Impact Assessment 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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SUMMARY

The Package A of TA 8179-CAM: Mainstreaming Climate Resilience into Development Planning has developed four sector specific climate adaptation guides. To facilitate the use of these guides, the TA team has designed a two-day training workshop at national level on the application of the (i) Adaptation Technologies Guide – Agriculture and the (ii) Water Resources Adaptation Guide for National Level use by MAFF and MOWRAM, respectively in December 2018. To follow this training, another sub-national training workshop was designed to improve the capacity of sub-national government officials and relevant private firms and facilitate the use of the adaptation guides and implementation of adaptation measures in their workplace. As for MAFF, the training was conducted on 22-23 January 2019 at Kampong Thom province.

There were 47 participants (6 women) participated in the training workshop, including TA specialists, ministry representatives, PMU staff, adaptation working group members, provincial staff, private sectors involving in agricultural production, and local authorities and communities (Appendix 2).

The training consisted of a combination of short presentations, group discussion and short activity based assignments. There was interplay between theory and case study application. Each topic started with an overview presentation, with built-in question and answer sessions. Group discussion will then follow. The participants were given chances to visit fields to show participants actual climate change adaptation measures that have been implemented on the ground, and an opportunity to discuss with the local community about local issues and the implementation of the climate resilience measures. During the field visit, the participants were instructed to collect data that was used the following day for group discussions.

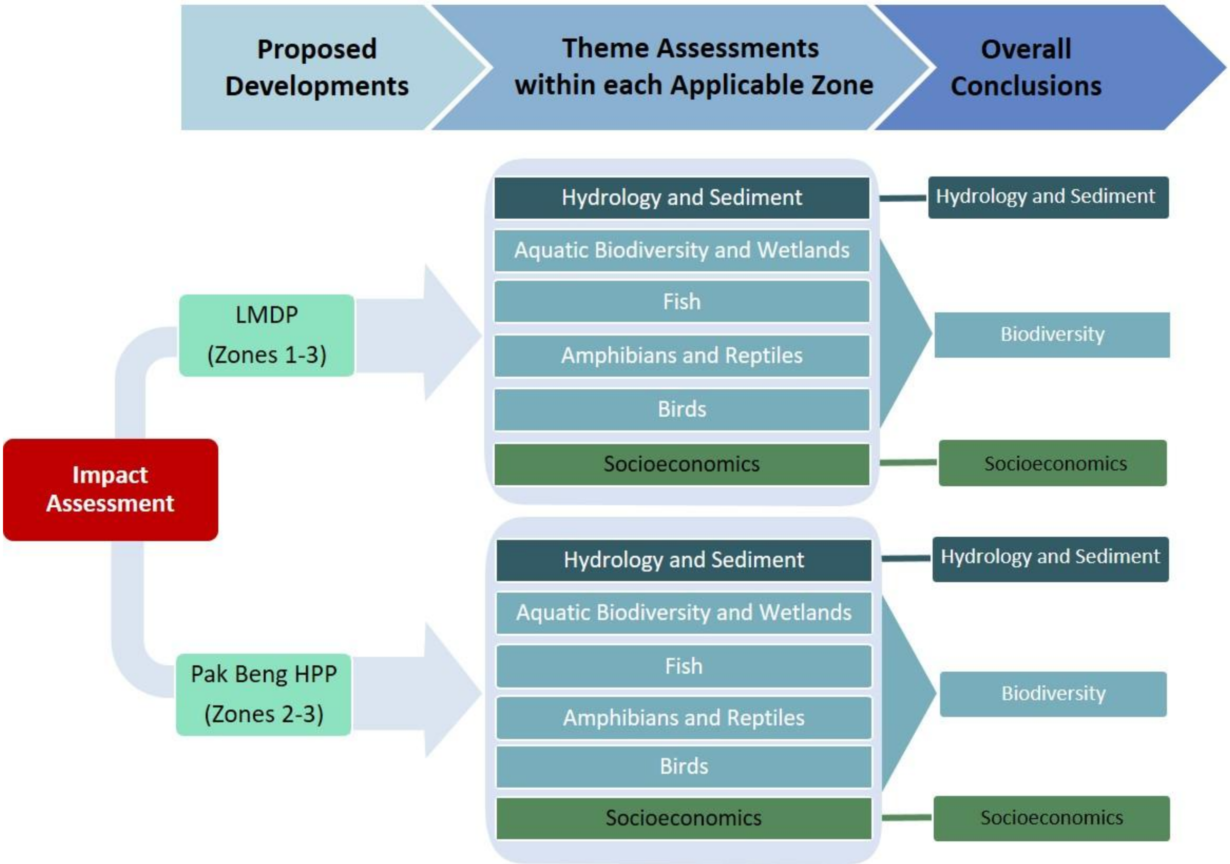
Participants discussed in small groups to what they could see and what they had learned from field as well. They also reflect to what they had learned from class due to link to the tools in each sector that were presented in class by facilitators then they provided comments to correct the practical methods in field of those tools too. Based on the results of group discussions of each group, could show that participants had more clear understanding about the adaptation due to see in the real practice at fields and reflected to the theory of tools. They understand what tools can apply in the real context of Cambodia situations for agricultural productions. In addition, participants were very actives in discussions, provided comments and suggestions during the training process.

The sub-national training workshop had finished with fruitful results, participants had full chance to discuss even in small groups as well as in plenary discussion. All comments from participants will be used as inputs for correction and update of the adaptation guide. Based on observation during the training, participants have commitment to share the knowledge from the training to their colleagues at their own provinces/ departments.

1 INTRODUCTION

This volume contains the results of an impact assessment of the Lancang-Mekong Development Plan (LMDP) and Pak Beng Hydropower Project on a 368 km stretch of the Lancang-Mekong River between the Golden Triangle and Luang Prabang. The volume firstly sets out the impact assessment approach and then outlines the nature of good practice navigation improvement works through two channel design case studies – to help in understanding the potential impacts of the LMDP (if carried out to international best practice). It then details the results of the impact assessment separated into two chapters – the first focuses on the LMDP and the second on the Pak Beng HPP. The impact assessment on each of these proposed developments was carried out for each of the study themes with overall conclusions drawn for hydrology and sediment, biodiversity and socioeconomics following the individual theme assessments (Figure 1.1).

Figure 1.1: The structure of the impact assessment as presented in this volume

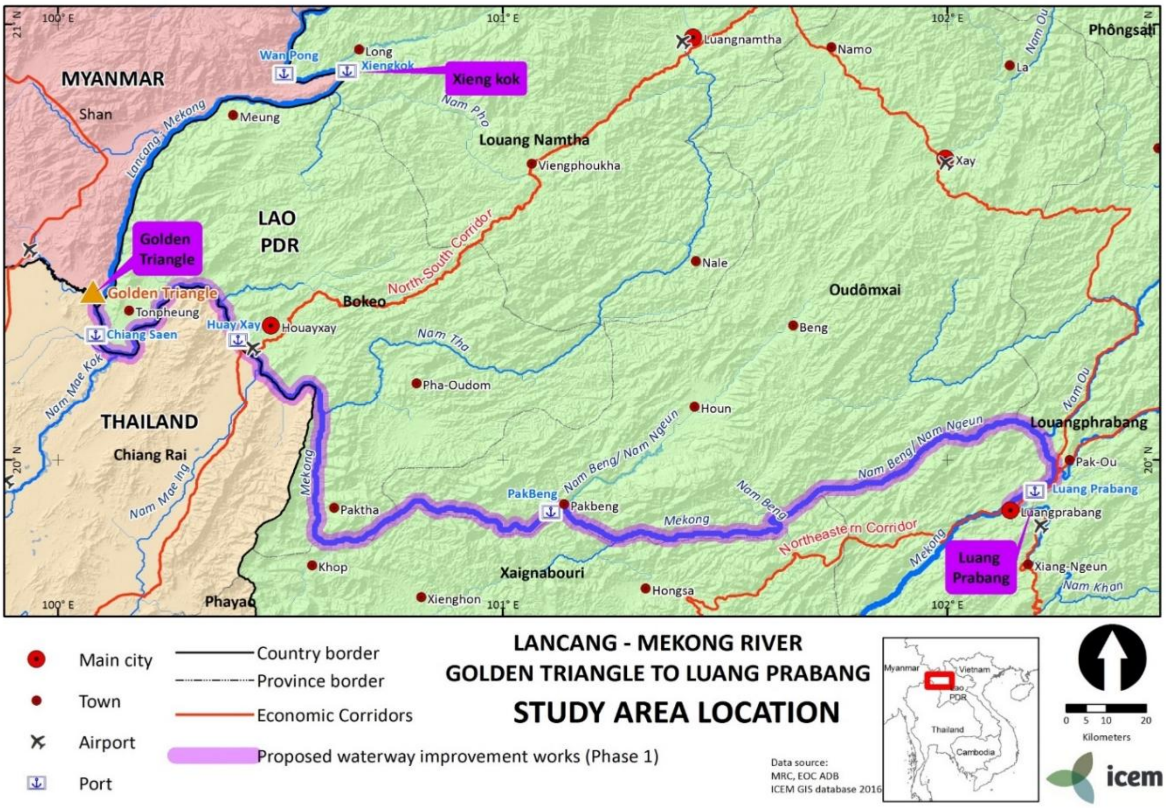


The impact assessment was the third phase in the Environmental Study of the Lancang-Mekong Development Plan (LMDP), following the scoping phase and baseline assessment phase and prior to the final development of mitigation strategies phase.

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 1.2). 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 1.2: 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.

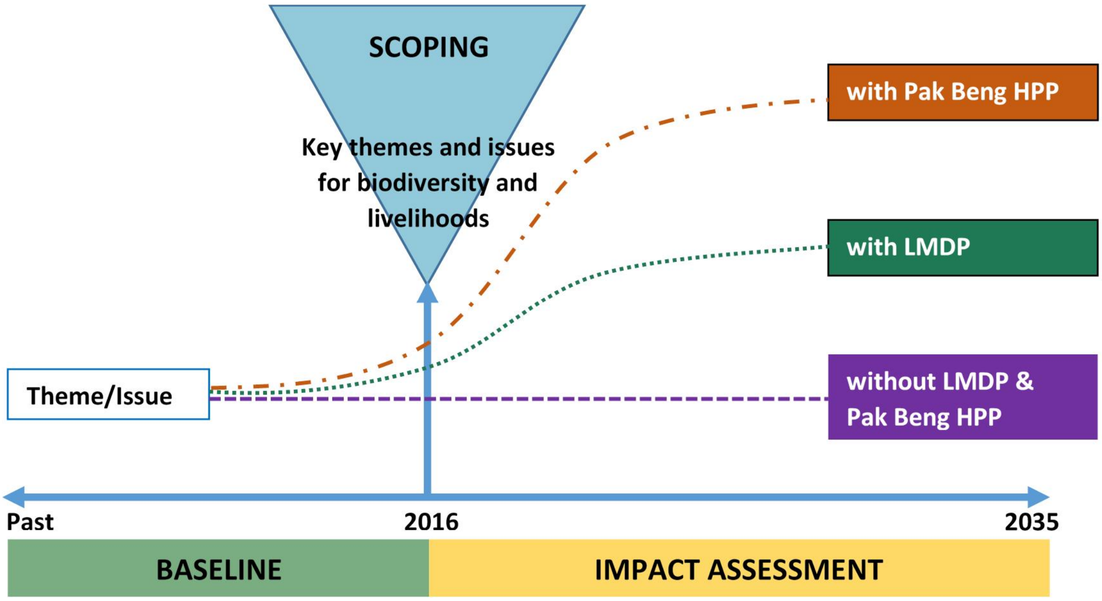
ICEM ensured that these concerns were taken into consideration in the ES including conducting a rapid integrated field survey in the development corridor between the Golden Triangle and Luang Prabang to inform strategic planning and sustainable decision-making.

2 IMPACT ASSESSMENT APPROACH

This section outlines the study approach to the impact assessment of the LMPD and Pak Beng HPP reservoir. The impact assessment uses trend analysis to identify the cumulative effects of the LMDP and Pak Beng HPP reservoir on future trends and drivers relating to the key themes and environmental and socio-economics issues identified in the baseline phase. Three scenarios were generated (Figure 2.1):

1. **Baseline:** Past, current and future trends without the LMDP and Pak Beng HPP
2. **LMDP**: Future trends with the LMDP
3. **Pak Beng HPP reservoir**: Future trends to 2030 with the Pak Beng HPP

Figure 2.1: Trend analysis of scenarios with and without LDMP and Pak Beng HPP



The assessed impacts of the **LMDP** and **Pak Beng HPP** scenarios were compared to a projected pathway to 2035 without the LMPD and Pak Beng HPP. This phase included assessing implications on the national/regional/global conservation value of Red List species and the impacts on hydro-morphology and riparian communities.

Box 1: Note on impact assessment approach

The impact assessment adopted an approach to include all possible impacts. The study team recognises that many impacts could be avoided or reduced if best-practice approaches are followed in river improvement and hydropower management. Nonetheless, it is the role of this study to highlight all possible impacts, assess their risk and propose mitigation options. This approach highlights the consequences of not adopting best practice, and leads in the mitigation phase to identification of best practices that need to be adopted.

