations

There are several key stakeholders involved or impacted in the navigation improvements works. Key roles and responsibilities in mitigating the impacts on hydrology and sediment include:

- **Navigation improvement works funding agency**: Ensure that a full Environmental and Social Impact Assessment and Environmental and Social Management and Monitoring Plan to international standard is developed for each country component of the LMDP and that the LMDP is designed to mitigate impacts, including the measures outlined in this report.

- **Navigation improvement works contractors:** Undertake the LMDP in line with relevant regulations and the components of the Environmental and Social Management and Monitoring Plan.
- **Lao PDR and Thai Governments:** Ensure that relevant regulations are in place and oversee the LMDP construction works and operation to ensure they are in line with relevant regulations.
- **Local communities and civil society:** Provide informal review and monitoring of LMDP works to ensure they are following best practice approaches to minimising impacts on social and environmental values.
- **Mekong River Commission:** Provide an avenue for discussion and debate on the planned works and ongoing operations, particularly related to transboundary issues.

The LMDP developer is primarily responsible (under Lao and Thai government requirements) for adequately assessing and addressing impacts of the LMDP. The developer will need to provide Environmental and Social Impact Assessments (ESIAs) and Environmental and Social Management and Monitoring Plans (ESMMPs) for the navigation clearing works and for each of the planned ports under respective riparian country requirements – including implementation of developed environmental and social management plans. Transboundary impacts will also need to be considered and dealt with, covered under the MRC transboundary EIA guidelines. These assessments and management plans will build on the current study and its recommendations to improve the baseline understanding (SR 1 and 4) and impact assessment, implement construction and operational mitigation measures (SR 3 and 6), and monitor impacts (SR 5).

Thai and Lao inland navigation (Box 3) and conservation agencies such as the Thai Marine Department and Department of National Parks, Wildlife and Plant Conservation and Lao Department of Waterways and Ministry of Natural Resources and Environment will play a central role in managing implementation of the LMDP and its impacts. It is essential that there is close cooperation and coordination between these agencies to ensure navigation, conservation and cross border management is harmonized.

The involvement of additional agencies for implementation of some socio-economic and livelihood impact mitigation strategies will be

Box 3: Thai and Lao PDR inland navigation agencies

In Thailand, the Marine Department[1] is a Government agency forming part of the Ministry of Transport (MoT). It is responsible for planning, under-taking and controlling, maintenance, improvements and navigation for inland waterways in Thailand. Its stated vision is to "Move towards sustainable water transport and maritime transport" and mission:

1. To enforce the Navigation in Thai Waters Act, Thai vessels Act, Prevention of Ships Collision Act and promotion of Mercantile Marine Act, Multimodal transport Act and other relevant laws.
2. To conduct the study for the development of water transport and infrastructure.
3. To promote and develop water transport system networks.
4. To regulate water transport and the shipping industry.
5. To cooperate and coordinate with other local and international agencies and organizations in the field of water transport and mercantile marine including international agreements and conventions.
6. To carry out other work entrusted law or the Ministry of Transport or the cabinet.

In Lao PDR, the Department of Waterways under the Ministry of Public Works and Transport (MPWT), is responsible for policy, planning, and managing all inland waterways in the country. This includes port and navigation channel management, flooding and river bank protection, and waterways transport.

required covering land titling, health, education, employment, agriculture, tourism and social welfare. A special purpose levy on navigation is recommended as the best way to fund ongoing management and monitoring of the LMDP impacts – potentially contributing to implementation of ESMMP requirements and beyond.

The MRC will also play a critical role in supporting Lao and Thai agencies in conducting additional baseline studies, implementation of operational mitigation measures including the conservation network and ongoing monitoring of impacts – particularly in facilitating cross border coordination.

International donors may also be a source of funds for supporting additional baseline studies, the conservation network and socio-economic and livelihood impact mitigation activities. Civil society and communities can also play a role in supporting management of the conservation network, ongoing monitoring and in implementing socio-economic and livelihood programs.

4.6.2 Institutional arrangements and structures

Institutional arrangements and structures provide clear roles and responsibilities for ensuring mitigation plans are developed and implemented. A summary of potential institutional arrangements that would help mitigate the impact of the navigation plan are outlined in Table 4.6.

Table 4.6. Possible institutional arrangements to help mitigate impacts of the navigation plan

Institutional arrangement	Description
Navigation improvement works Project Management Unit	Government unit set up to oversee the improvement works. The body would be responsible for day-to-day oversight of the project including ensuring best practice approaches are adopted to minimise impacts of the works. The unit would report to the Steering Committee
Navigation improvement works Project Steering Committee	Body consisting of government and local community representatives. The body would be responsible for oversight of the project ensuring best practice approaches are adopted to minimise impacts.
Boat operator oversight unit	Governmental body responsible for overseeing boat operations. Responsible for ensuring boat operators are operating to minimise their impacts – e.g. minimising pollution and boat wakes.
Conservation network management units	Permanent Thai and Lao conservation management units will need to be established for network survey, management planning and ongoing monitoring and management of the proposed conservation sites including rehabilitation and bioengineering works, supported by the MRC. For the five transboundary sites in Zone 1, a joint Thai-Lao sub-unit will also need to be established to jointly manage these sites.
Monitoring program	An institutional setup needs to be put in place for a long-term monitoring program, as well as a mechanism for responding to issues that may be identified through the monitoring.

4.6.3 Policies and regulations

Policies and regulations outline legally required actions, thus limiting the discretion of implementing organisations and provide a legal basis for enforcing certain actions. A summary of possible policies and regulations to mitigate the impact of the navigation plan and Pak Beng hydropower project are outlined in Table 4.7.

Table 4.7. Possible policies and regulations to help mitigate impacts of the navigation plan

Policy or regulation	Description
Dredging, rock clearance and port clearing regulations	Outline clear requirements that dredging, rock clearance and port clearing contractors must follow. For example, the regulations may outline where dredged materials must be placed.
Boat operation regulations	Outline clear requirements for boats operating in the reach. For example, this may include: i) setting a boat size and weight restriction; ii) setting a boat exclusion distance from the bank; and iii) setting boat speed limits

4.6.4 Environmental management plan components

An Environmental Management Plan outlines what actions will be taken to mitigate the environmental impacts of planned works. Table 4.8 outlines key components that should be included in an Environmental Management Plan for the navigation works.

Table 4.8: Key components of Environmental and Social Management and Monitoring Plan to help mitigate impacts of the navigation plan

Policy or regulation	Description
Dredging and rock removal impact mitigation plan	Outlines the procedures to be adopted by contractors undertaking dredging and rock removal works.
Port construction mitigation plan	Outlines the procedures to be adopted by contractors undertaking port dredging and construction works.
Boat transport mitigation plan	Outlines the procedures to be adopted by boat operators to minimise the impacts of heavier and large number of boats.
Biodiversity management plan	Outlining the requirements for ensuring impacts on biodiversity are minimised
Monitoring plan	Monitoring program to evaluate the impact of river navigation improvement works including: • Identifying zones of riverbed and bank erosion • Measuring suspended sediments to understand changes to sediment dynamics • Monitoring water pollution • Monitoring biodiversity • Monitoring socio-economic changes

5 PAK BENG HPP RECOMMENDATIONS

All six of the key strategic recommendations are proposed to address the impacts of Pak Beng HPP. Prior to implementation of the Pak Beng HPP, it will be necessary to conduct further detailed biodiversity and livelihoods baseline studies in the impacted areas to fill gaps in knowledge and ensure all impacts have been identified and are appropriately mitigated. Then, as a key strategy to avoid the most serious impacts of Pak Beng HPP, an alternative project layout and design is proposed (Strategic Recommendation 2). Best practice construction and operation requirements for the alternative layout Pak Beng HPP (Strategic Recommendation 3) aims to further avoid or minimise impacts of the project.

Even though the Pak Beng HPP will transform Zone 2 of this study into a lake or lentic ecosystem there will still be opportunities to identify important biodiversity conservation areas which need to be reconstructed and maintained. The Pak Beng HPP will have a key role in establishing and maintaining the Mekong mainstream conservation area network to remedy or offset biodiversity and livelihoods impacts through habitat restoration and enhancement under Strategic Recommendation 4.

Ongoing monitoring of biophysical and socio-economic conditions and impacts of Pak Beng HPP will ensure that the ongoing management actions are working, adjusted as necessary and any unforeseen impacts are dealt with (Strategic Recommendation 5). Measures to ensure the rights of ethnic minority groups and other vulnerable groups are protected will need to be established prior to implementing Pak Beng HPP (Strategic Recommendation 6). The development and application of each of these strategies is described in detail below.

A summary of measures under strategic recommendations 1, 3 and 5 and how they relate to hydrology and sediment, biodiversity and socio-economics, is provided in Annex 3.

5.1 STRATEGIC RECOMMENDATION 1: ADDITIONAL DETAILED BIODIVERSITY AND LIVELIHOODS BASELINE STUDIES

Hydrology and sediment

As recommended for the LMDP, the establishment of an improved baseline will also be necessary for Pak Beng HPP. Before the works are started it is essential to establish an improved understanding of the baseline condition of hydrology and sediment. In the impact zone (2 and 3) this requires additional discharge monitoring, particularly of tributaries, and a better understanding of current sediment loads and dynamics.

An independent review commissioned by International Rivers of the Pak Beng HPP EIA[4] concluded that the data presented in the reports on hydrology and sediment is largely drawn from studies conducted in 2011 and earlier, with little consideration of more recent information and changes to the Mekong River, including the construction of the Xayaburi and Don Sahong Dams.

In addition to the need for an enhanced baseline, there is also a need to establish a hydrological and sediment monitoring plan for Pak Beng HPP, including monitoring before the dam is built. This is discussed further under Strategic Recommendation 5, below.

[4] https://www.internationalrivers.org/sites/default/files/attached-files/independentexpertreview_pakbengdameia_may2017.pdf

Biodiversity

There is also a need to enhance the ecological baseline for the Pak Beng HPP through additional biodiversity surveys in the reservoir inundation area (Zone 2) and downstream impact zone (extending into Zone 3).

The Pak Beng HPP EIA has also been criticized (by the same International Rivers commissioned review) for not adequately capturing the biological baseline in the project area and, in particular, has inadequate information with which to characterize fish resources at risk, and to assess the expected impact of the Pak Beng Dam on Mekong fish within the project area, as well as upstream and downstream of the dam site. The review recommends an immediate multi-faceted program of environmental monitoring and research studies, before further decisions are made regarding the Pak Beng Dam and particularly before construction is allowed to begin (and the site is disturbed and the environment altered). These studies should include:

- Collection of fish in the project area over all seasons and for at least 2 years, using a variety of active and passive collection techniques. Both resident and migratory fish species should be thoroughly characterized. Monitoring should quantify the numbers and biomass of resident fish and the numbers and seasonality of upstream migrating spawners and downstream drifting fish eggs, larvae, and juveniles.
- Laboratory and field studies should be carried out to evaluate the likelihood that the proposed upstream passage mitigation will be effective and the consequences of turbine passage to downstream-moving fish.
- The project will create a stratified reservoir, with cold and deoxygenated or anoxic layers not accessible to fish. An avoidance approach is required to analyse the expected level and extent of these layers in relation to dam characteristics or operation, the objective being that these anoxic and cold stratified waters do not act as additional barriers for fish having to migrate through the reservoir between adjacent sub-basins. This requires improved knowledge about the 3D connection between tributaries and the reservoir, and about the use of the water column by migratory fishes.
- One of the main local impacts of the dam will be the simplification of the river ecosystem into a single water body. An avoidance approach should include an analysis of the reservoir level management in relation to the creation of artificial wetlands within that reservoir (Meynell 2013, Meynell & Chu Thai Hoanh. 2013). An initial analysis of existing or potential riparian wetlands and definition of a target reservoir level/extent in relation to habitat protection is required.
- Comprehensive bird, amphibian and reptiles surveys in the inundation area should also be undertaken to better assess potential losses of habitat.

Socio-economics

The following additional surveys and studies are recommended:

- Improved modelling of whether aquaculture can stand in for loss of fish production.
- Improved modelling of the expected fish stocks in the reservoir that quantitatively takes into account the loss of migratory species because of the dam wall as well as loss of wild fish production.
- Socio economic surveys should be conducted in the up and downstream communities to determine the reasons for the reported differences in incomes, as well as to disaggregate health

outcomes by village, ethnicity, gender and age groups. This is particularly important because the populations upstream are on average living below the poverty line, and those downstream on average are living just above the poverty line (in 2015 the Lao poverty line was US$0.80, based on a food poverty line of 2100 kcal per day, and a non-food element comprising 30% of consumption.[5] The results of these surveys should be used to structure the interventions that will help communities maintain their livelihoods.

- With regard to sedimentation on river banks in the downstream areas, the design of the dam should be modelled for its impact on downstream flood pulses, as well as for the amount of sedimentation that will be trapped in the reservoir. This modelling will enable estimates to be made of the likely potential impacts in areas such as riverbank gardening. This way the actual impact could be quantified for downstream communities, and alternatives could be offered, such as composting arrangements.
- Collecting population data and livelihoods information at the household level, disaggregated by ethnicity for the 25 upstream villages.
- Detailed population surveys should be completed along the roads to Muang Xay, Muang Ngeun and Pak Tha, to identify populations living along these corridors. This is because there is a very high likelihood that these roads will be upgraded in relation to the dam construction. The easier access along these roads means it is likely that land concessions for logging or plantations will be sought in the area. This could result in poor people in the area losing their traditional lands.

Results of population and livelihood surveys should be used to prioritise titling of land in order to protect the rights of ethnic minority groups and others who have customary title to their farmland. In the areas surveyed, the poorest and most vulnerable communities and households should be prioritised for land titling. Official, permanent, free hold title over the land that people farm will make it more difficult for pressure to be applied on communities to allow their traditional lands to be turned into plantations or logging sites.

In addition, the International Rivers critique of the Pak Beng HPP EIA recommends:

- Meaningful consultation with communities who would be directly and indirectly affected by the Pak Beng Dam, including those in neighboring countries, must be carried out in accordance with international standards before any decision is taken on the project.
- Comprehensive studies of likely social impacts both upstream and downstream of the dam site that quantify the actual number of communities to be affected and are based on current data must be carried out. Studies must include disaggregated baseline data for communities directly and indirectly impacted by the Pak Beng Dam, based on the specific social, economic and cultural context. The report must provide more information regarding how the Pak Beng Dam would disproportionally impact women.
- An independent assessment of the land offered for resettlement, undertaken with the participation of those to be resettled, is also urgently required.
- Further study is needed of impacts of the Pak Beng Dam in Thailand, including adequate baseline data on fisheries and livelihoods of Thai communities.

[5] See http://www.thepovertyline.net/laos/

5.2 STRATEGIC RECOMMENDATION 2: ALTERNATIVE LAYOUT AND DESIGN FOR PAK BENG DAM

The 2018 MRC Initiative for Sustainable Hydropower (ISH) study[6] proposes that the most effective mitigation strategy against the impacts of any of the planned lower Mekong mainstream dams (including Pak Beng HPP) is to establish an alternative layout scheme that reduces the creation of reservoirs. The study indicated that that the incorporation of advanced fish passages and sediment flushing strategies can be beneficial, but significant impacts remain because long reservoirs with almost zero flow velocity are created, which are a barrier to fish migration and trap sediment (MRC 2018). Further, because the mainstream schemes are pure run of river, and limited peaking operation has very little commercial benefit, the stored water has no commercial value (MRC 2018).

Dam development is often undertaken with the sole purpose of hydropower generation, resulting is a single purpose-dam. Yet experience from Xayaburi or Lower Sesan 2 Dams shows that additional perspectives can be built in, and are much more effective and less costly when initiated at an early stage, without going through heated public opposition.

Two fully gated low head barrages could replace instead of the current single dam design for Pak Beng HPP and would capture a similar amount of energy if the cumulative head was the same (MRC, 2018). These structures would impound smaller volumes of water and keep the river closer to its natural regime (MRC 2018). At critical times of year (or on a regular basis such as weekends) the gates could be opened and the river returned to entirely natural conditions to allow sediment transport and fish migration in either direction (MRC 2018).

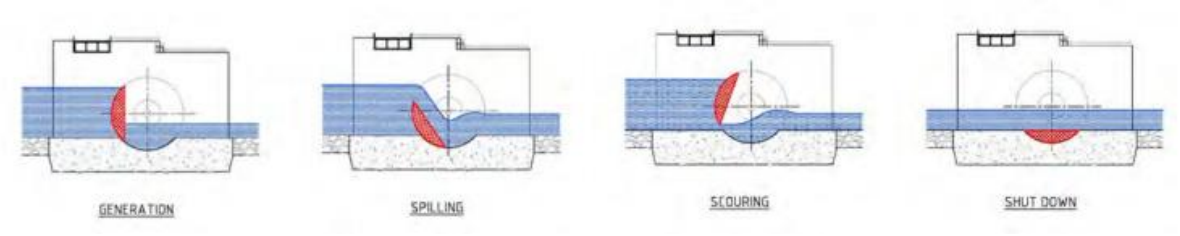
The lower head projects would provide the following environmental advantages (MRC, 2018):

- Substantial reduction in impounded water volume, potentially resulting in improved water quality, reduced temperature change and lower sediment retention;
- Lower head dams, making fish passage in either direction more feasible and survivable;
- Lower gross heads suitable for fully gated barrages;
- Lower gross heads suitable for horizontal axis low speed bulb turbines;
- Creation of impounded depths much closer to natural flood surcharge levels; and
- Making it feasible to draw down reservoirs to natural river conditions during flood periods without large changes in water level and corresponding ecological stress.

The adoption of rising sector gates would also permit the gates to be fully lowered so that natural river conditions are restored. This condition would permit natural fish migration in either direction, and facilitate natural sediment transport. Figure 5.1 shows the operating positions for these gates.

[6] http://www.mrcmekong.org/about-mrc/completion-of-strategic-cycle-2011-2015/initiative-on-sustainable-hydropower/guidelines-for-hydropower-environmental-impact-mitigation-and-risk-management-in-the-lower-mekong-mainstream-and-tributaries-ish0306/

Figure 5.1: Rising Sector Gate – Operating Positions (from MRC, 2018)



This rising sector gate design is operated as follows (MRC, 2018):

- All river flow is diverted through the turbines when the gates are in the fully raised position. This configuration would be adopted throughout the dry season when the river discharge is lower than the capacity of the generating plant.
- When the river discharge exceeds the generating plant capacity, spilling will commence. This will typically occur for at least 4 months each year. Spill flows will pass over the crest of the gates and down the downstream face. This configuration avoids rapid pressure gradients and fish can pass without injury. The correct discharge can be achieved by adjusting the angle of the gate. The head pond level can be permitted to rise, thereby maintaining the generating head.
- Local accumulation of sediment can scoured by rotating the gate in the opposite direction to release an undershot flow. Continued rotation in this direction will raise the gate out of the water for maintenance.
- At critical times of the year, the generating plant can be shut down and the gates lowered so that the river is returned to entirely natural conditions. This configuration will facilitate unimpeded fish migration in either direction and sediment transport in a downstream direction.

Cost comparison

In order to assess the feasibility of the alternative layout, the MRC ISH study carried out an examination into the implications of replacing a typical 30 m gross head mainstream project, with two 15 m gross head projects. The overall river reach of the two lower head projects would be the same as the full height scheme, as such, the extent of river reach concessions would remain unchanged (MRC, 2018).

To compare this baseline cost with the two 15 m gross head schemes, the percentage costs of the equivalent main components were calculated and are also shown in Table 5.1 below. The cost of the single 30 m gross head scheme was assumed to be the baseline cost of 100%.

Table 5.1: Cost comparison between a 30m high single scheme and two 15m high schemes (from MRC, 2018)

Cost Comparison – Alternative Schemes			
Scheme Component	**30 m Gross Head Scheme**	**15 m Gross Head Scheme**	**2 No. 15 m Gross Head Schemes**
Powerhouse Structure	26.9%	13.7%	27.5%
Spillway structure	7.7%	4.3%	8.6%
Central Island	8.9%	2.2%	4.3%
River Diversion	8.2%	4.4%	8.8%
Navigation Lock	2.1%	1.6%	3.2%
Fish Pass Structure	4.8%	4.1%	8.2%
Switchyard(s)	0.2%	0.3%	0.6%
Transmission line(s)	0.6%	0.4%	0.8%
Access Roads	0.2%	0.2%	0.3%
Preliminaries	10.2%	8.5%	17.0%
Indirect Costs	30.2%	17.2%	34.4%
Total	**100%**	**56.9%**	**113.7%**

The comparison between a typical full height mainstream project and the equivalent two half height schemes indicates that the combined construction cost of the two half height schemes will be approximately 15% greater. Conversely, the project finance cost for the two half height schemes is lower because energy and revenue is available approximately four years earlier (MRC, 2018). The overall implication is that the cost of energy from the half height schemes is approximately the same, and possibly lower, than the single full height scheme - this conclusion is based on river discharges, foundation conditions and cross sections being typical of the Lower Cascade reach of the Mekong (MRC, 2018).

5.3 STRATEGIC RECOMMENDATION 3: BEST PRACTICE DESIGN, CONSTRUCTION AND OPERATION REQUIREMENTS FOR THE PAK BENG HPP

This recommendation relates to the current Pak Beng HPP design and not the proposed alternate design outlined in Strategic Recommendation 2, above, which, if implemented, would avoid the need for many of the following operational mitigation recommendations.

Hydrology and sediment

The project will have an impact on sediment and nutrient retention basin-wide. In the long term, this is going to be, with contribution to downstream channel simplification and delta subsidence, the major environmental impact of the project (Baran et al. 2015, Nguyen et al. 2015). This calls for a specific analysis of the ways to manage sediment and nutrients, so that a minimal amount is retained by the dam –for the benefit of both downstream ecosystems and the dam operator. Experience shows that sediment management retrofitting is almost impossible once the dam is built, so an avoidance approach is essential at an early stage. Such approach should include sediment retention mitigation options (i.e. a physical component), but also, for the first time, an analysis of *nutrient* retention management, i.e. a chemical approach to mitigation.

Zone 2 – the reservoir

The highest risk impacts in Zone 2 are mostly related to the flooding of the reservoir area, decreasing flow velocities in the reservoir area, reservoir sedimentation and changes in water chemistry. The blocking of flow and sediment is an inherent part of building a reservoir, so can't be completely mitigated. A key element of mitigating impacts in this reach is therefore to ensure the reservoir size and dam wall height are minimized to the extent possible.

In addition to limiting the size of the reservoir, its impacts can be mitigated by ensuring that it is operated as a proper run-of-river dam. This ensures that velocities within the reservoir stay relatively high and residence times are low, which will limit sedimentation and changes in water chemistry. Key elements of best practice run-of-river design and operation that are important for this reach include:

- Minimize reservoir size and dam wall height
- Ensure that outflows approximate inflows at an hourly or at least daily scale

Reservoir sedimentation can affect both the productivity of the reservoir, habitat within the reservoir and downstream sediment dynamics. The reservoir must be designed with a sediment flushing mechanism to limit the volume of sediment trapped in the reservoir. Best practice sediment management:

- Is designed to ensure sediment of all sizes are passed downstream and sediment is passed downstream at a rate approximating the natural state (i.e. not just a large volume of sediment released at irregular intervals)
- Ensures the dam height and storage area are minimized to maximise flow velocities upstream of the dam and keep fine sediment suspended
- Includes low level sediment sluices, gates or diversion channels to transport sediment through the dam
- Includes low level outlets to enable sediment flushing to remove deposited sediment (generally sand and gravel)
- Minimises water levels during the flood season to ensure the natural high proportion of sediment transport through the reservoir during this time is maintained

The 2018 MRC ISH study estimated that sediment flushing at Pak Beng HPP can mobilise about 0.07-0.47 Mt of sediment per flushing event, which is about 0.7-5% of the total annual sediment load at the dam site (9.6 Mt/yr) prior to the dam.

Watershed management can also help to minimise sedimentation by reducing sediments produced by road construction, mining, agriculture and other land uses in the upper catchments. Three main tributaries enter the river in this reach, the Nam Tha, Nam Ngao and Nam Mae Ing. The Nam Tha and Ngao were identified as likely to be carrying significant amounts of sediment to the mainstream as they have medium sized catchments dominated by agriculture and sediment deposits visible in the lower tributary. Efforts to minimize catchment sediment mobilization should therefore be concentrated on these tributary catchments.

Changes in water chemistry also occur due to the decay of biomass in newly flooded areas. In the case of Pak Beng this may not be a major issue as the reservoir will cause permanent flooding of only approximately 11.0 km^2 of riverbank that is currently only sometimes flooded, and a large part of this

area will be bedrock. Despite this likely small impact compared to larger reservoirs, selective forest clearing within the impoundment area could be completed before reservoir filling to mitigate the potential for poor water quality resulting from decay of flooded biomass.

In addition to the above measures to minimize the possibility and impact of decreasing velocities, sediment deposits and changes in water chemistry, it will be important that a monitoring program is implemented within the reservoir. The monitoring program needs to be set up to track and identify changes in velocities and discharge throughout the reservoir, sedimentation rates and water quality parameters such as DO and temperature. An appropriate monitoring program will enable early identification of issues which can then be addressed.

Pak Beng Dam downstream to Luang Prabang (Zone 3)

The highest risk impacts in Zone 3 are mostly related to the construction of the upstream Pak Beng HPP reservoir. These impacts include an altered flow regime due to operation of Pak Beng HPP dam; reduced water quality of water released from the reservoir; changes in the sediment size distribution of the channel bed due to changing velocities; and reduced sediment load and increased water level variability causing bed and bank erosion. In addition, the dredging of bed and banks for navigation improvements works is expected to cause bed and bank erosion downstream.

Most of the downstream impacts of the Pak Beng HPP dam can be mitigated by ensuring the operation of the dam is undertaken as a run-of-river. A properly design and operated run-of-river hydropower dam minimizes the impact on the natural discharge regime and sediment dynamics.

Maintaining the natural flow regime means ensuring that the outflow approximates inflow at an hourly or daily scale. It is important that all the components of a flow regime are maintained including low flows, high flows and flow variability. For the Mekong it is essential that the flood pulse hydrology is maintained. A natural flow cycle maintains the range of downstream habitats that are dependent on natural cycles of sediment erosion, transport and deposition; and can also be important in its own right, for example to trigger fish migration and enabling fish to pass natural barriers.

Natural migration of sediments downstream and erosion and deposition cycles are essential for the creation and maintenance of natural river habitats, as well as the carrying of nutrients downstream. Therefore, a run-of-river reservoir needs to be designed to avoid disruption of sediment transport. This can be achieved by: i) ensuring that the velocities in the reservoir are not too low, ii) ensuring the design of the dam structure allows for sediments to move over it during high flows, iii) operating valves or other mechanisms to pass sediment through the dam wall; and iii) if required, sedimentation upstream of the dam wall can be excavated and transported immediately downstream of the dam to re-introduce to the river.

The dam design also needs to ensure that it does not cause scour and erosion immediately downstream by designing the dam structures to avoid concentrating high flows onto bed and bank areas that may be vulnerable to erosion.

Biodiversity

Impacts during the construction phase on biodiversity will stem from: water quality changes, blasting and increased human population. High turbidity in the water caused by construction activities will affect aquatic biodiversity both at construction site and downstream, in particular their breathing and reproduction. Blasting will cause mortality and noise disruption to aquatic organisms. Both these

aspects need to be managed including runoff control measures and timing and location of blasting to avoid sensitive receptors. The behaviour of construction workers also need to be controlled to limit hunting or trade in wildlife products.

The influence of various mitigation measures to reduce the impacts of the Pak Beng HPP operation on habitats and ecological functions and aquatic biodiversity and biomass from alterations to abiotic parameters is shown below in Figure 5.2.