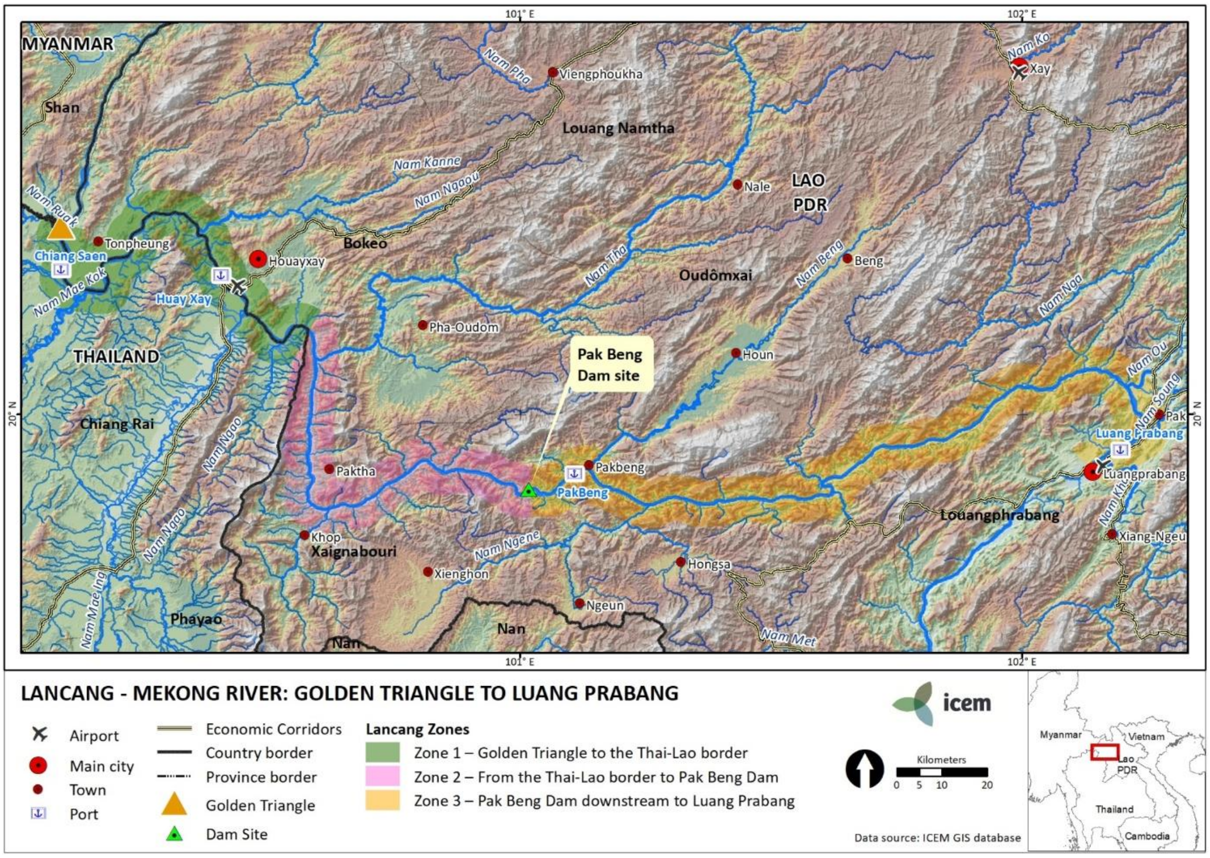
2.1 SUMMARY OF WORKS AND ASSESSMENT ZONES

Two major developments are proposed for the study reach:

- **LMDP** - Improving the river for navigation by up to 500 tonne 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 from the proposed developments along the target river stretch, the study reach has been divided into three zones representing the areas of influence of the developments and distinctive biophysical features (Figure 2.2).

Figure 2.2: Study assessment zones

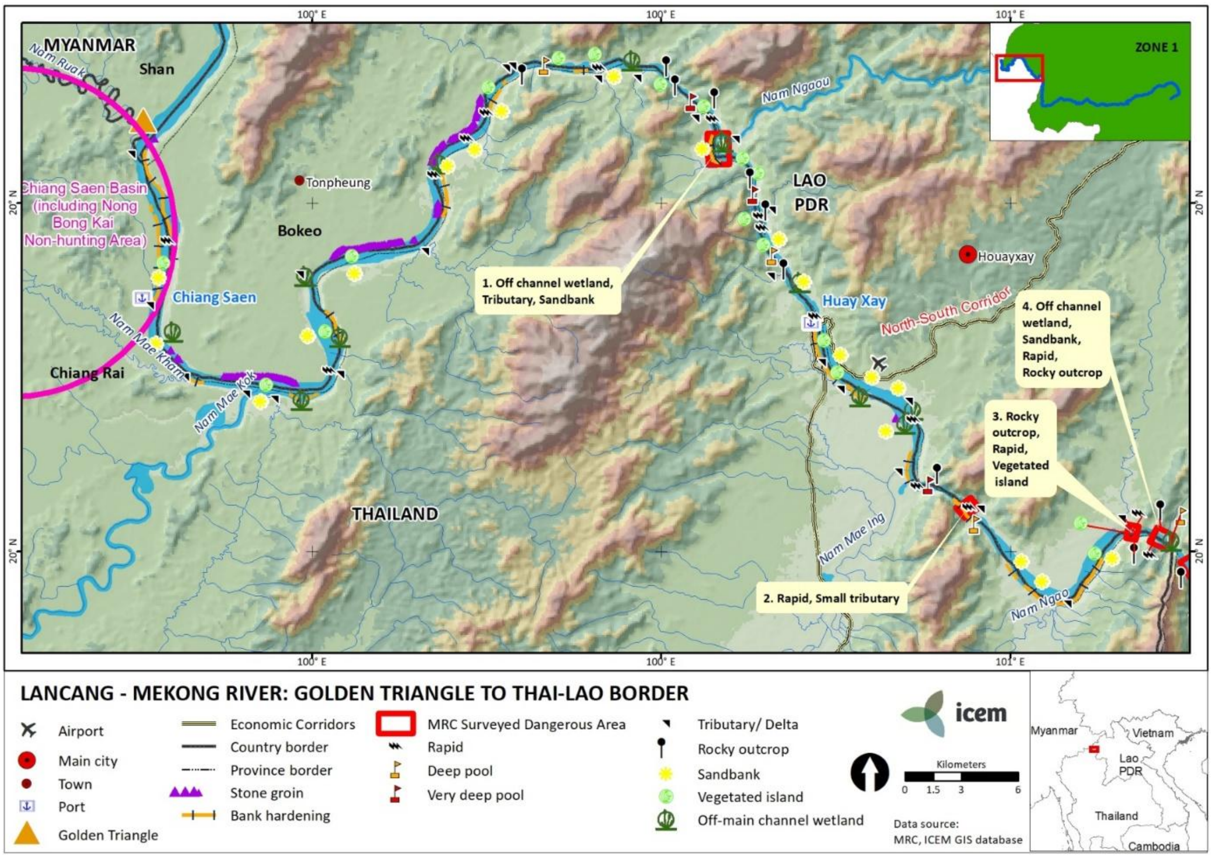


ZONE 1 (Figure 2.3) - Open flood plain and wide channel with sandy bed and banks (Golden triangle to the Thai-Lao PDR border - approx. 98 km): The Mekong River from Chiang Saen to Pak Tha is relatively more developed than the following two sections, particularly on the Thai side. It also typically has a wider channel and is sandier with more numerous and larger sand islands and wetlands. The terrain either side of the river is mostly flat, particularly on bends where there are typically large alluvial floodplains with cropping or settlements. There are fewer rocky outcrops and dangerous areas. The whole of Zone 1 is within the Upper Lao Mekong Important Bird and Biodiversity Area (IBA).[1]

This zone has four MRC surveyed dangerous areas for navigation where obstruction removal and/ or channel dredging is likely to occur under the LMDP. Construction of the Houay Xay and Chiang Khong ports as part of the LMDP will also occur in this zone.

[1] http://datazone.birdlife.org/site/factsheet/16651

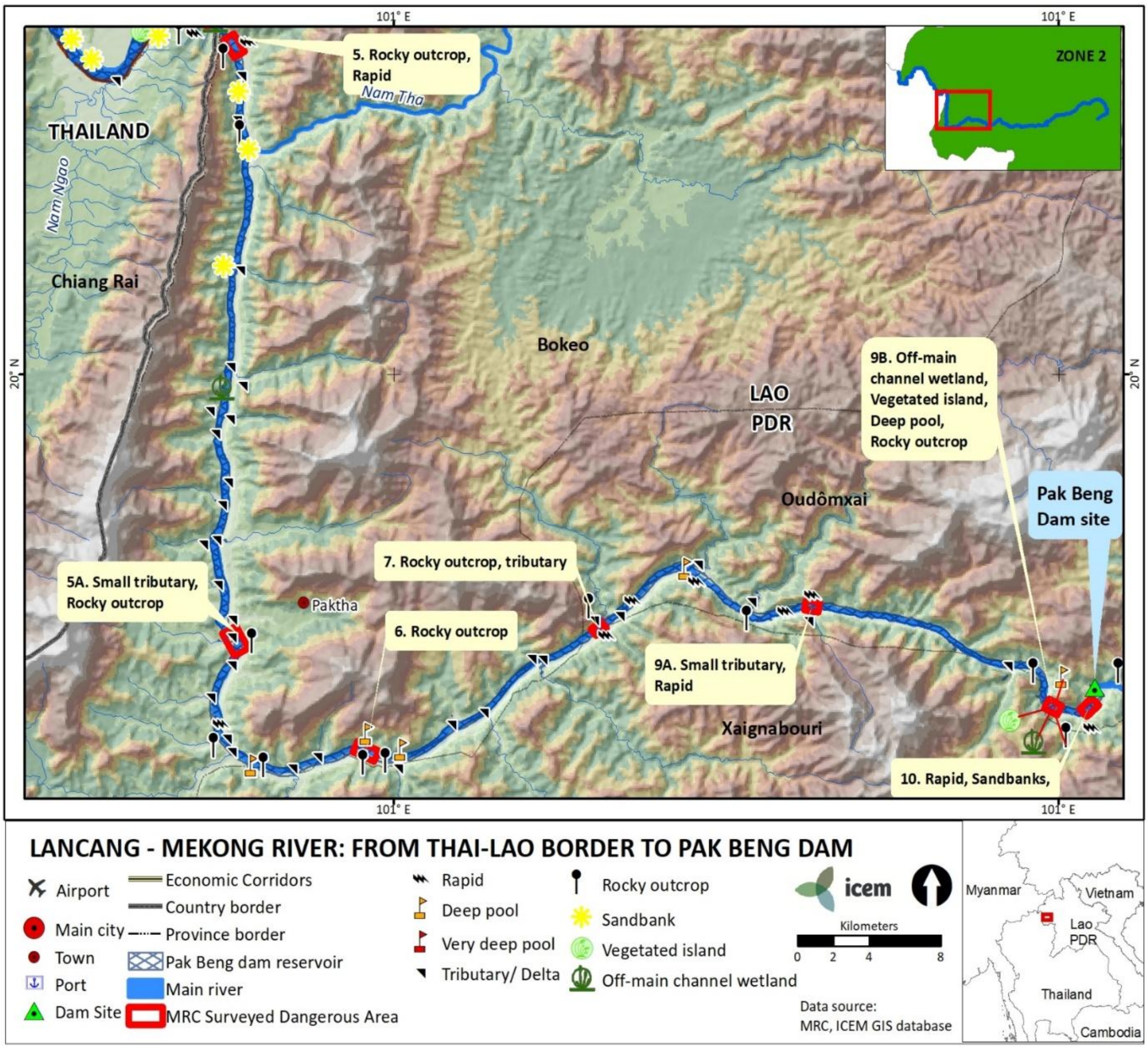
Figure 2.3: Zone 1 – Golden Triangle (Chiang Saen) to Thai-Lao PDR border



ZONE 2 (Figure 2.4) - Narrow steep channel mainly bed rock with V shaped valley (Thai-Lao PDR border to Pak Beng dam site - approx. 94 km): The Mekong in this section is typically narrower, more incised, straighter and rockier than the first section. The terrain is steep with short steep valleys running perpendicular to the river down the sides of mountains, creating many small tributaries. The section is less developed with no large towns and has significant forest cover. There are more dangerous areas for navigation. There are few vegetated islands, sandbanks and wetlands. The whole of Zone 2 is within the Upper Lao Mekong Important Bird and Biodiversity Area (IBA).

The impoundment reservoir of the Pak Beng hydropower project is expected to reach as far as the Thai-Lao border. This zone has seven MRC surveyed dangerous areas for navigation where obstruction removal or dredging is likely to occur 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.