Figure 5.2: The influence of various operational mitigation measures from first to second and third order impacts of Pak Beng HPP – dashed lines indicate a partial effect (from MRC 2018)

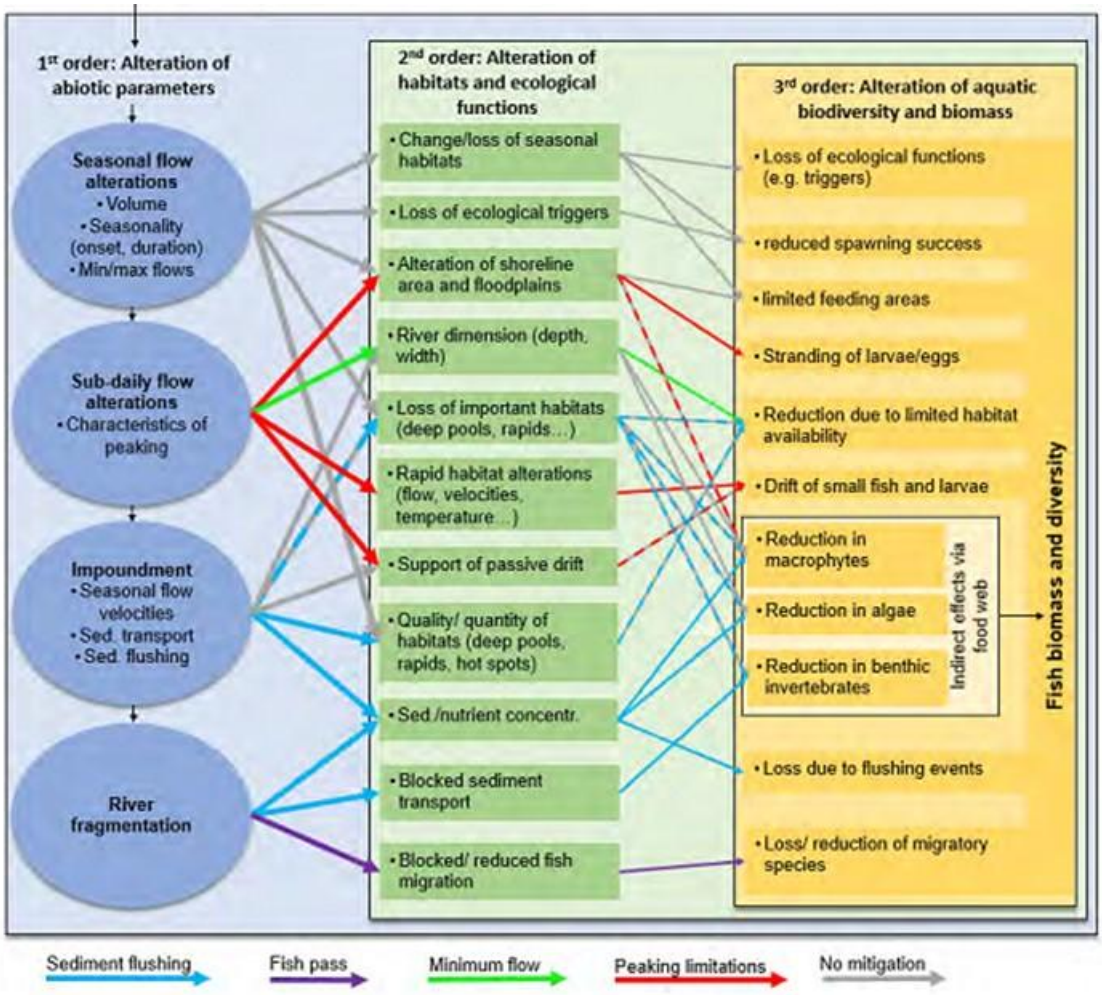


Figure 5.2 highlights the potential for sediment flushing, fish pass, minimum flow and peaking limitations measures for reducing impacts on biodiversity. However, it also highlights the limitations, with many alterations going unmitigated or partially mitigated, particularly those stemming from seasonal flow alterations and sub-daily flow alterations. The potential for some of these mitigation measures to reduce impacts to biodiversity is discussed further below.

Fish

Flow is the most important trigger for fish to migrate or spawn and the high flows of the rainy season make a vast floodplain area for nursing and feeding. Changes to the natural flow of the river, and any hydrological regime e.g. low floods, shorter floods, or late floods, will decrease fish production (Baran and Myschowoda 2009). Therefore, mitigation efforts for fish should focus on maintenance of

environmental flows i.e. the quantity, timing, and quality of water flows that are required for sustaining river ecosystems (see Dyson et al., 2003), within the impacted areas both upstream and downstream.

Blockage of fish migration is one of the most critical issues for dam building in the Mekong. Mitigation through fish passage must be seriously considered in the design of all Mekong dams. The bypass fishway is the best option because it allows the fish to move naturally, compared with other fish pass designs in large tropical rivers (Schmutz and Mielach, 2015). However, prior to selection and design of the fish pass, knowledge on fish migration behavior of fish in the impacted area must be acquired. This will inform considerations such as the appropriate flow rate to induce the fish to enter the bypass. The current design of Pak Beng HPP includes a fish bypass, however, it does not appear that adequate study of fish migration behaviour has been undertaken to inform the detailed design.

The extirpation of some lotic fish species that cannot acclimate to the created lentic environment upstream is a key impact of the Pak Beng HPP reservoir. Mitigation by stocking of adults or fries of commercial species, which are well adapted to reservoirs, is recommended. This also requires the establishment of the fish hatcheries by the Pak Beng hydropower development company.

Connection to the nearby tributaries both in the upstream (Nam Beng, Nam Tha and Nam Ing) as well as the downstream (Nam Ou and Nam Xuang) of the Pak Beng Dam should be kept clear with no obstacles to fish passage. These tributaries that connect to the mainstream dam can act as important habitat for any fish species that cannot adapt to the new environment (Jutagate et al., 2011). An ecological trap within the reservoir can occur when fish move upstream of the dam but spawning habitats are unavailable due to blockages or other development constraints (Agostinho et al., 2007). Mitigation through the creation of spawning and rearing habitats is also an option but design and usefulness depends on the species of concern.

Deep pools: downstream of dams alluvial material may be scoured from pools and make them deeper, due to released water from dam. This would make the pool no longer appropriate dry season refuge because of the changes in depth, velocity and turbulence (Halls et al, 2013). Manipulation of the mass and flow rate of the released water from the dam to the appropriate level is recommended. In addition, the establishment of conservation areas including deep pools is also recognized as a potentially effective management measure to conserve fish integrity (Baird, 2006)

Mitigation on downstream fish migration, which mostly concerns larval and juvenile fishes should focus on the development of appropriate rakers and screens (i.e. to prevent migration through turbines), optimised spill flows, and fish friendly turbines (Schmutz and Mielach, 2015).

Birds

A potential Pak Beng HPP operational strategy to reduce impacts on bird populations (and other biodiversity) is to minimise the reduction in predictable seasonal variation in water levels in and downstream of the dam. In addition to reduce variation in any change in seasonal timing of these changes and minimise the number and extent of dry-season temporary surges in water level.

However, diverging from the current plans for water-level management may be extremely costly for the reservoir, and perhaps difficult even for the downstream stretch. It may be impossible materially to reduce the projected changes in water levels without compromising the viability of the Pak Beng HPP. It might be considerably cheaper to achieve the same end result, at the level of the entire project stretch's avifauna, to accept major loss within the reservoir and not to seek to mitigate them there or

immediately downstream, but seriously to deploy 'no go' safe havens above and below the zones of major impact to rebuild the already beleaguered populations there (but with the caveat that these are only worthwhile if activities upstream of the project stretch are not affecting water levels so seriously that the project stretch is already rendered of very low value for ground-nesters).

Socio-economics

The following construction and operation measures are proposed to reduce the socio-economic impacts of Pak Beng HPP:

- The towns where workers are likely to live, eat and otherwise spend their money should be clearly identified, and local authorities should be supported to plan for the changes in these towns ahead of time. These plans should include areas where new residential/accommodation buildings can be constructed, as well as ensuring that town WASH services will be able to cope with the extra people. If necessary, towns should plan to upgrade their WASH systems.
- The local government/administration in Pak Beng and Pak Ngeui towns should be supported to plan for the influx of 3,000 – 4,000 workers. This will be a massive change for these small towns. There will be a need for accommodation, water and sanitation services, recreation areas, shops for workers to buy meals and/or food, electricity for additional housing. It is unlikely that the town currently has the planning capacity to map out a desirable future.
- Planning for health complications such as STDs, vector and food borne illnesses. The current medical facilities in Pak Beng and Pak Ngeui towns will not be sufficient for the expanded population. Even if the project will provide medical services to workers, the influx of workers will have health ramifications for the resident population as well, such as growth in STDs as well as vector-, water- and food-borne diseases.
- Provide support for those in the town who would like to use the opportunity to establish small businesses. This support could be in the form of training in business skills or loans/grants for those displaying entrepreneurial aptitude such as a desire to provide accommodation services or eateries.
- Mechanisms to fully address social impacts need to be devised, including for those communities to be relocated and those who will experience disruptions to their river-based livelihoods upstream and downstream due to the dam.

5.4 STRATEGIC RECOMMENDATION 4: ESTABLISH A TRANSBOUNDARY MEKONG MAINSTREAM CONSERVATION AREA NETWORK

The implementation of the proposed conservation area network will be affected if Pak Beng HPP goes ahead. On the one hand, Pak Beng HPP will likely completely inundate site 6 and 7 within the reservoir in Zone 2. It will also likely physically destroy most of Site 8, which is located at the dam site itself. Site 5, at the top of the reservoir near the border with Thailand will likely be partially inundated by a slight rise in water level and increased sedimentation. Therefore, site 6, 7 and 8 will be need to be excluded from the network with implementation of Pak Beng HPP (however other biodiversity conservation and enhancement sites can be established in the reservoir). Site 5 could potentially remain within the network pending further assessment of its biodiversity (as outlined in section 4.3) and ongoing conservation value considering the impact of Pak Beng HPP.

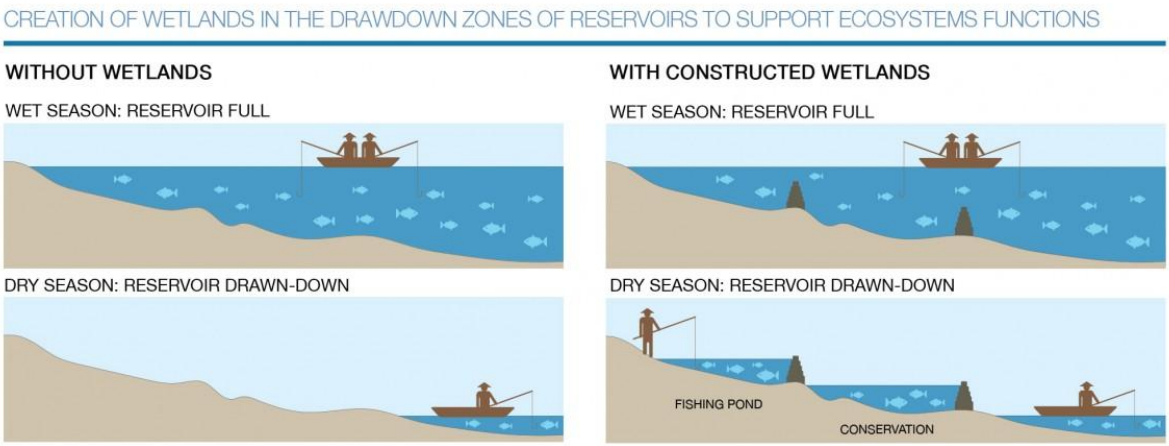
In addition, added management considerations will be required for sites downstream of Pak Beng HPP in Zone 3 – both in terms of Pak Beng HPP operation (water and sediment releases) and the sites – mitigating against and monitoring unavoidable Pak Beng HPP impacts on flow and sediment. It will also mean that conservation and enhancement of sites in Zone 1 and Zone 3 becomes even more important and funding for doing managing these sites and others in the network can be provided by the Pak Beng HPP developer. It is recommended that the potential for Pak Beng HPP support the proposed conservation network is explored, including through:

(i) paying for the conservation management of other sites in the network as biodiversity offsets for the loss of sites 6, 7 and 8; and

(ii) establishing biodiversity enhancement sites[7] within the reservoir and tributaries as part of mitigating environmental and social impacts, which can then become part of the conservation network (including management and enhancement of Site 5).

The establishment of biodiversity enhancement sites within the reservoir could be in the form of constructed wetlands (Figure 5.3). Constructing wetlands within reservoirs, which are primarily designed for hydropower production, can play a significant role in increasing biodiversity and fish productivity, thereby contributing to the livelihoods of local communities.

Figure 5.3: Schematic describing the operation of constructed wetlands within a reservoir (from Meynell and McCartney, 2014)



Source: Meynell and McCartney 2014

There is also some potential for establishing a PES scheme for the Pak Beng HPP developer to pay for the conservation network. However it is unlikely that the conservations sites would provide significant ecosystem services to the dam that the operator would be willing to pay for - such as sediment retention or maintenance of water supply. The sites are likely too small to provide sufficient services of this nature in order to set up a viable PES scheme. Generally, the provision of types of ecosystem services to dam operators requires larger-scale land management approaches.

[7] For example, constructing wetlands within reservoirs, which are primarily designed for hydropower production, can play a significant role in increasing biodiversity and fish productivity, thereby contributing to the livelihoods of local communities.

5.5 STRATEGIC RECOMMENDATION 5: ONGOING MONITORING OF BIOPHYSICAL AND SOCIO-ECONOMIC CONDITIONS AND IMPACTS OF THE PAK BENG HPP

Hydrology and sediment

A hydrology and sediment monitoring program should be implemented below the reservoir to ensure discharges are in-line with implemented operational mitigation measures. The monitoring program should cover from immediately downstream of the dam wall to a minimum 100km downstream. The program should monitor discharge, water quality and sediment loads as well as identify areas of bank erosion.

Biodiversity

To ensure the implemented Pak Beng HPP mitigation strategies for biodiversity are working and to adjust them over time in response to changing conditions, monitoring of biodiversity is necessary – within the reservoir and downstream. This will include short term monitoring of construction phase impacts and longer term monitoring of operation phase impacts. During construction, monitoring of biodiversity around the dam site will need to be undertaken to ensure the mitigation measures are working. This should include: a monitoring program on deep pool fish diversity and abundance; monitoring of macroinvertebrate populations in the immediate downstream and upstream areas; water quality monitoring; and monitoring of identified critical habitats for threatened or endangered species.

A monitoring program on water quality must be set and the water quality must be maintained at the level which adequate for aquatic resources and the aquatic community as a whole. Long-term water-quality concerns include eutrophication and sedimentation in the reservoirs, and elevated concentrations of nutrients (nitrogen and phosphorus) being transported from the upstream to the reservoir, as well as the water-borne bacteria and diseases (Koterba et al. 2011)

A monitoring program on fish diversity and abundance of rapid resident species such as *Gerra* spp. as well as some demersal species such as *Yasuhikotakia modesta* both within the mainstream and nearby tributaries of the Pak Beng HPP is recommended. These species are generally sedentary and require very well oxygenated water, are of small size and are equipped with suckers or spines to enable them to grip rocks and other submersed objects (Welcome et al., 2006). In addition, a monitoring program to ensure deep pools downstream of the dam are maintaining their ecological function is recommended. Many environmental scientists consider the health of deep pools to be indicative of the health of the Mekong River and its tributaries, in particular for fish and the fisheries sector (Viravong et al., 2006).

Socio-economics

Continuous monitoring and response to impacts: In addition to monitoring the bio-physical impacts, there should be continuous monitoring of changes in the socio-economic conditions with reference to the established baseline and broader trends. This will allow any unanticipated socio-economic impacts and consequences to be identified quickly, and any necessary plans developed to mitigate or otherwise deal with them.

An independent monitoring mechanism is needed to hold company or government officials accountable if promised compensation and resettlement benefits do not materialize or if project impacts are worse than envisioned in project documents and agreements.

5.6 STRATEGIC RECOMMENDATION 6: ENSURE THAT THE RIGHTS OF ETHNIC MINORITY AND OTHER VULNERABLE GROUPS ARE PRIORITISED FOR IMPLEMENTATION OF THE PAK BENG HPP

Better consideration of the impacts on downstream communities is needed, particularly how access to the reservoir will be facilitated. This will require consideration of how fisher people will get to the reservoir, as well as a methodology for ensuring that they have rights of access to fishing grounds.

There should be a much stronger consideration of the indirect impacts that are likely to be associated with the project. The indirect impacts have the potential to be larger and much more widespread than many of the direct impacts related to the dam. For example, there is already at least one foreign company in the area with a plantation concession. Improved roads, and shipping lanes is likely to attract more companies seeking land concessions, and with this there is likely to be pressure applied to rural communities to relinquish their rights to their customary lands (see e.g. McAllister 2015).