Figure 2.4: Zone 2 –Thai-Lao PDR border to Pak Beng HPP dam site

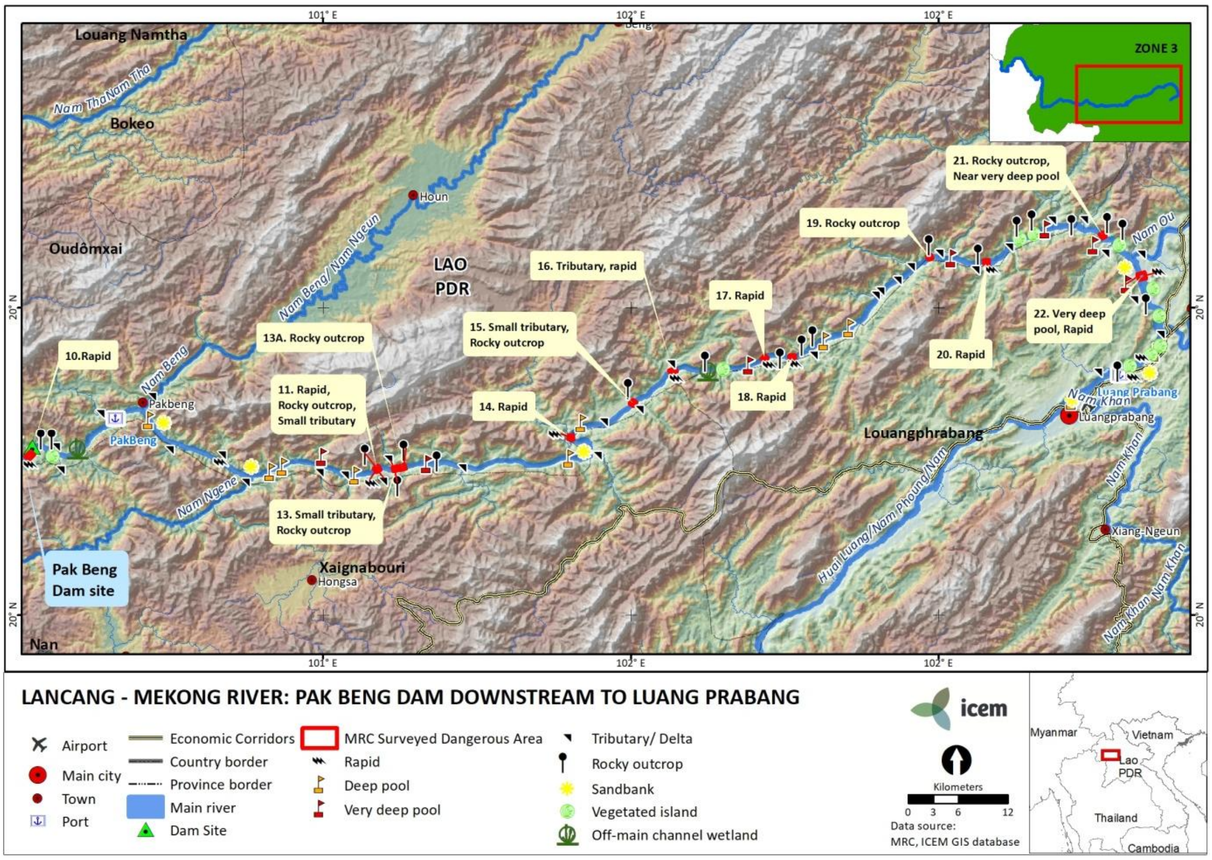


ZONE 3 (Figure 2.5) - Multiple rapids and rocky outcrops in broad channel mixed bed rock and sandy substrate (Pak Beng HPP dam site to Luang Prabang - approx. 176 km): The Mekong remains relatively narrow and rocky throughout this section with steep forested terrain and many dangerous areas. However, the valleys run more parallel to the river in this section compared to the previous section but there are still many small tributaries entering. There are also many deep and very deep pools in this section, which tend to be associated with the river cutting through mountain ridges and dangerous areas for navigation. The river widens and development increases closer to and including Luang Prabang. The upper 76 km of Zone 3 from the Pak Beng HPP dam site to Ban Houaykha is within the Upper Lao Mekong Important Bird and Biodiversity Area (IBA). The lower 23 km of Zone 3 from the Nam Ou confluence down to Luang Prabang is within the Mekong River from Luang Prabang to Vientiane[2] IBA.

This stretch is located downstream of the proposed Pak Beng HPP dam. It has twelve MRC surveyed dangerous areas for navigation where river improvement works are expected and two ports (at Pak Beng and Luang Prabang) to be constructed as part of the LMDP.

[2] http://datazone.birdlife.org/site/factsheet/mekong-river-from-luang-prabang-to-vientiane-iba-laos

Figure 2.5: Zone 3 – Pak Beng HPP dam site to Luang Prabang



The impact assessment was 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 HPP 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 HPP in Zone 3 focusses on altered flow and sediment regimes from the dam construction and scheme operation.

2.1.1 *Primary potential impacts in the study zones from the LMDP*

The immediate and longer-term changes resulting from the LMDP activities in all three zones are shown below. It is these changes that will be used to assess the impacts on biodiversity and socio-economics.

ZONES 1 to 3: Golden triangle to Luang Prabang (whole study reach) – approx. 368km; 23 MRC surveyed dangerous areas – focus is on navigation improvement works

Construction phase impacts:

- Rocky materials may be released and distributed in the immediate area of obstruction removal (the team's case study of Kheng Pai Dai estimates removal of 20,500 m^3 of rock)
- Some rocky material is likely to be deposited in deep pools downstream of obstruction removal. The volume of materials deposited in deep pools cannot be estimated at this stage.
- Sand from bed, banks and islands will be removed through dredging (the team's Hat Ngao case study estimates removal of 100,000m^3 of sand)

- Sand from sand banks and islands may be deposited downstream and on adjacent banks (the location for depositing large quantities of dredged materials is not identified in the LMDP).
- Port construction and annual dredging of channels will involve clearing and releasing materials into the river
- Waves from obstruction removal and related large boats may lead to increased bank and island erosion where not bedrock

Long term impacts:

- The main river channel will be wider and less obstructed (extent of change is not known at this stage, although the team's 2 case studies applying best practice indicate a minor change)
- The flow in the channel may be less restricted and consequently the flow may be slower (unless removed materials are placed within the vicinity of removal to replicate natural obstruction)
- Slower flows may reduce sediment generation due lower rates of bank erosion
- Sediment transport may be reduced – resulting in potential greater build of sediment upstream and decreased sediment supply downstream
- Increased large boat traffic will cause bank erosion and pollution

2.1.2 *Primary potential impacts in the study zones from Pak Beng Dam*

The immediate and longer-term changes resulting from Pak Beng Dam in Zone 2 and Zone 3 are shown below. The impact of Pak Beng HPP is expected to be less in Zone 1 although flow rate and sedimentation could be affected, in addition to overall aquatic ecology due to diminished migratory species and communities. The primary changes identified in Section 2.1.1 are used to assess the impacts on biodiversity and socio-economics in Zones 2 and 3.

ZONE 2 From the Thai-Lao border to Pak Beng Dam – approx. 94 km with 7 MRC surveyed dangerous areas; dam = 62 m, reservoir =90 km long – focus is on impacts from creation of Pak Beng HPP dam and reservoir

Construction phase impacts:

- Increasing water levels and decreasing flow velocity upstream of dam as the reservoir fills

Long term impacts:

- Change from lotic to lentic environment upstream of the dam
- Sediment transport will reduced – resulting in sediment build up at the upstream end of the reservoir
- Existing riverine habitats will be flooded
- Anaerobic conditions in the reservoir, down to a certain depth (regardless of vegetation, because of reduced circulation)
- New delta's forming at the bottom of tributaries (likely located further upstream of tributary)
- Barrier to sediment and fish passage

ZONE 3 Pak Beng Dam downstream to Luang Prabang – approx. 176 km with 12 MRC surveyed dangerous areas – focus is on downstream impacts from construction and operation of Pak Beng HPP

Construction phase impacts:

- Rocky materials may be released and distributed in the immediate area of the dam construction
- Some rocky material is likely to be deposited in deep pools downstream of dam construction
- Increased vehicle traffic around dam construction site may increase sediment loads downstream
- Limited or no flow downstream as the reservoir fills

Long term impacts:

- Erosion of bed and banks is likely to occur in areas without bedrock due to reduced sediment supply from Pak Beng HPP
- Increased temperature variability downstream
- Reduced water quality due to anaerobic conditions of lake
- Depending on operation mode, water level variability downstream may cause bank erosion
- Depending on operation mode, there may be small or large-scale changes in the flow regime - likely to be some flattening of the hydrograph resulting in reduced area of seasonally inundated habitat
- Change in the sediment size distribution of the channel bed

3 UNDERSTANDING THE NATURE OF NAVIGATION IMPROVEMENT WORKS USING TWO CHANNEL DESIGN CASE STUDIES

3.1 INTRODUCTION AND DESCRIPTION OF THE SAMPLE AREAS

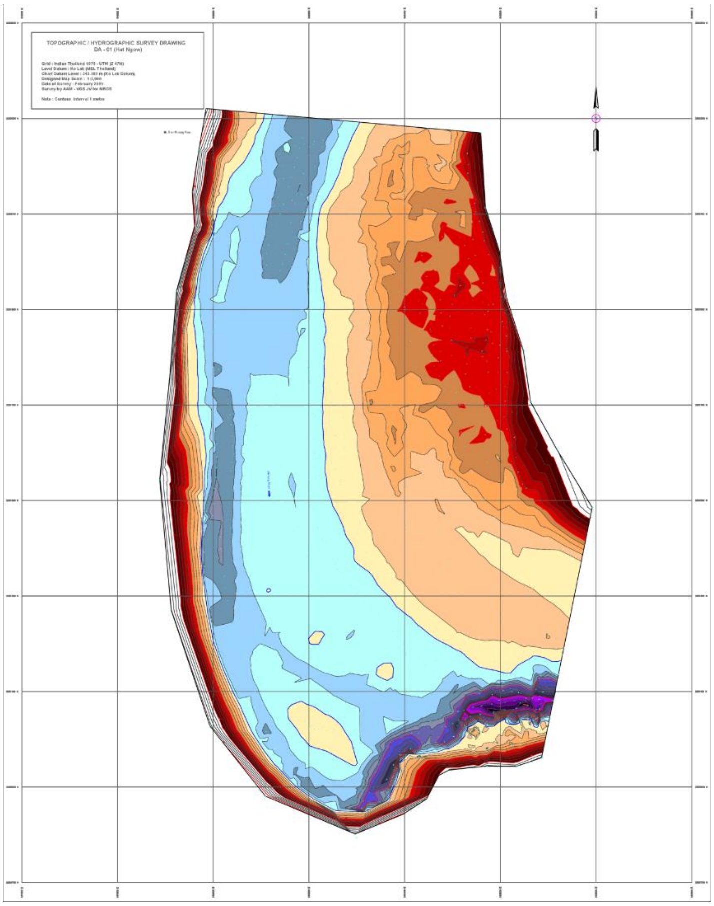
Following the ES field trip along the study stretch in March 2017, the navigation team were requested to describe and elaborate on "channel design" using two sample study-areas. This was undertaken to better understand the likely scale and nature of navigation works to occur under the LMDP (if done according to typical international practice familiar to the ES navigation team), example channel designs were conducted on two MRC surveyed dangerous areas for navigation both in Zone 1 of the study stretch:

- DA-01 at Km 2,324, named Hat Ngao: shallow area over a distance of 1,100m
- DA-04 at Km 2,289, named Keng Nhoy. The series of rapids, just at the border of Lao-Thailand, are commonly called "Keng Pha Dai" and stretch from Km 2,287 to Km 2,290. These are notorious rapids with bends, rock outcrops, narrow channel and strong currents.

Downstream the Kheng Pha Dai rapids, the navigation channel would be situated in the impounded section of the Pak Beng HPP dam and no longer constitute dangers for navigation if that project goes ahead. Although during periods of low flow the former rocky outcrops could be close to the surface and thus continue to be of concern.

Figure 3.1: DA-01: Hat Ngao

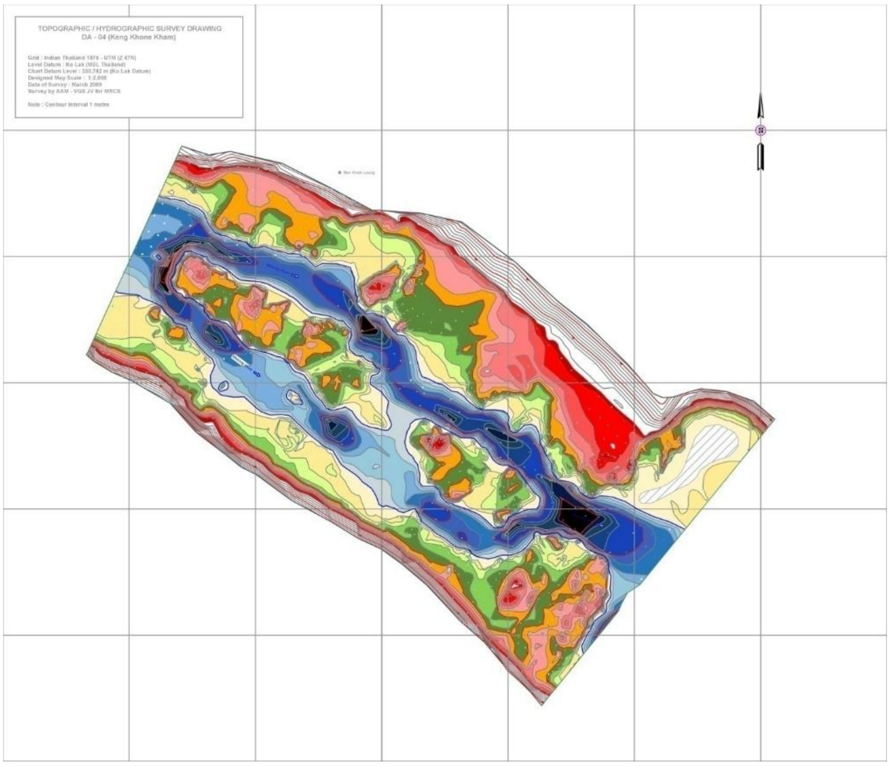
The current is going from top to bottom right. Left of the river is "right Bank" or Thai side. Left of the river is "left Bank" or Lao side. The Thai side is fully under bank protection construction.