Ensuring that poor and rural communities have been granted official permanent title to their lands, as per a new clause in the Land Law[8] (GoL, 2003) prior to the upgrading of roads will provide additional protection to these vulnerable people, so that they can maintain their livelihoods from their own perspective.

5.7 MANAGEMENT ARRANGEMENTS FOR IMPLEMENTING THE PAK BENG HPP STRATEGIC RECOMMENDATIONS

5.7.1 Roles and responsibilities

There are several key stakeholders involved or impacted in the navigation improvements works and dam construction. Key roles and responsibilities in mitigating the impacts include:

- **Pak Beng Dam funding agency**: Ensure that a full Environmental Impact Statement and Environmental Management Plan is developed and that the project is designed to mitigate impacts including the measures outlined in this report.
- **Pak Beng contractors:** Undertake the improvement works in line with relevant regulations and the components of the Environmental Management Plan.
- **Lao PDR and Thai Governments:** Ensure that relevant regulations are in place and oversee the works and dam operation to ensure they are in line with relevant regulations.
- **Local communities and civil society:** Provide informal review and monitoring of projects works to ensure they are following best practice approaches to minimising impacts on social and environmental values.
- **Mekong River Commission:** Provide an avenue for discussion and debate on the planned works and ongoing operations, particularly related to transboundary issues.

The Pak Beng HPP developer is primarily responsible (under Lao PDR Government requirements) for adequately assessing and addressing impacts of the dam. The developer will need to develop an ESIA and ESMMP for the dam that adequately characterize the baseline situation, assess impacts and define required management and monitoring plans – including implementation of these plans. The current

[8] https://www.namtheun2.com/images/Document_for_website/Social%20Development%20Plan%20(SDP)/Volume%201/Appendix%20C%202%20The%20Land%20Law%20(Amendment,%2021%20Oct%2003).pdf

EIA and SIA are inadequate with several deficiencies on both the environmental and social baselines, impacts and mitigation strategies (actions to address these are included in Annex 3). Transboundary impacts will also need to be properly considered and dealt with, covered under the MRC transboundary EIA guidelines. The Lao PDR Government plays a central role in ensuring the Pak Beng HPP developer meets its environmental and social obligations and supporting implementation and monitoring of management plans. The MRC is also providing technical and administrative support through the PNPCA process and will also indirectly contribute to monitoring of the dam and its environmental impacts through its ongoing monitoring programs. Civil provides a critical role in independently assessing impacts (such as the International Rivers critique of the current Pak Beng HPP EIA and SIA) and contributing to ongoing monitoring of impacts and working with communities to restore or improve livelihoods (however they should not be relied on for this as it should be covered by the developer's social and environmental management programs.

5.7.2 Institutional arrangements and structures

Institutional arrangements and structures provide clear roles and responsibilities for ensuring mitigation plans are developed and implemented. A summary of potential institutional arrangements that would help mitigate the impact of the Pak Beng hydropower project are outlined in Table 5.2

Table 5.2: Possible institutional arrangements to help mitigate impacts of the Pak Beng hydropower project

Institutional arrangement	Description
Pak Beng Dam construction Project Management Unit	Government unit set up to oversee dam development. The body would be responsible for day-to-day oversight of the project including ensuring best practice approaches are adopted to minimise impacts of the construction. The unit would report to the Steering Committee
Pak Beng Dam construction Steering Committee	Body consisting of government and community representatives. The body would oversee construction of the dam and ensure that measures are taken to minimise impacts. Would oversee the work of the Project Management Unit.
Pak Beng Dam operation coordination body	Body consisting of dam operators, as well as government and community representatives. The body would oversee operation of the dam including releases, sediment flushing and monitoring of impacts of the dam. This body would help make sure that dam operations are transparent and adhere to best practice environmental and social impact mitigation measures.

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7 ANNEX 1: SUMMARY OF MEASURES UNDER STRATEGIC RECOMMENDATIONS 1, 3 AND 5 FOR THE LMDP

Table 7.1: LMDP mitigation measures under strategic recommendations 1, 3 and 5 covering one or more themes

SR	Hydrology and Sediment	Biodiversity	Socio-economics
Enhanced Baseline (SR 1)	Additional discharge monitoring, particularly of tributaries	Comprehensive baseline survey of the pre-project avifauna and its threats, which serves as the basis to a long-term monitoring programme	Field surveys in the communities proximate to the dangerous areas to assess their ethnic compositions, to quantify areas of riparian farmland that may be at risk of erosion, to assess the financial and overall well-being of community members, and to determine community needs and aspirations with regard to improving or maintaining their livelihoods
	Monitoring of concentrations and grain size of suspended sediment concentrations for several years and across all seasons	Detailed field survey of amphibians and reptiles in forested portions of the mainstream Mekong and its tributaries	Modelling of urban growth in towns where ports will be developed
	Bed material grain size should be documented by sampling at several locations along the river at low flow	Further local fish surveys, to assess in more detail i) knowledge of fish species swimming capabilities and flow and sediment range requirements; ii) migratory patterns among the species listed; iii) requirements of endemic or endangered species for specific aquatic habitats; iv) fishers' knowledge about the ecological role of each deep pool; v) identification of the sites where blasting of rapids would create channelization and new flow conditions not passable by fish anymore	Survey of vessels using the river on how waste is currently disposed of (human waste, food waste, rubbish)
	A full geomorphology study - include repeat cross-section surveys, temporal analysis of satellite imagery and field studies		Socio-economic field surveys of those who harvest and sell kai (including an assessment of the total value of kai traded compared to agricultural crops and other produce, and the length of the river in which it grows)
			Modelling of additional urban run-off from port town expansion
	A prioritization of the sites to be blasted, based on a multiple-objective analysis		
Best practice C&O (SR 3)	The volume of sand and silt removed is minimised; the area of affected riverbank and riverbed is minimised; dredged sand and silt is placed in a location that minimises the potential downstream impacts; sand and silt mobilised during the dredging process is contained into a small area		
	Setting a limit to the size and weight of boats on the river; ensuring that boat traffic maintains a certain distance from the river banks where possible; setting speed limits for boats		
		Limit blasting in scale and to dry season to minimise underwater noise and shock wave impacts	
		Restrict discharge of wastes such as fuel and lubricants into the river during dredging operations	

SR	Hydrology and Sediment	Biodiversity	Socio-economics
		Halt dredging during the fish spawning season	
		Provide facilities for collection and disposal of waste oil and any other wastes such as garbage	
Ongoing Monitoring (SR 5)	Monitoring of discharge, sediment and erosion	Monitoring of biodiversity around the blasting and dredging sites and ports	
		Monitoring program on deep pool fish diversity and abundance	
		Water quality monitoring	
		Monitoring of macroinvertebrate populations	
		Monitoring of identified critical habitats for threatened or endangered species from detailed ESIAs	
		Increase wildlife and forestry enforcement capacity at new port developments	
			Continuous monitoring of changes in the socio-economic conditions with reference to the established baseline and broader trends

8 ANNEX 2: MAPS AND DESCRIPTIONS OF THE SELECTED CONSERVATION SITES

Zone 1 – 98 km (5 sites)

Zone 1 is transboundary, where the Mekong river thalweg is the border between Lao PDR and Thailand and contains five proposed sites for conservation management. Its topography is considerably flatter with a generally wider channel and broader floodplains than the other two zones. Deep and very deep pools tend to be shorter than in the other two zones, occurring where the river cuts through mountain ridges bounding extensive floodplain areas.

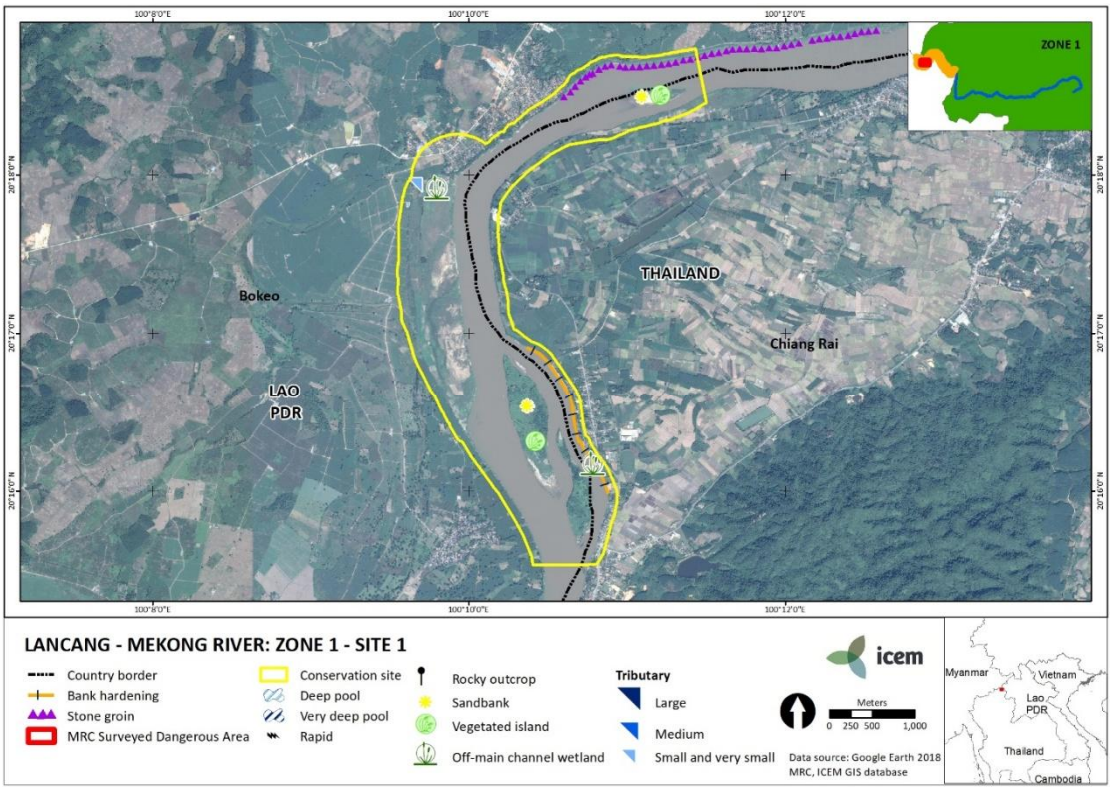
Site 1 – 7.3 km long

Site 1 is representative of Zone 1 biophysical features and habitat types including a wide channel and broad floodplain with a combination of vegetated islands and wetlands. These attributes are potentially important for breeding and feeding of birds and fish. The key features of Site 1 are:

- Sand and silt substrate with a relatively broad channel and floodplains;
- Sedimentary geology (gravel, sand, clay, silt and clay)[9];
- Three large vegetated islands; and
- Two wetlands – one on-channel and one off-channel. The left bank off-channel wetland is unique in the study area and has been identified as an important wetland.

Key threats to Site 1 include urban development, agriculture and river bank hardening (Thai side).

Figure 8.1: Proposed Mekong Conservation Site 1



[9] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

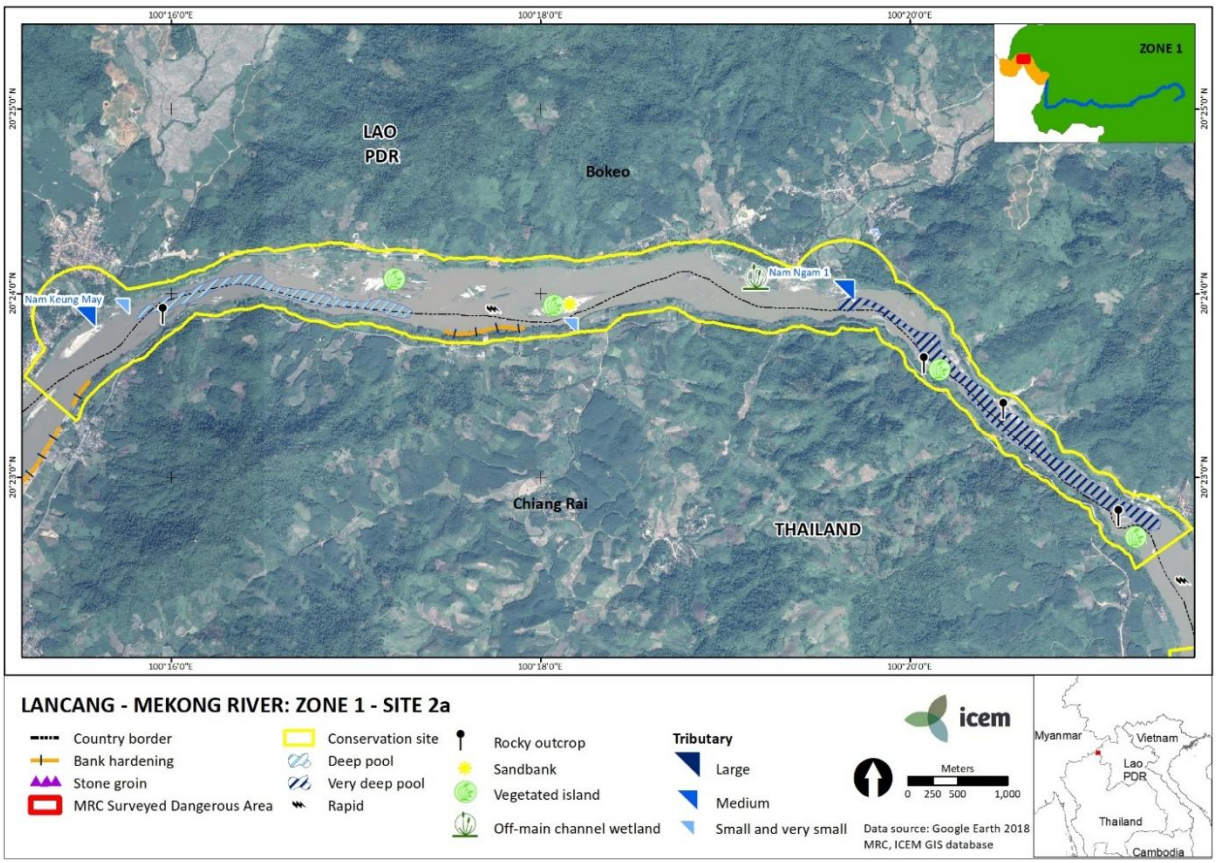
Site 2a – 29 km long

Site 2a is about 13km downstream of Site 1 and contains several important habitat features including deep pools, vegetated islands, tributaries, rocky outcrop, a rapid and a wetland. Key features of Site 2a are:

- Sand, silt and rock substrate with slightly narrowing channel and floodplains with rapids with some rocky outcrop;
- Combination of sedimentary (gravel, sand, clay, silt and clay) and igneous (granodiorite to monzogranite) geology[10];
- A deep pool and a very deep pool;
- A mosaic of vegetated islands and rocky outcrop;
- A river bank wetland;
- One small and two medium tributaries coming in on the Lao PDR side (including the Nam Keung May and the Nam Ngam 1)

Key threats to Site 2a include: urban development, agriculture and forestry, mining and river bank hardening (Thai side).

Figure 8.2: Proposed Mekong Conservation Site 2a



[10] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

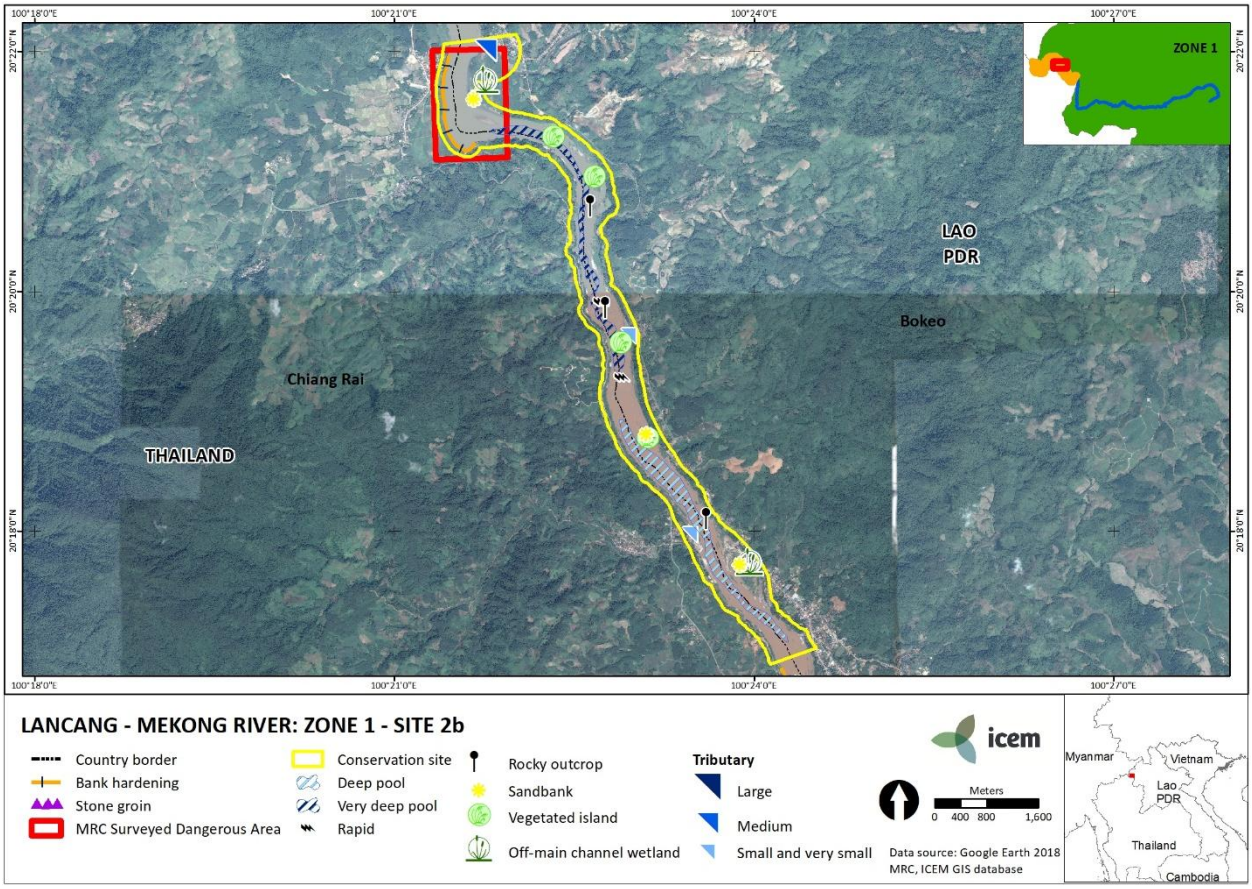
Site 2b – 11.4 km long

Site 2b begins about 1 km downstream of Site 2a and exhibits similar features within a slightly narrowing channel including deep pools, vegetated islands, rocky outcrop and rapids but also exhibiting increased sandbank formation and the first MRC surveyed dangerous area in the study stretch. Key features of the Site 2b include:

- Sand, silt and rock substrate with slightly narrowing channel and floodplains with greater sandbank formation and more numerous rocky outcrop;
- Combination of sedimentary/ volcanic (mudrock, sandstone, limestone, volcanic rocks) and igneous (granodiorite to monzogranite) geology[11];
- One MRC surveyd dangerous area;
- A very deep pool and a deep pool;
- A mosaic of rocky and sandy vegetated islands;
- Two wetlands; and
- A medium (Nam Ngam 2) and a small tributary entering on the Lao PDR side.

Key threats to Site 2b include urban development, agriculture and river bank hardening (Thai side).

Figure 8.3: Proposed Mekong Conservation Site 2b



[11] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

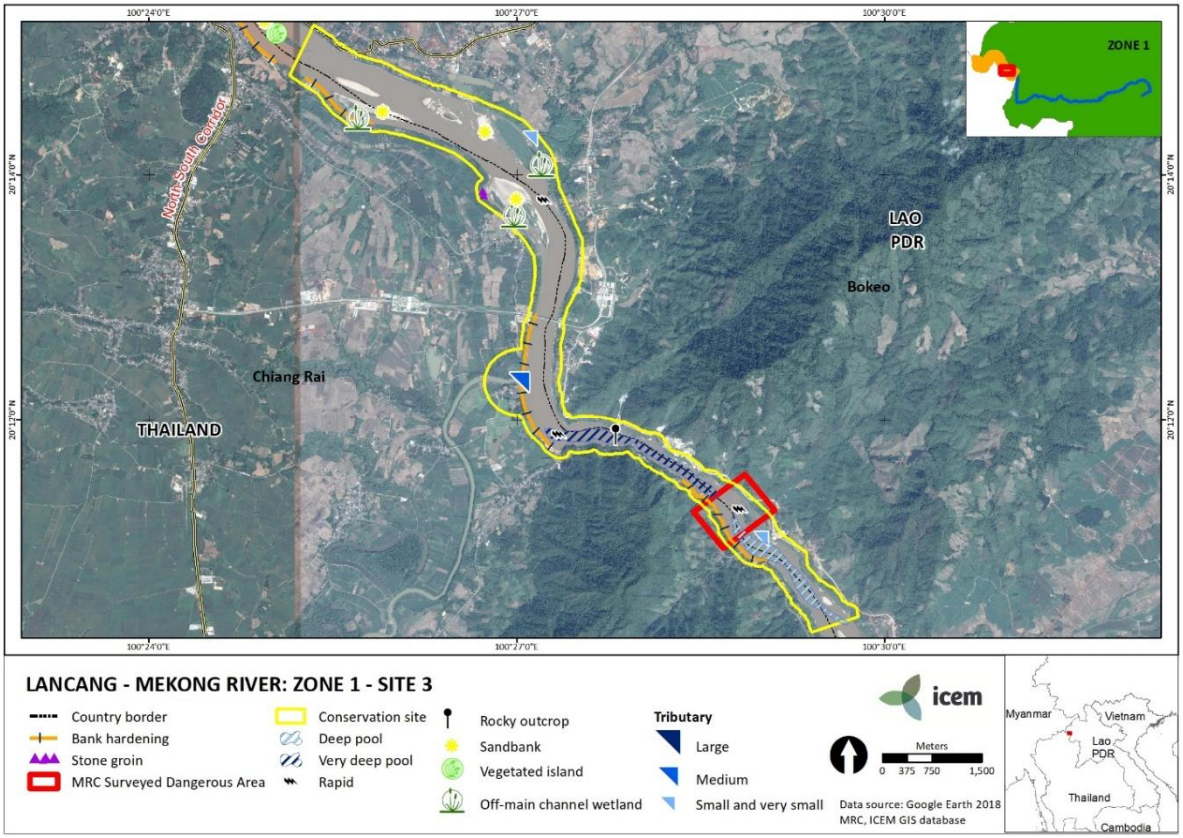
Site 3 – 12.7 km long

Site 3 is about 4 km downstream of Site 2b and begins with a broad channel and floodplain exhibiting several sandy islands and wetlands before narrowing as the Mekong cuts through a mountain ridge producing a very deep and a deep pool. Key features of Site 3 include:

- Sand, silt and rock silt substrate beginning with a relatively broad channel and floodplains that narrows downstream;
- Combination of older (mountains) sedimentary (sandstone, shale, limestone, volcanic rocks) and younger (floodplains) sedimentary (gravel, sand, clay, silt and clay) geology[12];
- Several large vegetated and non-vegetated sand islands;
- An MRC surveyed dangerous area for navigation and other rapids;
- Some rocky outcrop;
- A very deep pool and a deep pool;
- Three wetlands;
- Several sand banks;
- Two small tributaries on Lao PDR side and one medium tributary on Thai side (Nam Ing); and
- Is within the Giant Mekong catfish fishing zone.

Key threats to Site 3 include urban development, mining/quarrying, agriculture and river bank hardening (Thai side).

Figure 8.4: Proposed Mekong Conservation Site 3



[12] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

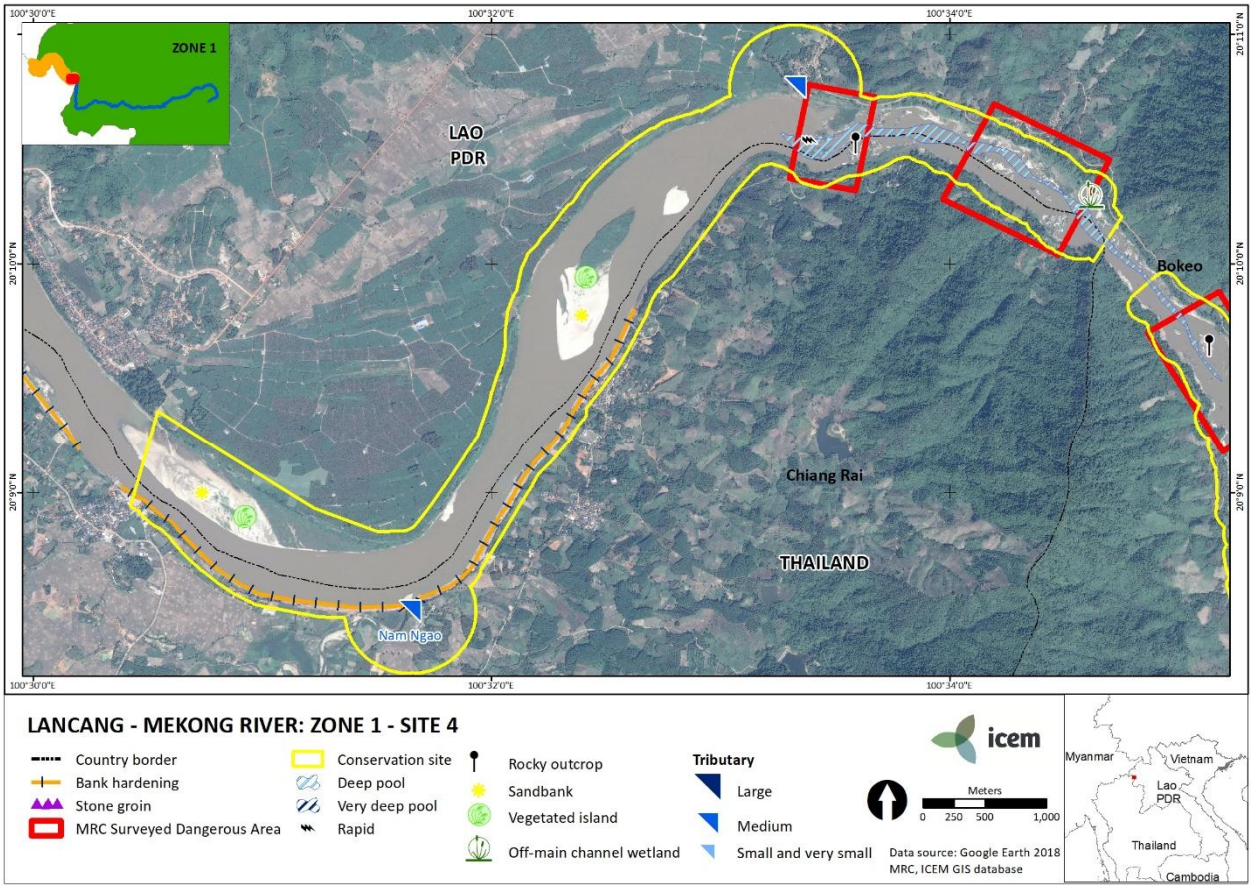
Site 4 – 9.5 km

Site 4 has a relatively broad channel and floodplain beginning about 2.6 km downstream of Site 3 and then exhibits some constriction and rapids as it moves into more mountainous terrain near its extent at the Thai-Lao PDR border. Key features of Site 4 include:

- Sand, silt and rock substrate with a relatively broad channel and floodplain getting narrower at the downstream end;
- Combination of older (mountains) sedimentary (sandstone, shale, limestone, volcanic rocks) and younger (floodplains) sedimentary (gravel, sand, clay, silt and clay) geology[13];
- Two dangerous areas;
- A large partially vegetated sand bank with isolated pools;
- A partially vegetated sand island;
- One on-channel wetland;
- A deep pool;
- Two medium tributaries – one on the Thai side (Nam Ngao) and one on the Lao PDR side;
- Several very small tributaries and some rocky outcrop; and
- Is within the Giant Mekong catfish fishing zone

Key threats to Site 4 include agriculture and some urban development.

Figure 8.5: Proposed Mekong Conservation Site 4



[13] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Zone 2 – 94 km long (4 sites)

Zone 2 is entirely within Lao PDR and contains four proposed sites for conservation management. It is the shortest of all three zones and typically has a narrow and rocky channel with limited floodplain extent.