In 2008, under the Mekong River Commission's project for "*Condition survey of dangerous areas for navigation between Huay Xay and Luang Prabang*" a number of rapids and shoals were condition surveyed including topographic as hydrographic details. This allowed the river engineer to draw the map in contour lines of equal depth/equal altitude. The two project areas are shown in the following colored figures (Figure 3.1 and Figure 3.2) where every color corresponds to one meter water depth/altitude. The blue colors are related to water depths with reference to chart datum. Chart datum in rivers is the water level that corresponds to the average lowest low water levels (95% of all low water levels in the Gauss distribution). However, this first ever survey of the "Updating of the hydrographic Atlas" from the MRC at that level of precision had no reliable records over a sufficiently long time of every year's low water level in the river stations. Therefore an estimate of the chart datum has been accepted whilst the intermediate points between two stations have been defined by linear interpolation.

Figure 3.2: DA-04: Keng Pha Dai (Keng Khone Kham and Keng Nhoy)

The current is going from top left to bottom right. From this point on, the Mekong river flows entirely on Lao territory, whilst downstream of the rapid, the future impounded area from the Pak Beng dam will start.



These surveys are the basis of the channel design. Channel design is searching for the best navigation channel where design vessels can operate without danger and without hinder from hidden or visible obstacles. The main aim is to keep the excavations, be it dredging or rock removal, to an absolute minimum in order to cause as minimal environmental damage as possible. The main challenge is to create an open channel that does not disturb water levels up- and downstream and therefore a golden rule is to "relocate" the obstacle in the navigation channel to a place in the current where it no longer constitutes a danger for navigation.

Channel geometrics are imposed by the "design vessel" that is chosen and accepted to travel in the project river-stretch. They follow the waterway classification, which for every stretch of the river can be different, as not all river stretches are identical and do not show the same characteristics. It is however the aim of the waterway developer to obtain identical channel conditions in as long as possible stretches and in so far as it is reasonably possible to realize with acceptable changes and modifications to the river.

The waterway surveys have been made in detail to allow the channel design to be made in the best possible conditions. There are hundreds, even sometimes thousands of points measured in X, Y and Z (Figure 3.4). They are brought together by computer calculations in a triangulation network that allows the designer drawing lines of equal depth or equal altitude (Figure 3.3). Every node of this triangulation corresponds to a measured survey point in X, Y and Z. The blue line is the calculated chart datum which corresponds to the average lowest low water level. It is computer defined by interpolation between adjacent nodes.

Figure 3.3: Kheng Pha Dai (DA-04) triangulation model

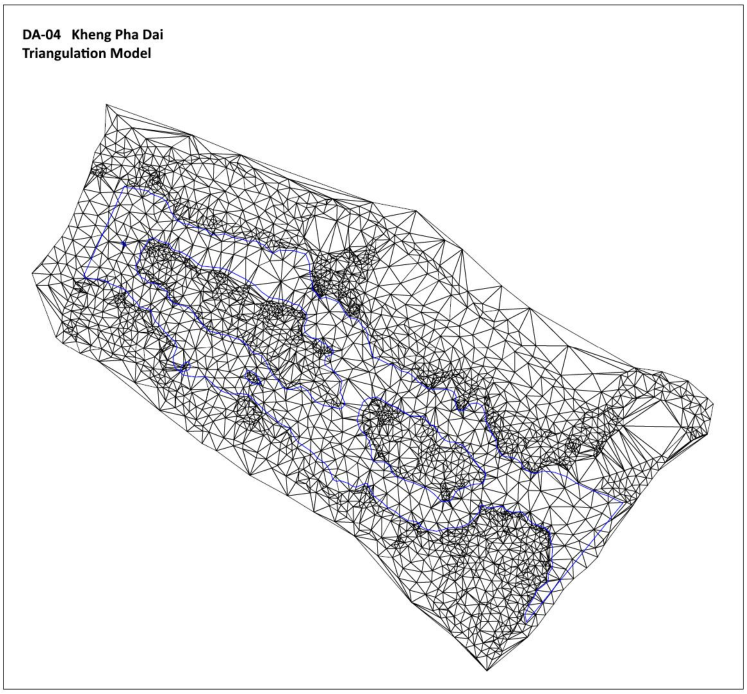


Figure 3.4: Kheng Pha Dai (DA-04) waterway design survey points

This figure shows only the survey points, known in X, Y and Z. This is the basis of every river survey.

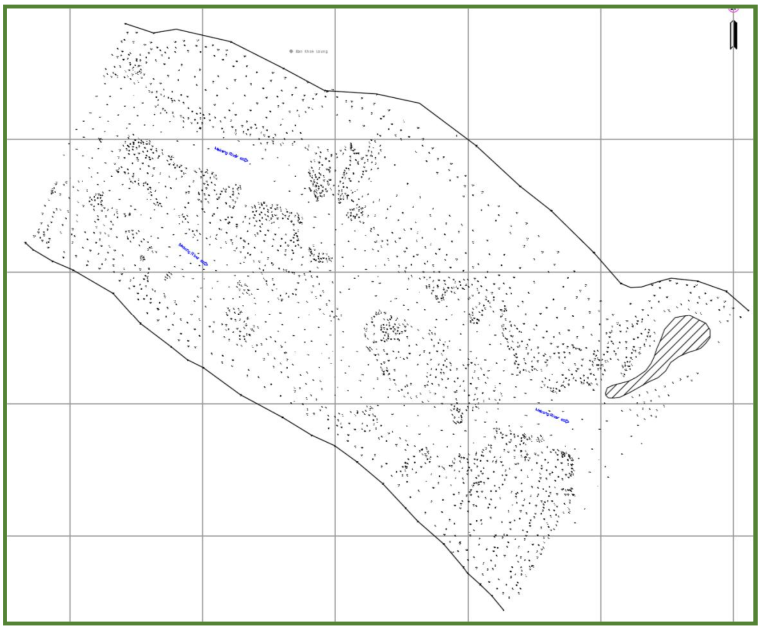
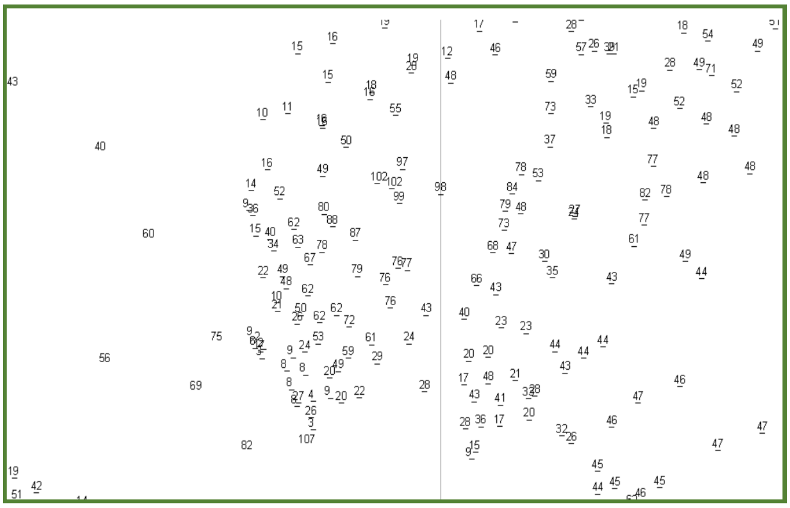


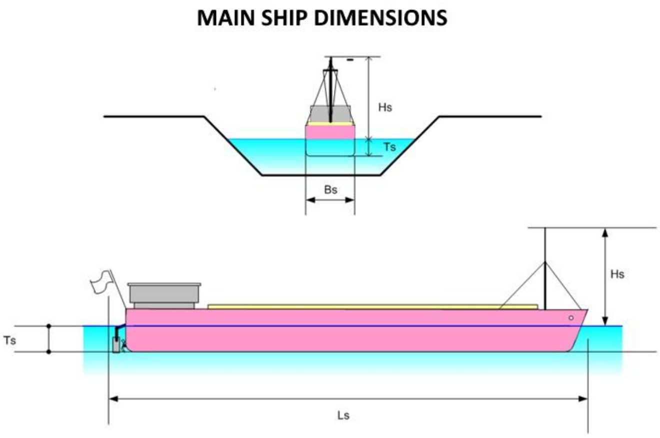
Figure 3.5: Detail of an area with survey points



Detail of an area with survey points is shown in Figure 3.5. The underlined point-levels are *above* the chart datum (topographic survey). Levels are expressed in dm. The other points (not underlined) are hydrographic soundings, expressed in dm *below* chart datum. It's from this information (plotting the survey points) that the result shown in Figure 3.2 is obtained.

The design vessel that has been accepted by the Mekong countries is the one that has to pass the ship locks alongside the hydropower dams on the Mekong is the 500t Chinese model-vessel. It dimensions are shown in Figure 3.6.

Figure 3.6: Main ship dimensions



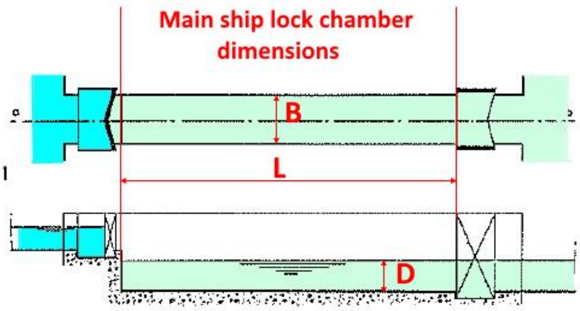
Its dimensions are:

- Ls = 55 m (overall length)
- Bs = 10.80 m (ship beam)
- Ts = 1.60 m (draught)

Figure 3.7: Main ship lock chamber dimensions

The ship lock chamber dimensions which were accepted by the four Mekong countries in the Preliminary Design Guidance (PDG) were (Figure 3.7):

- L = 120 m (length of the chamber)



- B = 12.00 m (width of the chamber between chamber walls)
- D = 4.00 m (useful water depth in the chamber)

Channel characteristics in the river (for the design of waterway improvement) are mentioned in the waterway classifications that every country has accepted. The Mekong navigation channel has been inspired by the PIANC recommendations in terms of width, radii of curvature and minimum water depth. Smaller radii of curvature lead to over widths in the bends.

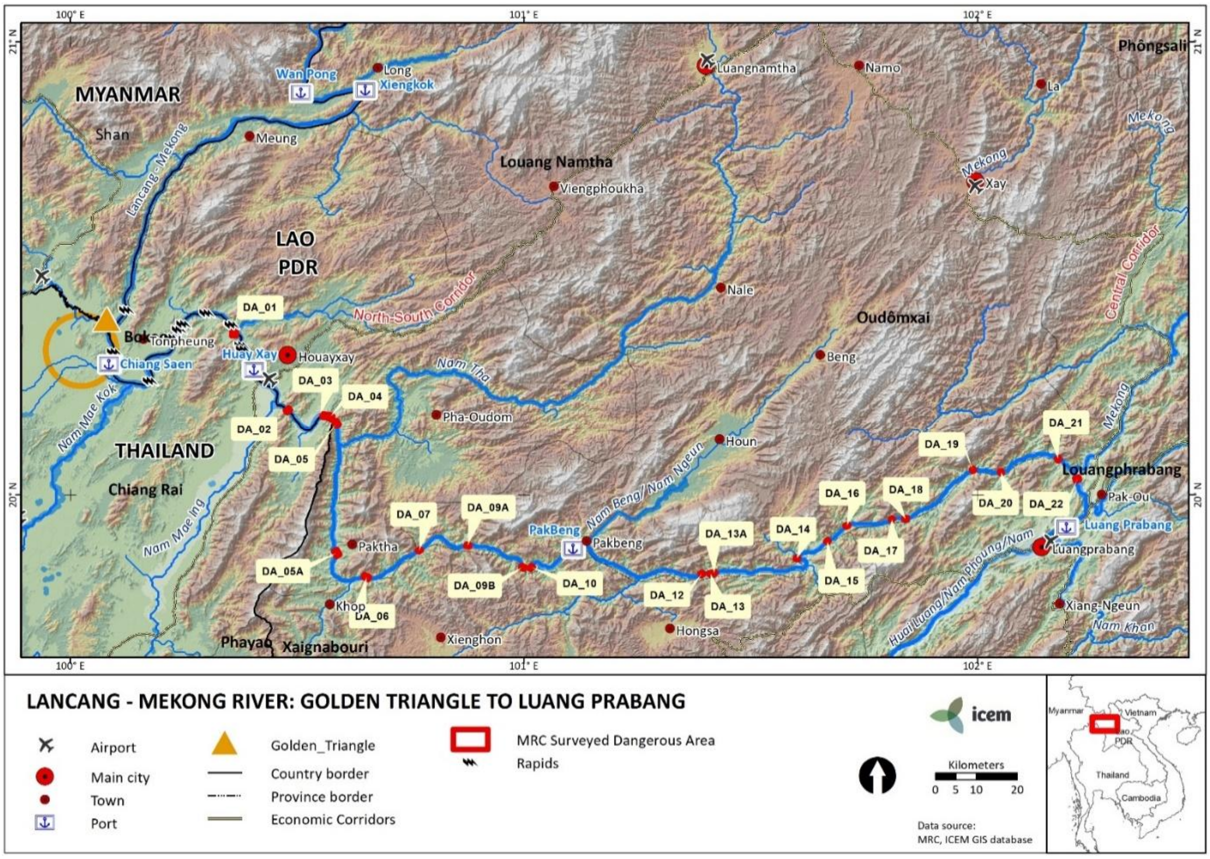
For the two sample cases (DA-01 and DA-04), a minimum water depth of 3.00 meters below chart datum has been accepted. This allows vessels of 2.50m draught to sail on the Mekong. Rock excavations under water have steep slopes, close to vertical in order to limit the volumes. Sand dredging under water has been calculated with slopes of 8/4 average.

Considering the above chosen and accepted dimensions for lock chambers, it becomes clear that the potential of the ship locks bypassing the hydropower dams is much bigger than the 500t Chinese design-vessel. It is therefore wise to keep this possibility in mind when studying navigation improvement on the Mekong and designing permanent infrastructure within environmentally acceptable limits. For this reason, permanent modifications to the waterway should be as minimal as possible allowing for maximum safety in navigation.

The task of the waterway engineer is clear: design a safe navigation channel in a river area, full of obstacles, hidden or not, that meets the above criteria. It is evident that both criteria will meet each other somewhere halfway in the "optimum solution".

There are a number of identified dangerous areas for navigation in the study stretch, including rapids, some of them shallow, others deep and with scattered rock outcrops and sandy beaches, which are an ideal habitat for fish and other aquatic organisms. These MRC surveyed "dangerous areas" are schematically presented in Figure 3.8. The two sample sites Hat Ngao (DA-01) and Kang Pha Dai (DA-04) are shown and described further below.

Figure 3.8: The 23 MRC surveyed dangerous areas in the study area

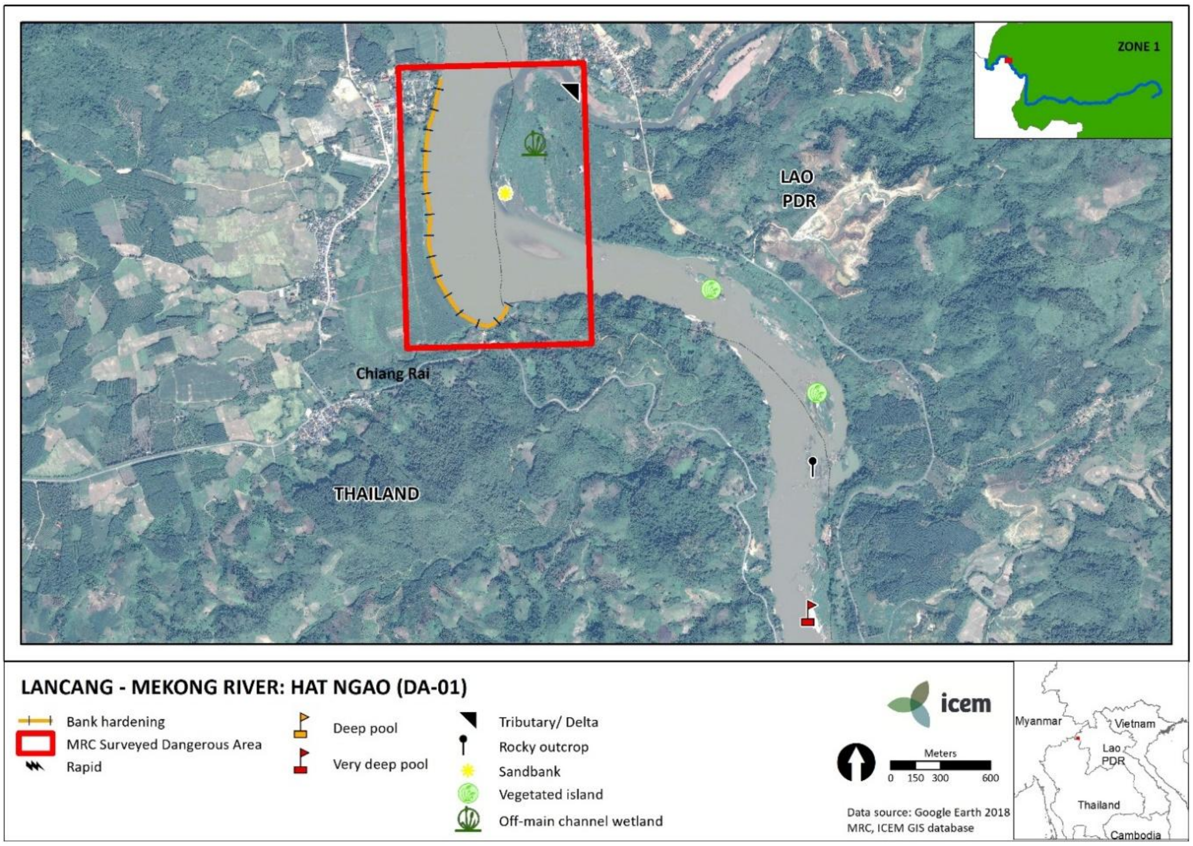


3.2 DA-01: HAT NGAO

Hat Ngao (Figure 3.9) is a shallow river stretch, a relatively wide stretch with gentle bottom slope that steadily erodes (has eroded) the right bank (Thai river bank) in a bend which is downstream getting sharper and sharper. The ultimate bend hits the hard rock and erosion stops. Thai authorities have systematically constructed heavy duty bank protections to stop the erosion on their side. The river flow channel closely follows the right bank and ends in a sharp bend to the left where a deep scour hole of 9 to 15 meters deep has been formed. The sharp bend has a radius of curvature of approximately 80 meters which is too sharp for every medium-sized vessel. Currents are dangerous in this bend due to the sudden deviation from the rocky river bed.

Figure 3.9: Hat Ngao dangerous area for navigation

Above - view upstream in N-W direction. Below – satellite image from above.



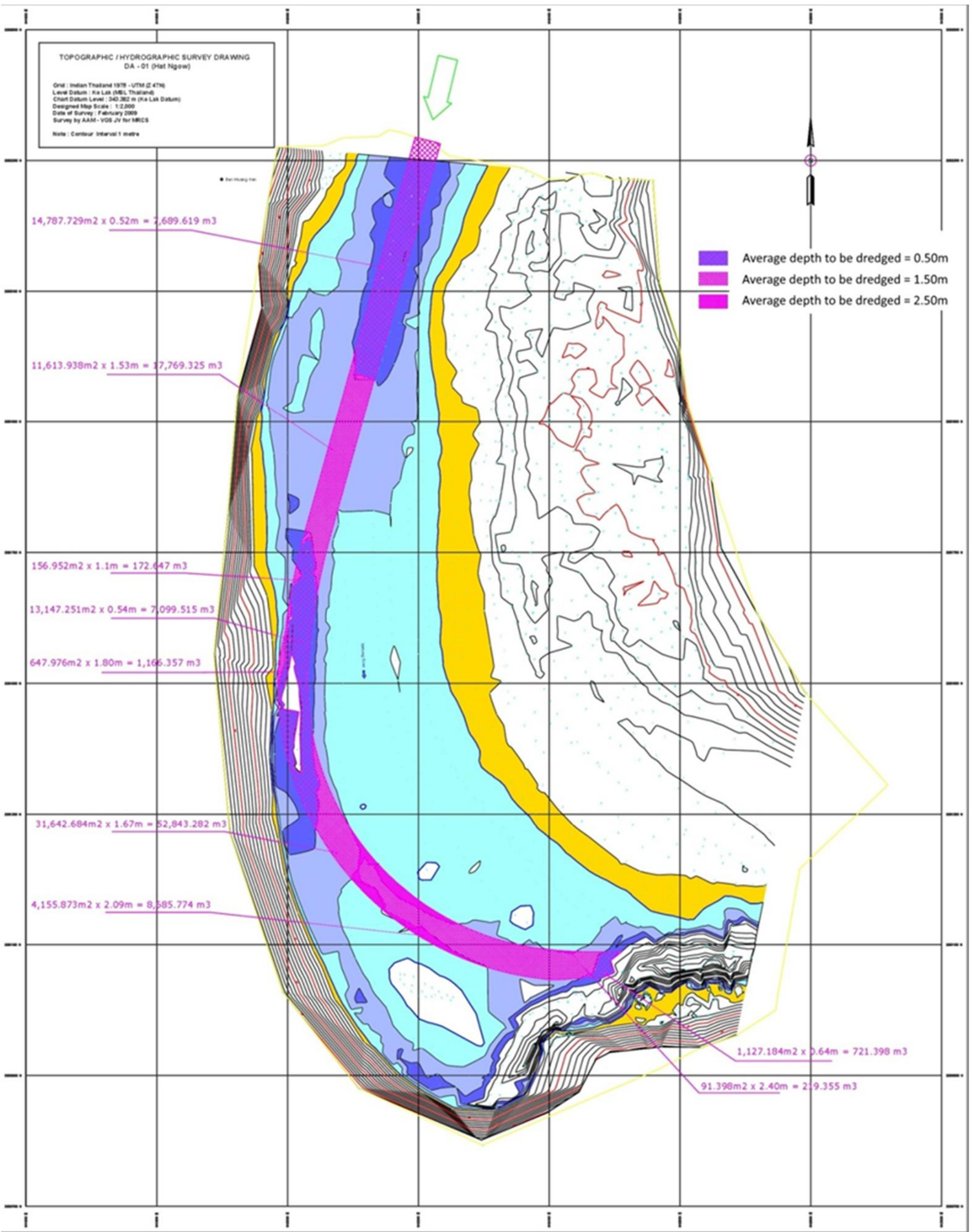
The current navigation channel in the bended scour hole is too sharp for safe navigation, due to the strong current during flood season and the dangerous random mushroom-shaped upwards flows (the water depth is not an issue).

The low level sand bank in front of this sharp curve which inundates at water levels from CD+0.70m on, should be avoided in the new design and a channel should be dredged North of the sand bank with consecutive bends of R=1000m, R = 430m and again R = 1000m, which gently accords with the downstream deep channel. Some scattered rock outcrops just downstream the bend on the left river bank (clearly visible on the drone-picture - Figure 3.9) and some out of the survey area can easily be avoided with a next bend to the right (not shown as out of the survey area).

No rock removal is needed in this design (Figure 3.10). The channel is entirely situated in a sandy area in which the channel has to be dredged. Without proper river training works upstream, this dredged gully will probably silt up rather quickly and will have to be maintained over the years to come.

Figure 3.10: Designed navigation channel with the areas to be dredged to average water depths of -0.50m, -1.50m and -2.50m

The corresponding volumes to be dredged are indicated on the side of the drawing for the various water depth zones. Yellow = Mekong floodplain; Purple = dredge depth 1.5-2.5m; Blue = water depth



The chosen navigation channel is the result of a number of attempts with corresponding calculation of the dredging volumes. Dredging volumes are less important than rock removal, the latter being permanent whilst dredging is likely an operation which needs yearly follow up with maintenance dredging.

The DA-01 (Hat Ngao) navigation channel could be stabilized by proper river training works like groynes starting from the Thai river bank (instead of the expensive heavy duty bank protections). The new dredged channel as-such is unstable due to the up- and downstream configuration of the river. The course of the river leans towards the right bank and groynes will be needed to deviate this current midstream to create a scouring effect in the dredged channel.

The total dredging volumes are as follows:

DA-01 - Hat Ngao								
R.O.			**Bottom river bed deepening**			**L.O.**		
surface	average depth	volume	surface	average depth	volume	surface	average depth	volume
			14,787.729	0.520	7,689.619			
			11,613.938	1.530	17,769.325			
156.952	1.100	172.647						
			13,147.251	0.540	7,099.516			
647.976	1.800	1,166.357						
			31,642.684	1.670	52,843.282			
4,155.873	2.090	8,685.775						
						91.398	2.400	219.355
			1,127.184	0.640	721.398			
		10,024.779			86,123.140			219.355

DA-01 - Hat Ngao					
R.O.			**L.O.**		
channel length L	average depth d	volume: $d^2 \times L$	channel length L	average depth d	volume: $d^2 \times L$
338.050	0.500	84.513	372.500	0.500	93.125
305.880	1.500	688.230	329.370	1.500	741.083
37.310	0.500	9.328			-
27.400	1.500	61.650			-
25.580	0.500	6.395			-
134.670	1.500	303.008			-
224.680	0.500	56.170	228.080	0.500	57.020
91.980	1.500	206.955	153.340	1.500	345.015
248.000	2.500	1,550.000	221.290	2.500	1,383.063
145.530	1.500	327.443	135.420	1.500	304.695
		-	50.320	2.500	314.500
		-	35.990	1.500	80.978
32.860	0.500	8.215	33.800	0.500	8.450
		3,301.905			3,327.928

In total 96,367.274 m^3 of sand has to be dredged, not including the underwater slopes.