Site 5 – 6.8 km long

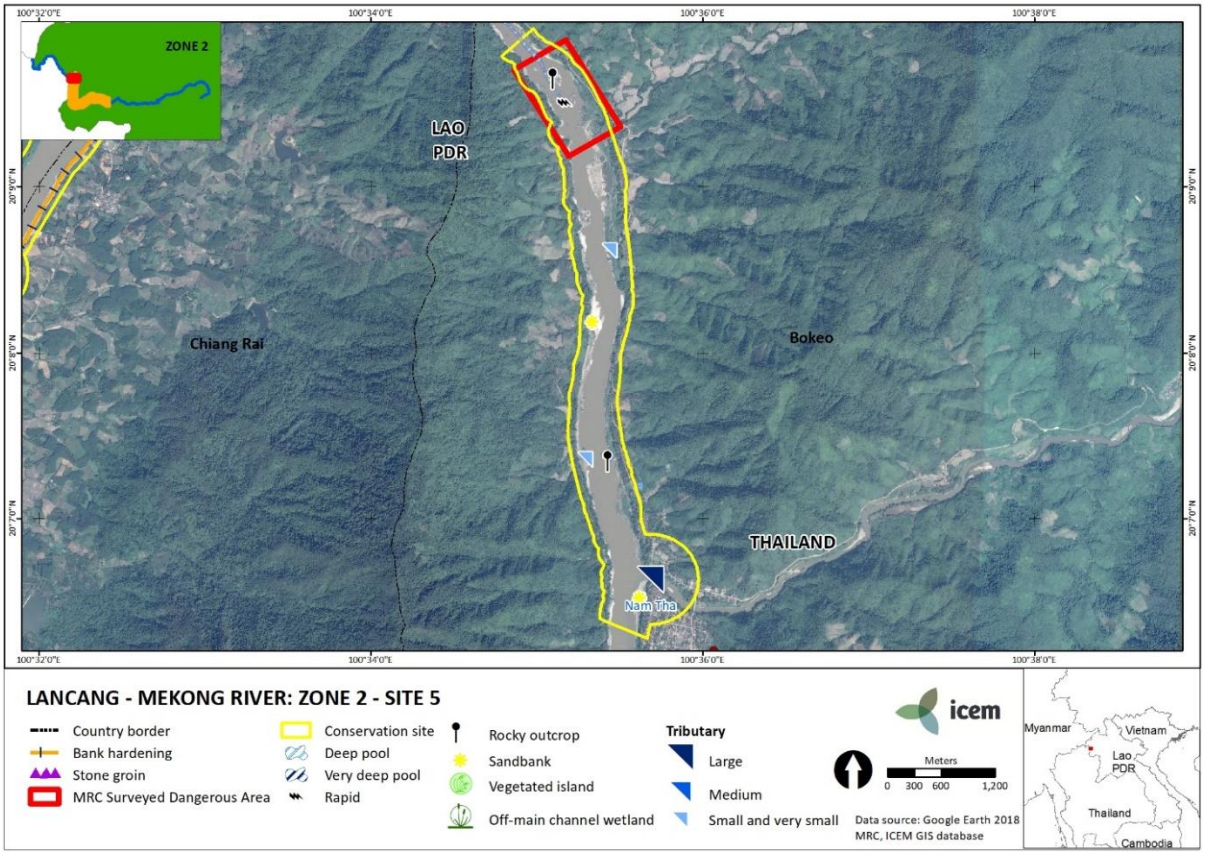
Site 5 begins at the start of Zone 2 where the Mekong leaves Thailand, turns south and flows between steep ridges with valleys running perpendicular to the narrow and rocky channel draining many small tributaries. Key features of Site 5 include:

- Sandy and rocky substrate with a relatively narrow and incised channel with a limited floodplain;
- Sedimentary (sandstone, shale, limestone, volcanic rocks) geology[14];
- A dangerous area;
- A deep pool;
- Several sand banks;
- Some vegetated sandy islands;
- Some rocky outcrop; and
- Several small tributaries associated with small sandy deltas and a large tributary (Nam Tha).

Key threats to Site 5 include urban expansion from Pak Tha and forestry/ agriculture on surrounding hills.

[14] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Figure 8.6: Proposed Mekong Conservation Site 5



Site 6 – 4.4 km

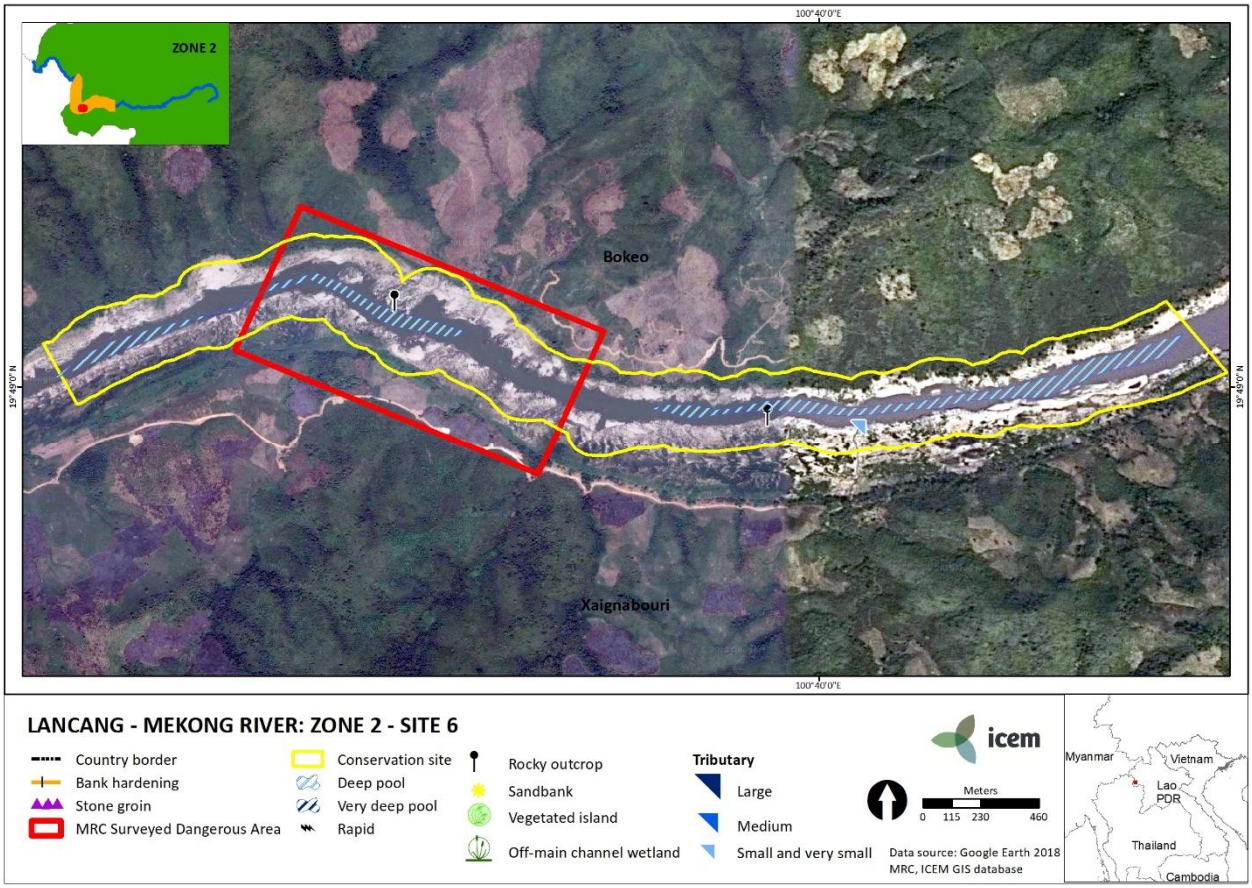
Site 6 lies about 40 km downstream of Site 5 shortly after the Mekong turns east and becomes very narrow and rocky, exhibiting a combination of deep pools, rocky outcrop and rapids. Key features of Site 6 include:

- Rocky, narrow and relatively incised channel;
- Sedimentary (sandstone, shale, limestone, volcanic rocks) geology[15];
- An MRC surveyed dangerous area for navigation;
- Two deep pools;
- Extensive rocky outcrop in the channel;
- Stretches of sandy vegetated banks with isolated pools (particularly along the right bank); and
- A very small tributary.

The key threat for Site 6 is complete inundation by Pak Beng HPP reservoir. Otherwise the site is relatively remote with little or no activity on banks and surrounding hills limited to swidden agriculture and forestry.

[15] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Figure 8.7: Proposed Mekong Conservation Site 6



Site 7 – 30 km

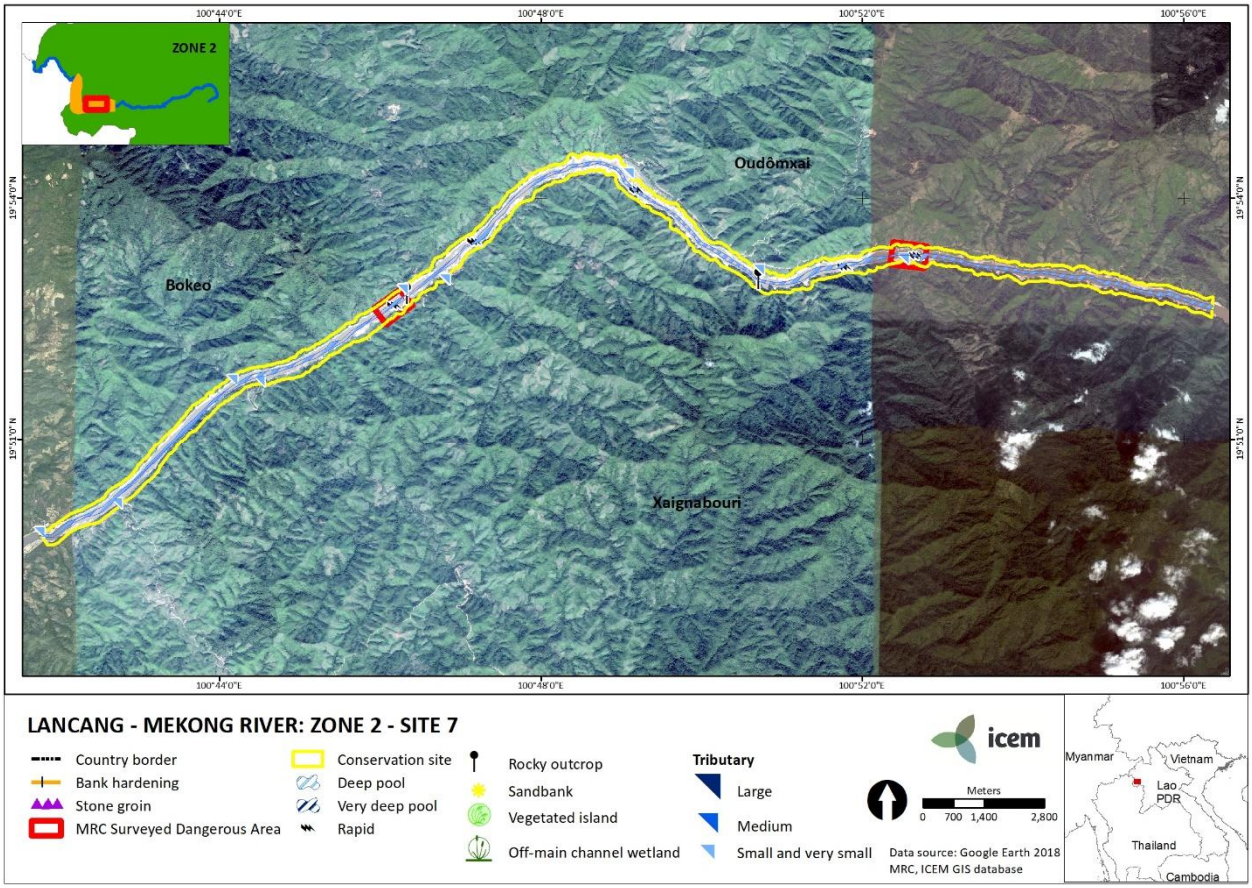
Site 7 is situated approximately 2 km downstream of Site 6, is situated in steep mostly forested mountainous terrain and has a relatively narrow and rocky channel with a deep pool along its entire length. It is the longest of all the conservation sites. Key features of Site 7 include:

- Rocky and sandy substrate with a narrow and relatively incised channel;
- A combination of older (Permian) sedimentary (sandstone, shale, limestone, volcanic rocks) and younger (Jurassic-Triassic) sedimentary (red clyed arenite, coal, conglomerate, limestone) geology with a small amount of igneous rock (granodiorite to monzogranite)[16];
- A long deep pool along its entire length;
- Two dangerous areas;
- Numerous very small tributaries; and
- A significant amount of rocky outcrop.

The key threat for Site 7 is inundation by the Pak Beng HPP reservoir. Otherwise the site is remote with minimal activities on banks and surrounding hills – some forestry and swidden agriculture.

[16] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Figure 8.8: Proposed Mekong Conservation Site 7



Site 8 – 4.3 km long

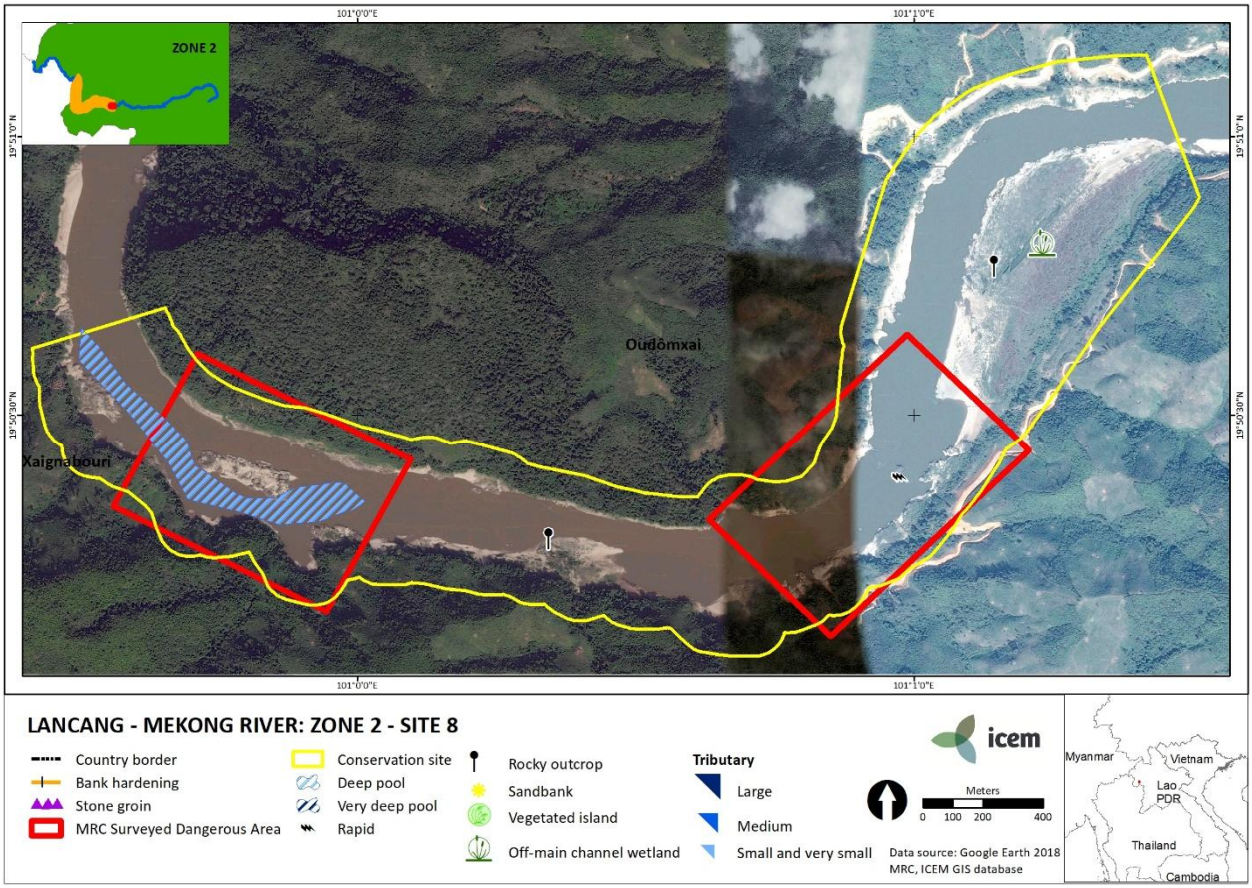
Site 8, at the end of Zone 2, is about 7.2 km downstream of Site 7, is situated on two sharp bends in the river and has a narrow rocky channel with significant rapids and two MRC surveyed dangerous areas for navigation. It is also the site of the planned Pak Beng HPP – located in the downstream dangerous area. Key features of Site 8 include:

- A rocky and sandy substrate with a narrow and incised channel;
- Sedimentary (red clyed arenite, coal, conglomerate, limestone) geology[17];
- Two MRC surveyed dangerous areas for navigation;
- A deep pool;
- A rocky and sandy vegetated bank and wetland;
- Some very small tributaries and;
- Significant rocky outcrop.

The key threat for Site 8 is that it will be destroyed or inundated by the Pak Beng HPP dam and reservoir.

[17] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Figure 8.9: Proposed Mekong Conservation Site 8



Zone 3 – 176 km long (5 sites)

Zone 3 is also entirely within Lao PDR, is the longest of all three zones and contains five proposed sites for conservation management. The channel is typically narrow and rocky and is situated within steep mountainous terrain. Deep and very deep pools extend along the majority of its length.

Site 9 – 17.6 km long

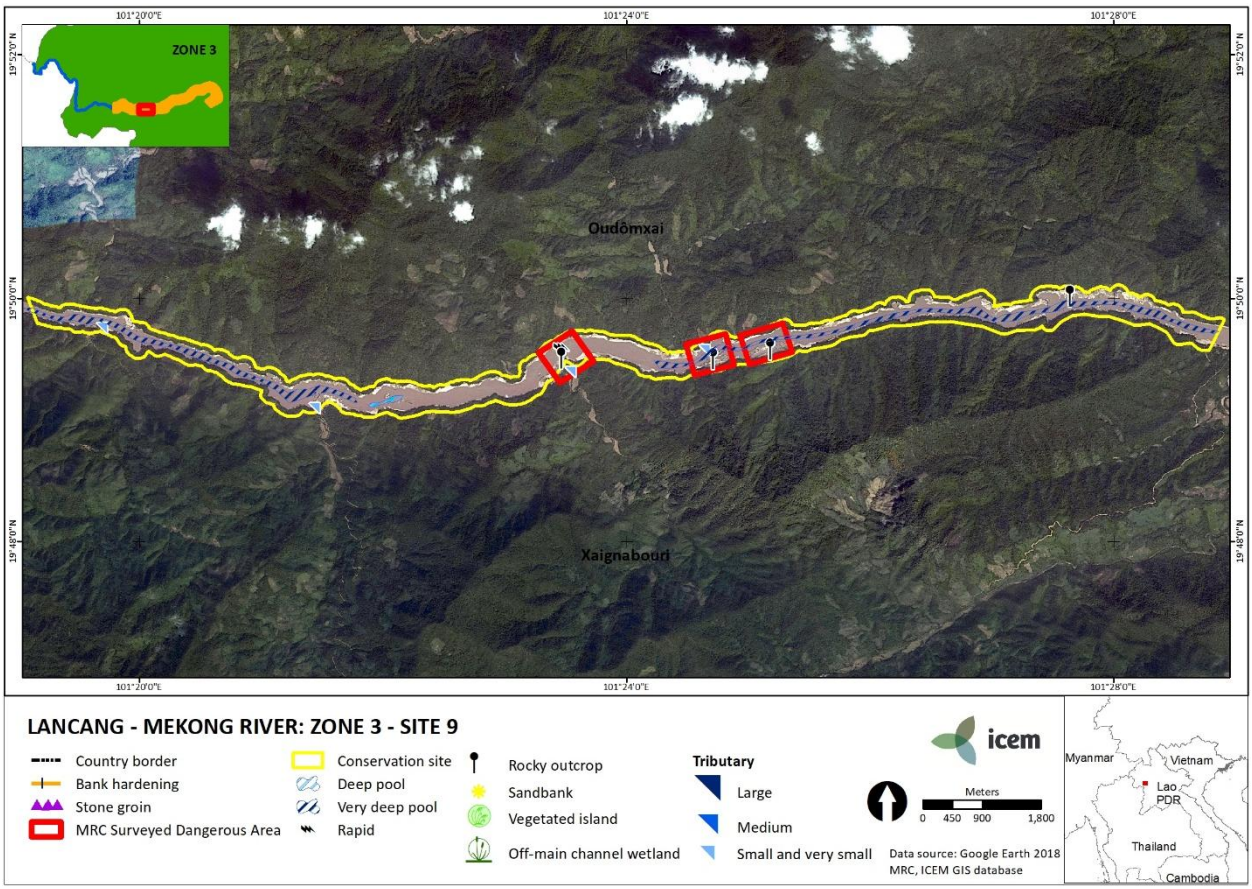
Site 9 is located approximately 38 km downstream of Site 8 and is situated within remote, mountainous and extensively forested terrain. The channel is narrow, incised and rocky with extensive very deep pools and rapids. Key features of Site 9 include:

- A rocky and sandy substrate in narrow and incised channel;
- Sedimentary (red clyed arenite, coal, conglomerate, limestone) geology[18];
- Three MRC surveyed dangerous areas for navigation;
- Two very deep pools and one deep pool;
- Several sand banks;
- Significant rocky outcrop and;
- Three very small tributaries – two on the right bank and one on the left bank.

[18] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Key threats to Site 9 include flow, water quality and sediment changes associated with Pak Beng HPP. Otherwise the site has low level threats with limited use of banks and surrounding hills – forestry (Teak) is the main activity.

Figure 8.10: Proposed Mekong Conservation Site 9



Site 10 – 20.5 km long

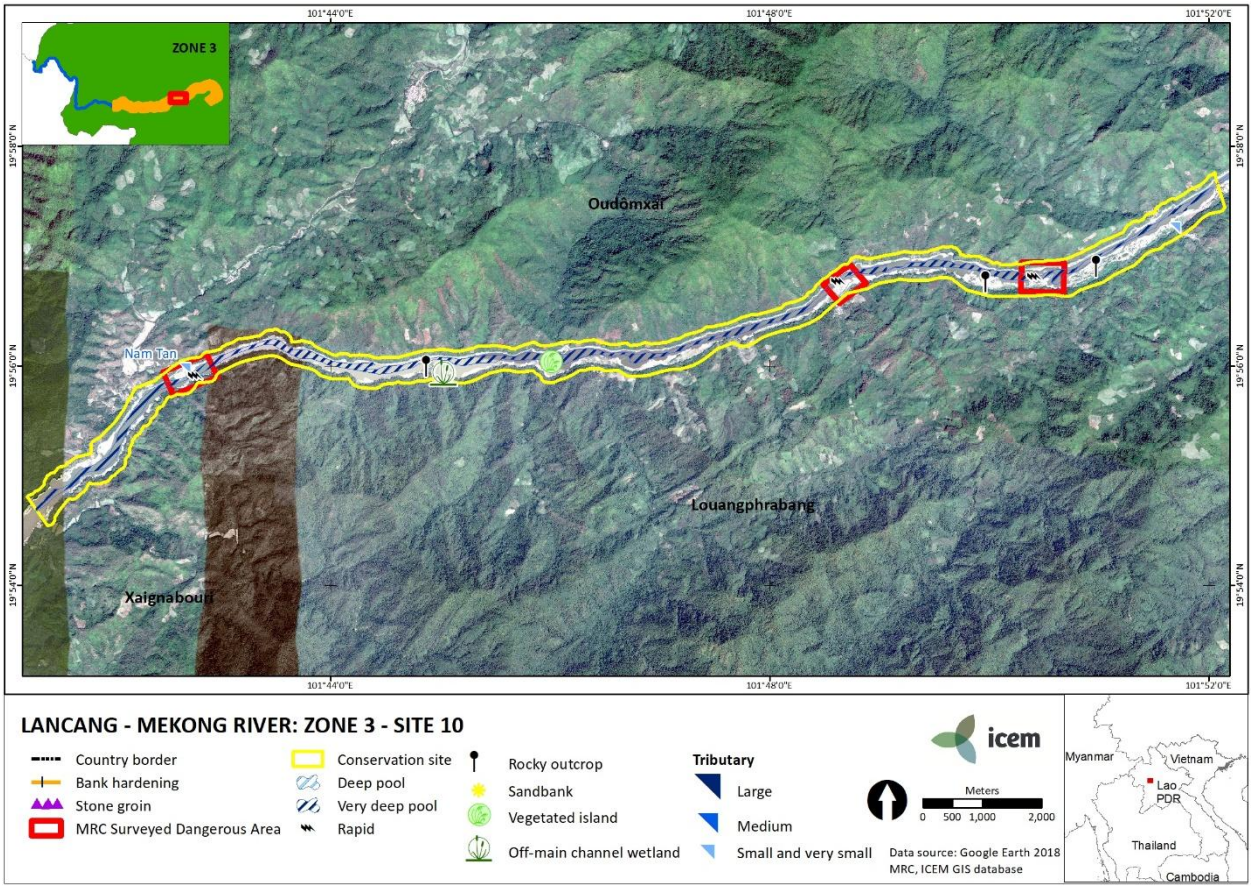
Site 10 is situated about 31 km downstream of Site 9 with a narrow, rocky and very deep channel cutting through steep and forested terrain. Key features of Site 10 include:

- A rocky and sandy substrate in narrow and incised channel;
- Sedimentary (red clyed arenite, coal, conglomerate, limestone) geology[19];
- One long very deep pool running the entire length;
- Three MRC surveyed dangerous areas for navigation;
- Significant rocky outcrop – some vegetated;
- A wetland area;
- Several very small tributaries often associated with sandy deltas and;
- Several sand banks.

Key threats to Site 10 include flow and sediment changes associated with Pak Beng HPP; otherwise limited use of banks and surrounding hills – some agriculture and forestry.

[19] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Figure 8.11: Proposed Mekong Conservation Site 10



Site 11 – 7.9 km

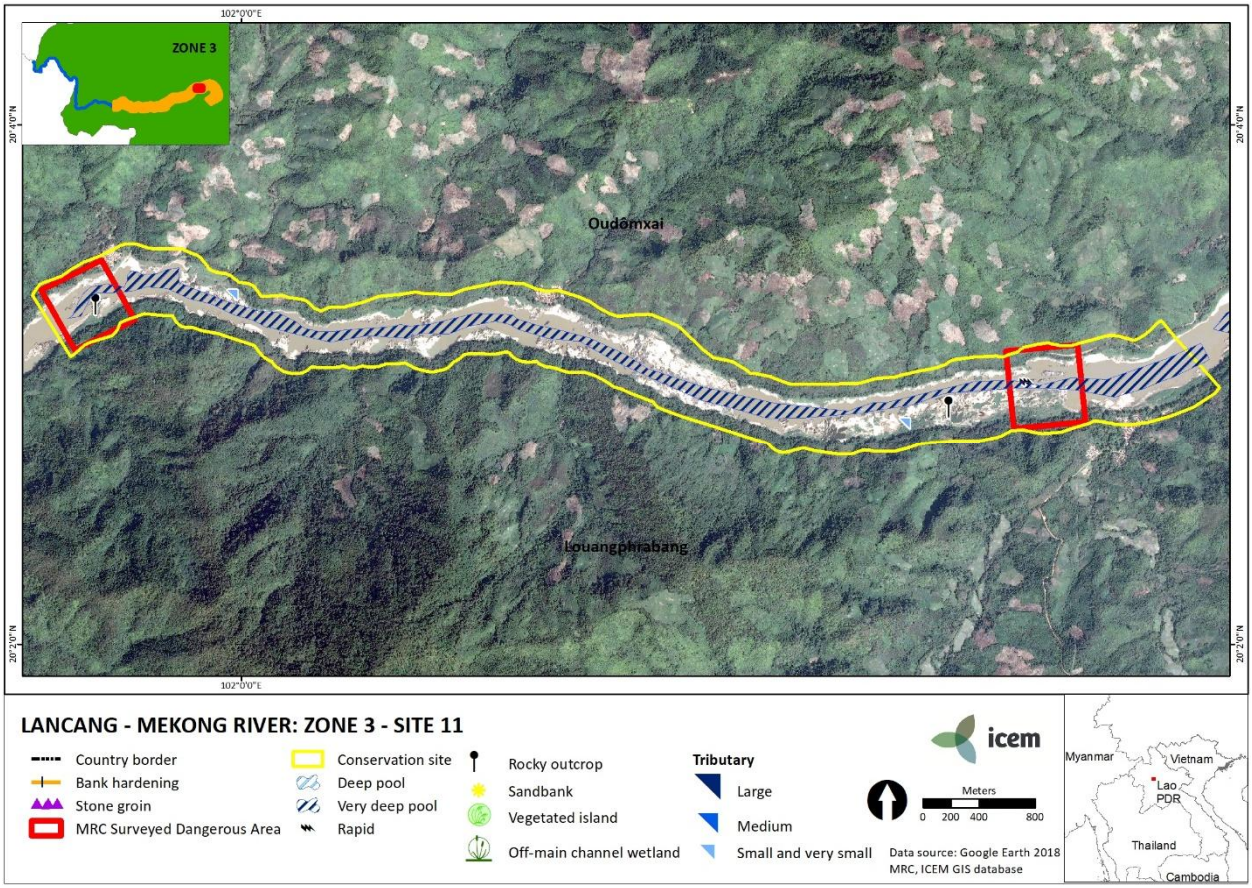
Site 11 begins approximately 17 km downstream of Site 10 and has an incised, deep, rocky and narrow channel with extensive rocky outcrop and some sand banks. Key features of Site 11 include:

- Rocky and sandy substrate with narrow and incised channel;
- A combination of older (Permian) sedimentary (sandstone, shale, limestone, volcanic rocks) and younger (Jurassic-Triassic) sedimentary (red clyed arenite, coal, conglomerate, limestone) geology[20];
- A very deep pool along its entire length;
- Two MRC surveyed dangerous areas for navigation;
- Significant rocky outcrop (some vegetated) and;
- Two very small tributaries.

The key threats to Site 11 are flow and sediment changes associated with Pak Beng HPP.