Underwater slopes of 8/4 will add up to 6,629.833 m^3 which brings the grand total at 102,997.107 m^3

Key points:

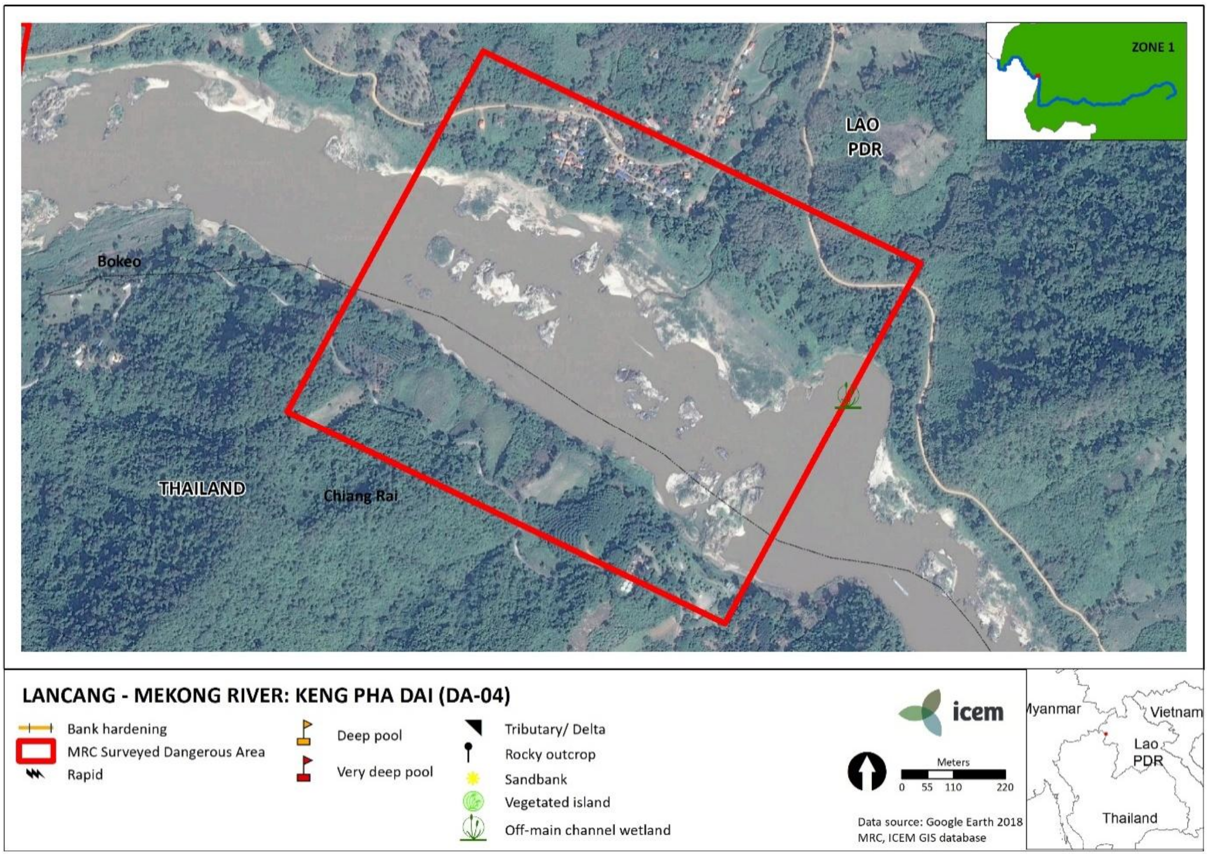
- No rock removal necessary
- Channel in sandy area, to be dredged
- Without river training works upstream, gully might silt up
- Some 103,000 m^3 sand to be dredged annually

3.3 DA-04: KHENG PHA DAI

Kheng Pha Dai (Figure 3.11) or DA-04 is a typical rapid and like many others along the Mekong and in the ES area. The river runs over two branches with many scattered rock outcrops and islets where sand has deposited between the rocks. For this reason there are no deep holes in this area. This rapid is the last rapid situated on the common Mekong between Thailand and Laos before the Mekong flows on into entirely Lao PDR territory. It is narrowly out of the influence of the Pak Beng HPP reservoir although it is expected that during some high water conditions and maximum storage conditions of the impounded area some water level influences may occur. The most important influence however may come from the early deposit of sand, gravel and silt. However it's likely that this accretion phenomenon will be more pronounced downstream in Lao PDR territory.

Figure 3.11: Upstream view of Kheng Pha Dai rapid (top) and satellite image (bottom)

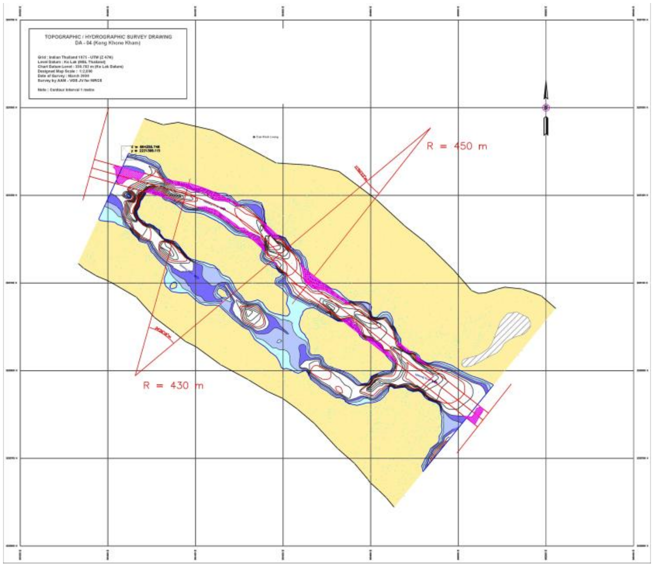
Left is the Thai riverbank, right the Lao riverbank. The Northern channel is deeper and straighter and with less obstacles for navigation.



A condition survey was carried out in 2008 and a channel design has been made for a channel of 4 meters deep. However, the design presented here (Figure 3.13) maintains the channel depth to 3 meters below chart datum, with a 40 meter wide channel and bend radii of not less than 430 meters.

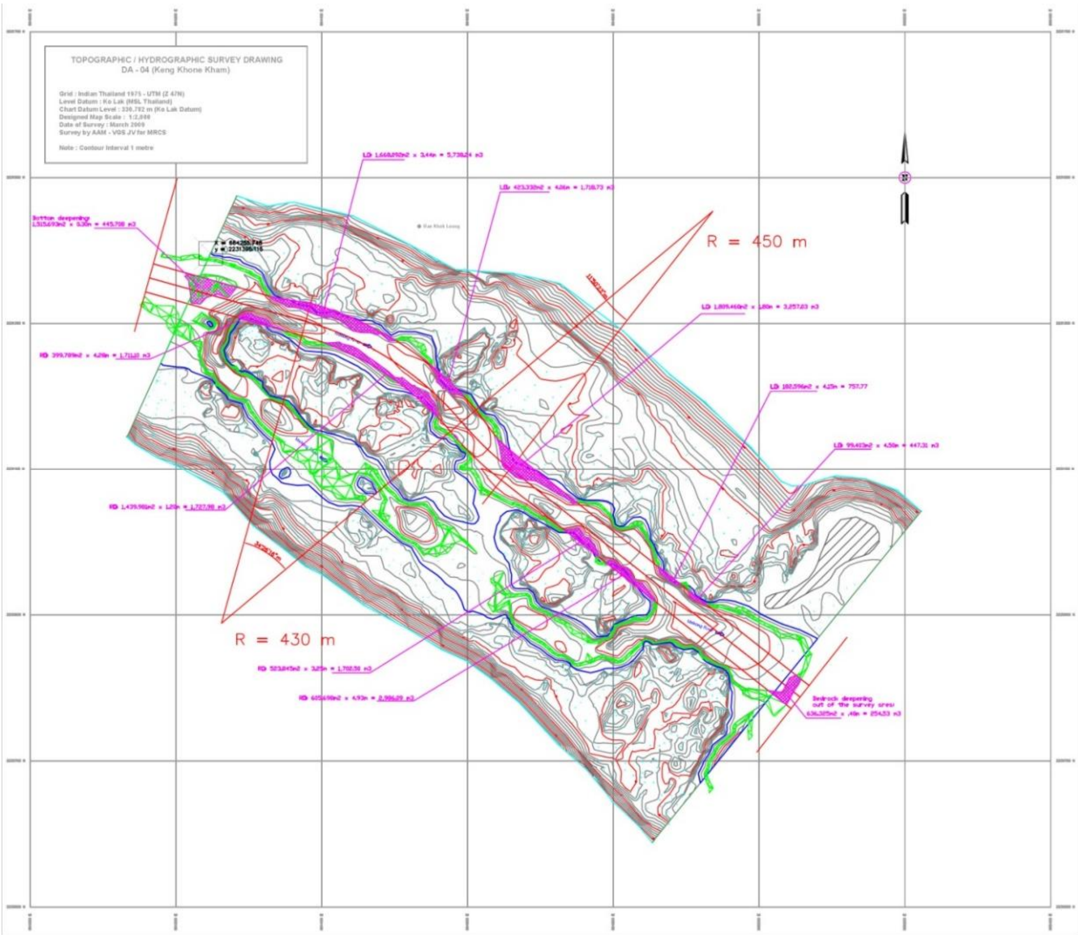
In this type of rapid it is laborious work of trial and error to find the most suitable channel requiring the least excavations and the best result.

Figure 3.12: Kheng Pha Dai rapid design schematic showing floodplain (yellow)



The yellow colored area (Figure 3.12) is the flood plain of the Mekong, although not all islands are completely flooded. The Mekong is about 450-480 meters wide at this location while the two channels together are about 2 x 40m = 80m. The Northern channel is the most suitable; deep but narrow and some sharp short bends that need chiseling. Excavations are moderate for this size of rapid and a carefully planned storage of the rock debris from the excavations will nullify the changes in water levels from the rock removal.

Figure 3.13: Channel design at Kheng Pha Dai (purple/pink = areas to be removed)



In total 20,501.499 m^3 of rock (some of the three above) has to be removed mainly from chiseling the channel banks (Figure 3.14). Debris from this rock chiseling can be stored in the coves between two chiseling areas, contributing to the same flow obstacle for the current and reducing turbulences from outcropping river banks.

Figure 3.14: Excavation volumes at Kheng Pha Dai

DA-04 - Kheng Pha Dai								
R.O.			**Bottom river bed deepening**			**L.O.**		
			1,515.693	0.300	454.708			
399.789	4.280	1,711.097				1,668.092	3.440	5,738.236
1,439.981	1.200	1,727.977				423.332	4.060	1,718.728
		-				1,809.460	1.800	3,257.028
523.845	3.250	1,702.496				182.596	4.150	757.773
605.698	4.930	2,986.091				99.403	4.500	447.314
		8,127.662			454.708			11,919.079

Underwater slopes are almost vertical in rocky soils unless it is feared that the embankments of the channel consist of weak weathered rocks. This possibility is rather small given the centuries old attacks from often very strong currents with floating logs and trees coming down the river and continuously bumping into the embankments.

These rock removals would constitute a very small surface area of the entire rapid. Considering the low water surface during dry season with water levels at chart datum, the rock surface to be removed constitutes 8,667.89 m^2. This represents **6.97% of the wet surface** at chart datum level, or **1.88% of the entire surface of the rapid**. In other words, **98.12% of the surface of the Keng Pha Dai rapid remains untouched** during the navigation channel improvement.

Key points of the example design for Keng Pha Dai are:

- 20,501.499 m^3 removal of rock – from chiseling of channel banks
- Removal represents a small part of the rapid (6.97% of wet surface at low water level / 1.88% of total rapid surface)
- 98.12% of rapid untouched
- Design allows vessels up to 1,500-1,600t (3m water depth) to safely pass the rapid

3.4 CONCLUSION

Navigation channel improvements are in most cases surgical excavations if best practice is applied, mainly consisting of chiseling rocky banks or removal of scattered rock outcrops in the middle of the channel, that generally impact on a small part of the entire surface of the outcrop.

The Keng Pha Dai rapid can be made accessible for vessels of up to 1,500 – 1,600 t (3 meters water depth) with only 1.88% of the total rapid surface affected, with a guarantee that water levels up- and downstream will not noticeably be affected as the rock debris from rock removal or excavation will be dumped in the river to obstruct and direct the current into the navigation channel (groynes). These groynes are also potential new habitats for aquatic life and fish habitats. Hat Ngao requires no rock removal and only dredging requiring regular maintenance dredging.

4 LMDP IMPACT ASSESSMENT RESULTS

4.1 HYDROLOGY AND SEDIMENT IMPACT ASSESSMENT

4.1.1 *Introduction*

Hydrology and sediment transport are river characteristics that have major implications for ecology and biodiversity. For example, flooding enables connectivity to the floodplain and rising water levels can serve as a trigger for fish spawning. Changes in sediment transport can provide new habitat for fish species, or alternatively can smother existing habitats or fill in pools.

In this report we document the potential impacts on hydrology and sediment transport from improving the river for navigation by clearing “dangerous areas” and constructing ports in the section of the Mekong River between Luang Prabang and Chiang Saen.

4.1.2 *Summary of baseline condition*

The baseline report established the current situation of hydrology and sediment transport in the Mekong mainstream and identified recent drivers of change across two key time frames i.e. before and after construction of the first upper Mekong dam, the Manwan Dam i.e. pre- and post-1992. The study was conducted based on a literature review and analysis of data obtained from two stations in the Mekong mainstream: Chiang Saen (located upstream in the lower Mekong) and Luang Prabang (located downstream of the lower Mekong).

4.1.2.1 Hydrology status and current trends

The hydrological characteristics of the reach are described under five key themes:

- **Annual flow volumes:** Analysis of the annual flow volumes at Chiang Saen and Luang Prabang reveal little long-term change in flow volumes despite annual and decadal fluctuations. A large volume of water joins the Mekong along the study reach - annual flow volumes at Luang Prabang average around 40,000 Mm^3 higher than that at Chiang Saen, and the difference has reached as high as 95,000 Mm^3;
- **Annual flood pulse (seasonal hydrology):** The seasonal hydrology of the Mekong Basin is largely shaped by the combination of two monsoon regimes resulting in a monomodal flood pulse from July to September. Water levels recorded at Chiang Saen fluctuate by up to 10 m between mid-April and mid-August, and at Luang Prabang, the seasonal changes in water levels can exceed 15 m. Despite these major fluctuations, the study reach is in the upper section of the Lower Mekong Basin, above many of the large left bank tributaries, and its flood pulse is far less pronounced than further downstream;
- **Extreme floods:** Extreme floods are a regular occurrence in the Mekong River. Analysis of Annual Recurrence Intervals (ARI) in the study reach indicate that floods are of greater magnitude at the lower end due to the numerous tributary confluences. For example, the 2-year ARI peak discharge at Chiang Saen is 10,130m^3/s, and 14,950m^3/s at Luang Prabang;
- **Floodplain connectivity:** With the available datasets, particularly the lack of cross-sections, the study team were not able to estimate bankful discharge, an important indicator of the connectivity of the river to its floodplain, although other studies have suggested that it is a rare event in the study reach; and
- **Influence of the upper Mekong Basin**: The study reach is located at the top end of the Lower Mekong, approximately 250 km downstream of the Chinese Border and its hydrology is still heavily influenced by the Upper Mekong catchments. At Chiang Saen the Upper Mekong catchments contribute 70% of wet season and almost all the dry season flow.