[20] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Figure 8.12: Proposed Mekong Conservation Site 11



Site 12 – 11.23 km long

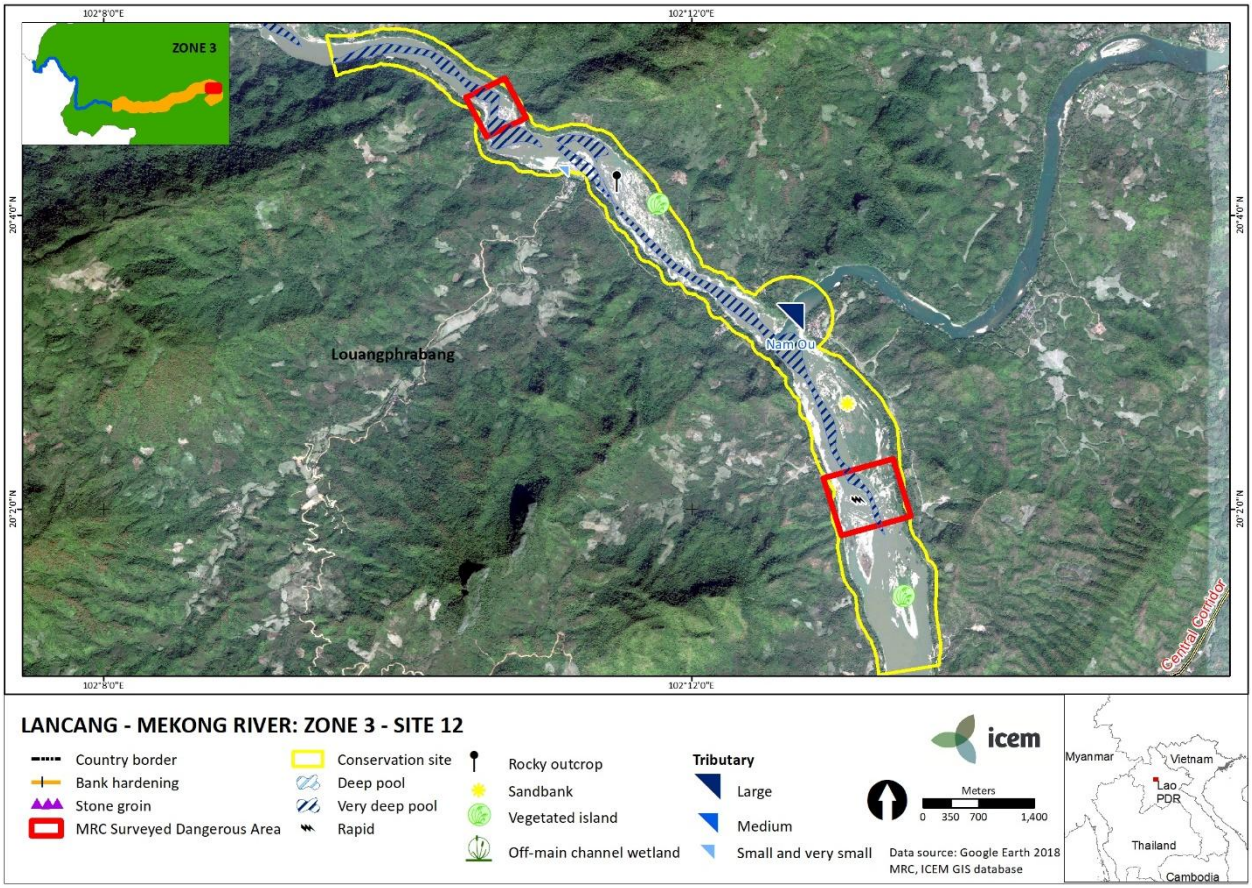
Site 12 is situated approximately 12 km downstream of Site 11 on a bend in the river where it turns south towards Luang Prabang and the Pak Ou tributary enters. The channel broadens and becomes sandier with significant mosaic habitat of vegetated sand islands and rocky outcrop. Key features of Site 12 include:

- Sandy and rocky broader and less incised channel with a mosaic of large vegetated sandy islands and rocky outcrop but still relatively limited floodplain;
- A combination of volcanic (acid to intermediate and mafic volcanic rocks) and sedimentary (sandstone, siltstone and shale) geology[21];
- Two MRC surveyed dangerous areas for navigation;
- Two very deep pools;
- Large tributary (Pak Ou) and two very small tributaries;

The key threats to Site 12 include flow and sediment changes associated with Pak Beng HPP and, to a lesser degree, urban expansion and agriculture.

[21] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Figure 8.13: Proposed Mekong Conservation Site 12



Site 13 – 8.3 km long

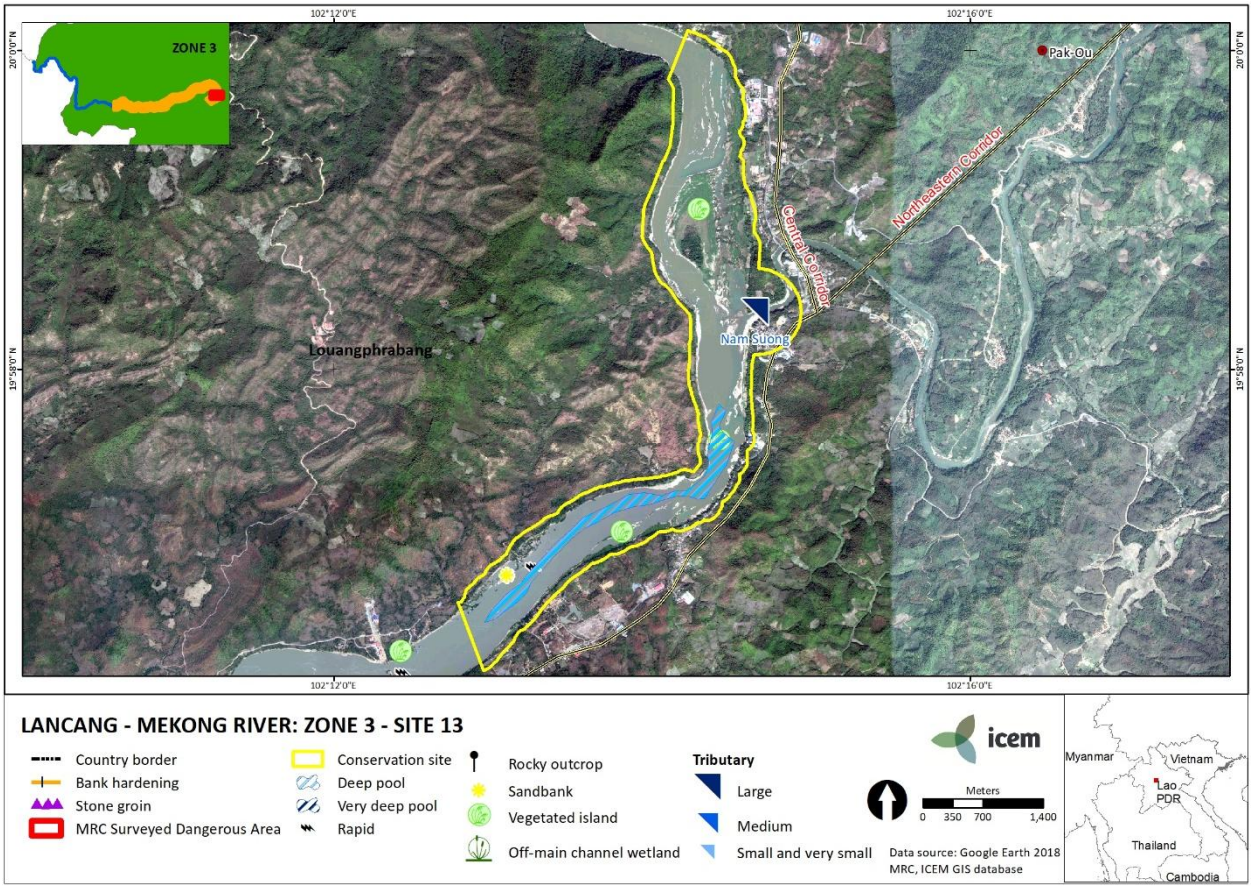
Site 13, the last in the network, is about 2.3 km downstream of Site 12 has a relatively broad channel containing a large vegetated sand island and mosaic of small sandy vegetated islands. Key features of Site 13 include:

- Sandy and rocky substrate with a broader channel and a large vegetated sand island;
- Significant mosaic of vegetated sandy islands;
- A combination of volcanic (acid to intermediate and mafic volcanic rocks) and sedimentary (sandstone, siltstone and shale) geology[22];
- A deep pool;
- Several sand banks; and
- A major tributary (Nam Suong).

The key threats to Site 13 include urban expansion, agriculture and flow and sediment changes associated with Pak Beng HPP.

[22] Laos 1:1M Bedrock Lithology. Lao PDR, Department of Geology and Mines. Khounboulom Road, Vientiane Municipality Lao PDR.

Figure 8.14: Proposed Mekong Conservation Site 13



9 ANNEX 3: SUMMARY OF MEASURES UNDER STRATEGIC RECOMMENDATIONS 1, 3 AND 5 FOR PAK BENG HPP

Table 9.1: Pak Beng HPP mitigation measures under strategic recommendations 1, 3 and 5 covering one or more themes

<table>
<tr><th>SR No.</th><th>Hydrology and Sediment</th><th>Biodiversity</th><th>Socio-economics</th></tr>
<tr><td rowspan="4">Enhanced Baseline (SR 1)</td><td>Additional discharge monitoring, particularly of tributaries in zones 2 and 3</td><td>Comprehensive bird, amphibian and reptiles surveys in the inundation area</td><td>Improved modelling of whether aquaculture can stand in for loss of fish production</td></tr>
<tr><td>The design of the dam should be modelled for its impact on downstream flood pulses, as well as for the amount of sedimentation that will be trapped in the reservoir</td><td>Laboratory and field studies should be carried out to evaluate the likelihood that the proposed upstream passage mitigation will be effective and the consequences of turbine passage to downstream-moving fish</td><td>Improved modelling of the expected fish stocks in the reservoir that quantitatively takes into account the loss of migratory species because of the dam wall as well as loss of wild fish production</td></tr>
<tr><td rowspan="3"></td><td>Collection of fish in the project area over all seasons and for at least 2 years; Monitoring should quantify the numbers and biomass of resident fish and the numbers and seasonality of upstream migrating spawners and downstream drifting fish eggs, larvae, and juveniles</td><td>Socio economic surveys should be conducted in the up and downstream communities to determine the reasons for the reported differences in incomes, as well as to disaggregate health outcomes by village, ethnicity, gender and age groups</td></tr>
<tr><td rowspan="2">Further local fish surveys, to assess in more detail: i) knowledge of fish species swimming capabilities and flow and sediment range requirements; ii) species similarities and connections between the mainstream section and adjacent tributaries; iii) migratory patterns among the species listed; iv) fishers' knowledge about the ecological role of deep pools in the dam impact zones; v) the impact of a change in river hydrology on algae; vi) analysis of existing or potential riparian wetlands and definition of a target reservoir level/extent in relation to fish habitat protection</td><td>Collecting population data and livelihoods information at the household level, disaggregated by ethnicity for the 25 upstream villages</td></tr>
<tr><td>Detailed population surveys should be completed along the roads to Muang Xay, Muang Ngeun and Pak Tha, to identify populations living along these corridors</td></tr>
<tr><td rowspan="2">Best practice C&O (SR 3)</td><td colspan="3">Minimize reservoir size and dam wall height; Ensure that outflows approximate inflows at an hourly or at least daily scale</td></tr>
<tr><td colspan="3">The dam design must: ensure sediment of all sizes are passed downstream and sediment is passed downstream at a rate approximating the natural state (i.e. not just a large volume of sediment released at irregular intervals); ensure the dam height and storage area are minimized to maximise</td></tr>
</table>

SR No.	Hydrology and Sediment	Biodiversity	Socio-economics
	flow velocities upstream of the dam and keep fine sediment suspended; include low level sediment sluices, gates or diversion channels to transport sediment through the dam; include low level outlets to enable sediment flushing to remove deposited sediment (generally sand and gravel); Minimises water levels during the flood season to ensure the natural high proportion of sediment transport through the reservoir during this time is maintained		
	Watershed management can also help to minimise sedimentation by reducing sediments produced by road construction, mining, agriculture and other land uses in the upper catchments		
	Selective forest clearing within the impoundment area could be completed before reservoir filling to mitigate the potential for poor water quality resulting from decay of flooded biomass		
	It is important that all the components of a flow regime are maintained including low flows, high flows and flow variability. For the Mekong it is essential that the flood pulse hydrology is maintained		
	If required, sedimentation upstream of the dam wall can be excavated and transported immediately downstream of the dam to re-introduce to the river		
	Designing the dam structures to avoid concentrating high flows onto bed and bank areas that may be vulnerable to erosion		
		Creation of artificial wetlands within the reservoir	
		Runoff control measures and timing and location of blasting to avoid sensitive receptors	
		Behaviour and movements of construction workers also need to be controlled to limit hunting or trade in wildlife products	
		Install a bypass fishway ensuring that the design is informed by a baseline assessment of current fish migration behaviour	
		Stocking of adults or fries of commercial species, which are well adapted to reservoirs	
		Connection to the nearby tributaries both in the upstream (Nam Beng, Nam Tha and Nam Ing) as well as the downstream (Nam Ou and Nam Xuang) of the Pak Beng Dam should be kept clear with no obstacles to fish passage	
		Development of appropriate rakers and screens (i.e. to prevent migration through turbines), optimised spill flows, and fish friendly turbines	
		Minimise the reduction in predictable seasonal variation in water levels in and downstream of the dam or deploy 'no go' safe havens above and below the zones of major impact to rebuild the already beleaguered bird populations there as an offset for the loss of habitat in the reservoir	
		The towns where workers are likely to live, eat and otherwise spend their money should be clearly identified, and local authorities should be supported to plan for the changes in these towns ahead of time	
		The local government/administration in Pak Beng and Pak Ngeui towns should be supported to plan for the influx of 3,000 – 4,000 workers	
			Provide support for those in the town who would like to use the opportunity to establish small businesses
			Planning for health complications such as STDs, vector and food borne illnesses

SR No.	Hydrology and Sediment	Biodiversity	Socio-economics
			Mechanisms to fully address social impacts need to be devised, including for those communities to be relocated and those who will experience disruptions to their river-based livelihoods upstream and downstream due to the dam
Ongoing Monitoring (SR 5)	Monitoring of discharge, sediment load and erosion immediately downstream of the dam wall to a minimum 100km downstream	Monitoring of biodiversity around the dam site, reservoir, quarries, access roads and transmission lines	
		Monitoring program on deep pool fish diversity and abundance	
		Monitoring program on fish diversity and abundance of rapid resident species such as *Gerra spp*. as well as some demersal species such as *Yasuhikotakia modesta* both within the mainstream and nearby tributaries of the Pak Beng HPP	
		Water quality monitoring in the reservoir and downstream	
		Monitoring of macroinvertebrate populations	
		Monitoring of identified critical habitats for threatened or endangered species from detailed ESIAs	
		Increase wildlife and forestry enforcement capacity at villages and towns surrounding workers camp	
			In addition to monitoring the bio-physical impacts, there should be continuous monitoring of changes in the socio-economic conditions with reference to the established baseline and broader trends

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