4.1.2.2 Sediment transport status and current trends

Sediment transport through a river reach is influenced by sediment supply (from upstream or within the study reach) and sediment transport capacity. There have been numerous sediment transport studies conducted for the Mekong River, but few focussed specifically on the study reach. Sediment transport characteristics of the study reach are described under four key themes:

- **Sediment supply - upstream catchment**: For the study reach, the upper basin is the main source of sediment supply. Due to the high rate of erosion in the upper catchments, the average suspended sediment load at Chiang Saen (pre-construction of the Manwan Dam) has been estimated at 81.7 million tonnes a year, compared to 76.8 million tonnes a year at Luang Prabang. These volumes also show that the reach acts as a sediment sink.
- **Sediment supply - tributaries confluence**: The supply of sediment from tributaries within the study reach could not be quantified as no literature could be found and the study team could not obtain sediment or hydrological data for the tributaries. The study team therefore took a qualitative approach using satellite imagery to identify which tributaries are likely to be supplying large amounts of sediment. Two tributaries were identified as likely to be supplying large amounts of sediment as they have large catchments with large areas of agriculture and/or mining, and sediment deposits visible in the lower tributary – Nam Ou and Nam Ngeun. Five tributaries were identified as likely to be supplying moderate amounts of sediment to the mainstream.
- **Sediment supply - bank erosion**: Literature and analysis of satellite imagery showed that there is limited bank erosion in the study reach. Therefore, whilst bank erosion occurs within the study reach, its contribution to sediment supply is likely to be limited compared to upstream catchments and tributaries.
- **Sediment transport capacity**: Sediment transport capacity is the capacity of the river to move sediments along the channel, and is a function of flow velocity, channel cross-sectional area, channel slope and sediment grain-size distribution. For the study reach, the suspended load is comprised of silt and clay washload as well as graded coarse sand, and bedload is dominated by sand and gravel.

4.1.2.3 Drivers of Hydrology and sediment transport

There are several drivers of change to the hydrology and sediment transport of the study reach. The drivers are categorized under the following themes:

- **Upper Mekong dams**: Construction of the Manwan and Dachaoshan Dams (1992 and 2003) had minimal impact in the study reach due to their relatively small size. Since 2009 when the storage size of the constructed dams increased significantly, there has been a decrease in dry season flows and increase in wet season flows in the study reach. The influence of the Upper Mekong dams lessens moving downstream through the study reach.
- **Land clearing and deforestation**: At present, the large-scale land clearing and deforestation in the upper Mekong catchment appears to have had minimal impact on the river's hydrology. However, the 22% decrease in forest cover between 1960s and 2000s has significantly increased suspended sediment loads.
- **Embankment developments**: Analysis of satellite imagery shows that numerous embankments have been built within the study reach, particularly on the Thai banks. These embankments may decrease erosion on the bank where the embankment is constructed but field observations suggest they cause erosion on the opposite bank and further downstream.
- **Climate change**: Climate change is projected to increase rainfall across the Mekong Basin, leading to increased annual flows in the Mekong mainstream. At Chiang Saen and Luang

Prabang the flow is projected to increase throughout the year, with the greatest increases occurring during the wet season. The timing of the flood peak is also expected to change, with a delay of a few days at Luang Prabang and a delay of up to 14 days at Chiang Saen.

4.1.3 *Impacts in the study reach from the LMDP*

4.1.3.1 Hydrology

4.1.3.1.1 Construction phase impacts

No impacts on hydrology have been identified for the construction phase of the LMDP in the study reach.

4.1.3.1.2 Longer term impacts

Table 4.1: Longer term impacts on hydrology

Impact description	Likelihood	Consequence	Risk
Slowing of flow due to increase in river cross-section	Possible	Negligible	Low

Slowing of flow due to increase in river cross-section

The flow velocity within a river section is a factor of the discharge and the cross-sectional area (represented as $V=Q/A$ where V=velocity in m/s, Q = discharge in m^3/s and A = wetted cross-section area in m^2). When removing rock obstructions in the river, the river cross-section area may be increased which would cause a slowing of the flow velocity and lowering of the water level in the immediate area of the works.

Analysis of the potential works for one example rapid – Kheng Pha Dai – indicates that the total surface area affected would be minimal (1.8% for the example). Although the details of every rapid would be different, the finding that only small percentage changes will be required is likely to be consistent, and therefore the impacts on flow velocity will be localized and small.

In addition, the impact can be avoided if best practice navigation improvement works are adopted as they aim to place the removed rock in a location outside of the channel but close to the removal areas. This creates an obstruction that approximates the removed rock, therefore minimizing any changes in velocity.

4.1.3.2 Sediment transport

4.1.3.2.1 Construction phase impacts

Table 4.2: Construction phase impacts on sediment transport

Impact description	Likelihood	Consequence	Risk
Rocky material released and distributed in the immediate area of obstruction removal	Possible	Moderate	Moderate
Rocky material deposited in deep pools downstream of obstruction removal	Unlikely	Moderate	Low
Sand from bed, banks and islands removed through dredging	Almost certain	Moderate	High
Sand from sand banks and islands deposited downstream and on adjacent banks	Possible	Moderate	Moderate
Port construction clearing and dredging releases materials into the river	Almost certain	Moderate	High

Distribution of rocky materials

In removing rock obstructions from the river, a significant amount of rocky debris will be created. For example, an estimate of the works required at Kheng Pai Dai indicates a removal of 20,500 m^3 of rock (equivalent to around nine Olympic sized swimming pools).

Rock obstructions are generally removed through boring or blasting. Boring is a more precise approach and the rocky debris can be relatively easily captured and re-placed according to engineering designs. When blasting, most debris may be captured, but there will also be some materials that are not captured and are distributed in the immediate area. This debris may range from large boulders unlikely to be easily moved once re-settled to smaller sized debris that can be transported downstream. Of the smaller sized debris carried downstream, some may be deposited in nearby deep pools.

With the available information it is not possible to provide an estimate of the debris that will be created and transported downstream, but if best practice approaches are adopted in removing the obstructions, then only a small amount of debris is likely to be created and deposited.

Dredging of sand in bed, banks and islands

In undertaking river improvements works, sand is often removed from the channel bed and islands through dredging to make a deeper channel. Analysis of stream powers along the Mekong has indicated that bedload sediment transport in the study reach is comprised of sand and gravel (Bravard and Goichot, 2013). Therefore, dredging will not cause a permanent change in the riverbed at the site, as sand and gravel sediment transported from upstream will fill the dredged area. However, the dredging works can be expected to change the downstream sediment dynamics as the sediment replacing the dredged area is not carried downstream, causing reduced sediment supply which may lead to bed and bank erosion.

The impacts of sand mining in the Lower Mekong Basin provide an insight into the possible impacts of dredging for navigation improvements. In an example calculation of the sand removal required for navigation at Hat Ngao, it was estimated that 100,000 m^3 of sand would need to be dredged. Research on the Mekong River in a section between Vientiane and Savannaketh - just downstream of the study reach - has shown that riverbed sand mining of an estimated 4,154,000m^3/year has led to riverbed incision, reaching up to 1 to 3 meters locally, and increased lateral erosion (Bravard and Goichot, 2013). Whilst the volumes of sand removed by dredging in the study reach will be lower, and the study reach is comprised of more bedrock stretches than downstream, it can be expected that similar, albeit less severe, riverbed incision and lateral erosion will occur.

When dredging, sand is either placed on the bank to be sold for construction use or on barges to be transported elsewhere. Whilst the eventual placement of the dredged materials will change from site to site, it may cause impacts if placed in an inappropriate area. For example, if deposited haphazardly downstream it may cover important habitats.

Clearing and dredging for port construction

Port construction will involve clearing and dredging which will impact on the sediments of the immediate area of the port and may release finer sediment into the river.

4.1.3.2.2 Longer term impacts

Table 4.3: Longer term impacts on sediment transport

Impact description	Likelihood	Consequence	Risk
Slower flows reduce sediment generation	Possible	Negligible	Low
Changing flow affects sediment transport	Unlikely	Moderate	Low
Increasing large boat traffic causes bank erosion and pollution	Almost certain	Moderate	High
Dredging changes downstream sediment dynamics	Almost certain	Moderate	High

Slower flows reduce bank erosion

Bank erosion rates are largely influenced by flow velocities and the bank substrate. Slower flows caused by channel widening may lead to lower rates of bank erosion as the stream powers are reduced. As discussed under the analysis of changes to hydrology, the impact on flow velocities will likely be localised and minor, therefore not likely to have a large impact on bank erosion. In addition, whilst erosion currently occurs within the study reach, it is limited by the large sections of bedrock bank. Bank erosion contribution to sediment supply is therefore limited compared to sediment entering from upstream catchments and tributaries (Dubeau, 2004), and any changes in bank erosion are unlikely to have a major influence on the sediment dynamics of the reach.

Changing flow affects sediment transport

Sediment transport capacity is the capacity of a river to move sediments along the channel, and is a function of flow velocity, channel cross-sectional area, channel slope and sediment grain-size distribution. Widening of the river may lead to wider channel cross-sectional area and slower velocities which lead to a lower sediment transport capacity. As mentioned above, the impact on velocities and channel width will be localised and minor, especially if best-practice construction approaches are adopted, therefore not likely to have a large impact on sediment transport through the reach.

Boat traffic causes pollution and bank erosion

Increased numbers and size of boat traffic may intensify bank erosion and pollution. As part of the navigation improvement works it is planned for Chiang Sean to become a large port and serve as a connection between China and Lao PDR commercial trade. With the planned increase in vessel numbers and sizes plying the route, water quality may be affected by the pollution caused by diesel powered ships and increasing likelihood of accidental oil spills (Osborne, 2004).

In bank sections with non-cohesive soils, the increased wave action from the larger size and number of boats may increase bank erosion. The Thai side of the river in this section is being progressively protected with embankments (example in Figure 4.1), so the impact can be expected to be more substantial on unprotected bank areas of the Lao side.

Figure 4.1: Construction of embankments between 2013 (left) and 2015 (right)

Dredging changes downstream sediment dynamics

Continuous dredging of the bed and banks will be required to maintain the channel for navigation. As described in the above section on the short-term impact of dredging, this is likely to lead to changes in downstream sediment dynamics, leading to long term increased bed incision and lateral erosion.

4.1.4 *Conclusions*

Based on the impacts analysis presented in this report, the **highest risk impacts identified** for the study reach are: dredging of sand from bed banks and islands for navigation improvement 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 extent and scale of the impacts will depend on how well the transport improvement works are undertaken according to international best practice. As follow up to this impact report, a mitigation report has been prepared to outline what mitigation opportunities are available, and what elements of best practice will be most important to implement.

Table 4.4: Summary of hydrological impacts across the three sections

Impact description	Construction/ long term	Likelihood	Consequence	Risk
Slowing of flow due to increase in river cross-section	Long	Possible	Negligible	Low

Table 4.5: Summary of sediment impacts across the three sections

Impact description	Construction/ long term	Likelihood	Consequence	Risk
Rocky material released and distributed in the immediate area of obstruction removal	Construction	Possible	Moderate	Moderate
Rocky material deposited in deep pools downstream of obstruction removal	Construction	Unlikely	Moderate	Low
Sand from bed, banks and islands removed through dredging	Construction	Almost certain	Moderate	High
Sand from sand banks and islands deposited downstream and on adjacent banks	Construction	Possible	Moderate	Moderate
Port construction clearing and dredging releases materials into the river	Construction	Almost certain	Moderate	High
Slower flows reduce sediment generation	Long	Possible	Negligible	Low
Changing flow affects sediment transport	Long	Unlikely	Moderate	Low
Increasing large boat traffic causes bank erosion and pollution	Long	Almost certain	Moderate	High
Dredging of the bed and banks to maintain the channel for navigation changes downstream sediment dynamics	Long	Almost certain	Moderate	High

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4.2 AQUATIC ECOLOGY AND WETLANDS IMPACT ASSESSMENT

4.2.1 *Introduction*

The impacts on aquatic ecology and wetlands of river training and rapid removal for improved navigation in the Lancang Mekong arise from the direct damages that will occur during the works, and the longer-term changes in the aquatic ecology that will develop due to changes in hydrology and sediment. In the baseline report, the aquatic ecology was disaggregated into four components – the geomorphology and habitats, water quality, aquatic and riparian vegetation, and macroinvertebrates.

In this section, we document the potential impacts on the aquatic ecology and wetlands from improving the river for navigation by clearing “dangerous areas” and constructing ports in the section of the Mekong River between Luang Prabang and Chiang Saen.

4.2.2 *Summary of baseline condition*

The baseline report established the current situation of aquatic ecology in the Mekong mainstream, trends and drivers of change. It used both the visualisation of the river habitats and conditions through field survey and the most recent water quality assessments undertaken by the MRC, and the BioRA assessments carried out for the MRC’s Council study. This study compared conditions between 1985 and 2014.

4.2.2.1 Water quality

- In general, the water quality in the reaches of the Mekong between Chiang Saen and Luang Prabang as measured by the Index for Protection of Aquatic Health, shows a Good Quality Rating (B) for 2015, though there has been a decline in water quality since 2011 when all three sampling sites achieved a High Quality rating (A). There would appear to be a trend in declining water quality since 2011.
- The water quality index for Protection of Human Health is a higher standard, reflecting the acceptability of river water for human use. The patterns of this index are very similar to the Index for Protection of Aquatic Life, with general changes from High Quality to Good Quality occurring after 2011, and all three upper sampling stations now registering as Good Quality.
- The Aquatic Ecological Health Index scores show that the upper Mekong near the Chinese border was in Poor health but has improved to Moderate in 2013. The sampling sites in the Mekong between Chiang Saen and Luang Prabang show Good Aquatic Ecological Health and this was confirmed through littoral macroinvertebrate survey in 2017.

4.2.2.2 Geomorphology

- The geomorphology of this section of the Mekong from the Chinese border through to Luang Prabang is predominantly described as a single, bed-rock confined channel. As with many upland rivers it has a high average slope and high velocities of water flow.

- However, although the river is bedrock-confined, the upper reaches of the Lancang are one of the most important areas of where sediment transport in the Mekong originates, and large volumes of sediment pass through the upper Mekong and create large alluvial deposits that are seasonally transported down the river during the wet season.
- Within the structure of the rocky channel, sand and gravel banks form at specific locations, such as confluences with tributaries, mid-stream islands and point bars where there are slower sections of the channel and backwaters. This part of the Upper Mekong has a higher percentage of gravel in the bedload compared to reaches further south. The alluvial deposits provide an important substrate for vegetation and aquatic fauna that find the faster moving water through exposed bedrock more difficult to colonise.
- The indicators for the changes in geomorphology include:
    - Erosion
    - Average bed sediment size in dry season
    - Availability of exposed sandy habitat in dry season
    - Availability of inundated sandy habitat in dry season
    - Availability of exposed rocky habitats in dry season
    - Availability of inundated rocky habitats in dry season
    - Depth of pools in bedrock in dry season
    - Water clarity and quality
- Trends in these indicators since 1985 assessed by the MRC Council Study, show that apart from Erosion, which has declined from an A rating in 1985 to a D rating in 2015, there has been little change in the other indicators in the stretch down to Pak Beng. Below Pak Beng the geomorphological indicators already showed a decline in 1985 but, this had not changed by 2015.

4.2.2.3 Wetland habitats

- The different types of wetland habitat identified in the study stretch in the Mekong system are shown in Table 4.6.

Table 4.6: Different wetland habitat types identified in this stretch of the Mekong

Wetland Habitat Type	Description
Rivers	Mekong and its tributaries
Streams	Several streams running through evergreen forest and joining the Mekong
Seasonal mudflats, pebble flats and sand bars	Seasonally inundated habitats
Seasonally inundated shrubland	Seasonally inundated herbaceous shrubland vegetation on either side of the Mekong river as well as in islands of the Mekong river
Seasonally inundated swamp forest	Areas with woody plants, including trees that are inundated during the rainy season, located in lowland areas beside the river
Rock outcrops	Wet rocks, boulders and cliffs emerging out of water. These would sometimes be colonised by specialised vegetation – e.g. *Kinsen* found at Tang Salum and Wong Wit rapids.
Riverine rapids and deep pools	Deep water pools in the river, especially in areas of riverine rapids
Pools in riverbank	Small water pools beside the river, with rocky/sandy/muddy substratum

4.2.2.4 Aquatic and riparian vegetation

- The Mekong river in this stretch has relatively steeper banks, faster moving waters and thus a smaller area of riparian vegetation. The characteristic riparian vegetation can be divided into the different horizons of the river.
- The lower banks and in-channel alluvial deposits are dominated by rheophytes – plants which are adapted to growing in fast moving waters, so that they have seasonal growth patterns that follow the water level, germinating and growing during low flows and being inundated during higher flows. The characteristic rheophyte of this low horizon is Homonia riparia, which grows throughout this stretch of the Upper Mekong.
- The middle and upper horizons of shoreline vegetation are mostly short trees, shrubs and lianas and further up the banks, secondary rainforest species grow.
- Pioneer herbaceous annuals and perennials, often dominated by grasses occupy the loose and shifting sandy and sandy loam substrates that form islets, islands and banks with river channels.
- Submerged aquatic vegetation usually consists of several species and strains of Cladophora glomerate and Aegagropila linnaei and provide riverine communities of northern Laos and Thailand with an ample, seasonal supply of green algae. This is an important commercial natural product – Mekong River weed. Clear waters are required for their culture and harvest.
- The indicators of change in aquatic and riparian vegetation are shown in Table 4.7.

Table 4.7: Indicators of changes in aquatic and riparian vegetation

BioRa Indicator	Indicator species/groups of species	Reasons for selection
Channel_Riparian trees	*Acacia harmandiana, Zyzygium mekongensis, Phyllanthus jullienii, Salix tetrasperma, Anogeissus rivularis,*	Encountered widely, frequently or not, riparian trees can dominate banks and represent a substantial portion of the system's biomass. They often serve as keystone species as producers and providers of cover, roosting and/or nesting space for other creatures.
Channel_Extent of upper bank vegetation	*Derris alborubra, Premna scandens, Drypetes salicifolia, Ficus heterophylla, Rubus spp.*	Frequently encountered and sometimes subdominant species that occur sporadically in different Focus Areas. They are exclusive to this Indicator.
Channel_Extent of lower bank vegetation	*Homonoia riparia, Eugenia mekongensis, Phyllanthus mekongensis, Phyllanthus jullienii, Telectadium edule, Acacia harmandiana*	Frequently encountered and sometimes subdominant species that occur sporadically in different Focus Areas. They are exclusive to this Indicator.
Channel: Weeds, grasses on sandbanks and sandbars	*Digitaria spp, Rumex dentatus, Rorippa indica, Ludwigia hyssopifolia, Grangea maderaspatan, Fibristylis* spp.	Dominate disturbed areas caused either by fast-moving currents across soft substrates or human activities. Being dominant as a vegetation type, they comprise a substantial portion of the biomass and provide critical cover for many animals.
Channel_Biomass freshwater algae	*Cladophora glomerata, Aegagropila linnaei*	These specific algae are collected to sell commercially. Countless other benthic and planktonic forms serve as a crucial link in food chains.

- The trends in these indicators between 1985 and 2015 has been quite stable for most indicators scoring a "B" or Good, except for the biomass of riparian vegetation which was an "A" in 1985 and which has declined to "B" by 2015.

4.2.2.5 Macroinvertebrates

- With the river habitats in this stretch of the Mekong consisting of a bedrock channel with deep pools and bedrock benches with large boulders and deposited cobbles and pebbles, there are areas of gravel, sand and alluvial deposits. The most abundant macroinvertebrates found in this stretch are those that live on stones and bedrock such as baetid mayflies.
- Macroinvertebrate species that are sensitive to disturbance and water pollution include the stoneflies (Plecoptera) and caddis flies (Trichoptera) and these are found throughout the area, indicating the fair river health conditions noted during the ES March 2017 field survey.
- Freshwater prawns (Macrobrachium spp) are also sensitive to disturbance and are found in some locations, especially in calcareous regions, e.g. the stretch around the Nam Ou confluence down to Luangprabang.
- The in-channel vegetation, e.g. the stands of Homonia riparia and grasses growing on sandbanks, provide a good habitat for different types of macroinvertebrates, and often the richest macroinvertebrate diversity is found in the small side streams and tributaries entering the river. Another important habitat for macroinvertebrates are the small ponds and pools left in the alluvial deposits as the high water levels recede during the dry season.
- The indicators of change in macroinvertebrates vegetation are shown in Table 4.8.

Table 4.8: Indicators of changes in littoral and benthic macroinvertebrates

Indicator Groups	Reasons for selection
Insects on stones	Insects living on stones include many mayflies (e.g., Heptageniidae and Baetidae) as well as some dragonflies, caddisflies and two-winged flies. They are sensitive to changes in habitat because they require clean stony substrates for attachment and feeding, and they are often sensitive to changes in water quality such as changes in concentrations of dissolved oxygen.
Insects on sand	Insects living on sand include some mayflies (such as Caenidae and some Baetidae), some dragonflies such as Gomphidae) and others. Once again these species are quite habitat specific, and any changes which alter the amount of sandy habitat available in the river will impact these groups of invertebrates.
Burrowing mayflies	Burrowing mayflies include Potamanthidae and Ephemeridae. They have specific habitat requirements requiring clay banks or other appropriate sediments in which to excavate their burrows. They are a major contributor to dry season insect emergence, and are also sensitive to changes in water quality.
Snails	Snails are important as food for people as well as being hosts for significant parasites of both humans and stock. Changes in abundance will impact human populations by altering availability of food, and income (since some harvested snails are traded or sold) and potentially also influencing health of humans and their stock
Diversity of snails	The Mekong River is a known global diversity hotspot for freshwater snails, especially in the family Pomatiopsidae of which there are over a hundred species known from the area around Khone Falls.
Bivalves	Bivalves are an important food source for people living along the river. They are collected for food and trade throughout the river from northern Laos to the Delta
Shrimps and crabs	Shrimps and crabs are an important part of the riverine ecosystem as important shredders and collectors. They are also significant food items throughout the main channel and tributaries, being harvested for food especially during the low flow periods.
Macrobrachium prawns	Macrobrachium is a genus of freshwater prawns that are because they are widely used by people as food.

Indicator Groups	Reasons for selection
Littoral invertebrate diversity	Invertebrates constitute an important component of biodiversity, and invertebrate diversity is a useful indicator of environmental stress. Poor water or habitat quality leads to a reduction in invertebrate diversity. Invertebrates are also an important food source for fish, birds and aquatic and semi-aquatic vertebrates.
Benthic invertebrate diversity	Invertebrates are an important component of biodiversity and invertebrate diversity is a useful indicator of environmental stress. Poor water or habitat quality leads to low invertebrate diversity. Invertebrates are also an important food of fish, birds, herpetofauna and mammals.
Zooplankton	Zooplankton are an important food source for many fish species, especially in Tonle Sap Great Lake and in the middle to lower reaches of the river.
Benthic invertebrate biomass	Invertebrates constitute an important component of biodiversity, and invertebrate diversity is a useful indicator of environmental stress. Poor water quality or poor habitat quality leads to a reduction in invertebrate diversity. Invertebrates are also an important food source for fish, birds and aquatic and semi-aquatic vertebrates. The biomass indicator was specifically included to account for invertebrates in Tonle Sap Great Lake.
Emergence	The Mekong has a very abundant dry season aquatic insect emergence at a time when water levels are low and other fish food and terrestrial insects are at their least abundance, so emergence is a potentially important fish food, and significant food source for insectivorous birds.

The trends in macroinvertebrates in this reach of the Mekong shows that in 1985 all of the above indicators in the reaches to Pak Beng would have scored an “A” – unmodified or nearly natural, while downstream of Pak Beng was already showing a decline to “B” or even a “C” for some indicators. By 2015 the upper reach to Pak Beng was considered to have declined to “B” or even a “C” for some indicators, with the same levels as downstream from Pak Beng reflecting a degrading trend in this foundation level of the aquatic food chain.

4.2.2.6 Drivers of change

The main drivers of change have been identified as:

- Changes of land use in the watershed
- Changes in agriculture down to the river banks
- Increases in urban run-off and pollution
- Increases in infrastructure development.
- Navigation improvements
- Increase in navigation traffic

4.2.3 *Method of assessing local and cumulative impacts*

The different indicators of change used in the BioRa method of the MRC Council study have been assessed for each of the aspects considered in this report – geomorphology, wetland habitats, aquatic and riparian vegetation and macroinvertebrates. The scale of impacts is assessed based upon professional judgment of what is likely to occur with the different expected changes during construction and longer-term operation of the navigation improvements.

- 0 – No Impact,
- 1 - Very Low Impact,
- 2 - Low Impact,
- 3 - Moderate Impact,
- 4 - High Impact, and
- 5 - Very High Impact

Initially the impacts are assessed for a localized activity of navigation improvement covering a typical 5 km stretch of the river where there would be direct impacts. The scores for each of the impact indicators chosen are then averaged to give the localized score for the study reach during construction and over the longer term.

Cumulative impacts are then calculated for the whole reach, by taking the average localized score for navigation improvements, factoring this score by multiplying the number of dangerous areas times the 5 km impact zone divided by the total length of the reach.

4.2.4 *Impacts in the whole study reach (Golden triangle to Luang Prabang)*

4.2.4.1 Geomorphology

The projected impacts upon the geomorphology of the whole study reach between the Golden Triangle and Luang Prabang are shown in Table 4.9 for both the construction phase and the longer term impacts after river training works have been completed.

Table 4.9: Table of impacts upon the geomorphology of the whole study reach between the Golden triangle and Luang Prabang

Geomorphology	Erosion	Average bed sediment size in dry season	Availability of exposed sandy habitat in dry season	Availability of inundated sandy habitat in dry season	Availability of exposed rocky habitats in dry season	Availability of inundated rocky habitats in dry season	Depth of pools in bedrock in dry season	Water quality	Local impact	Combined local impact	Cumulative impact
ZONE 1 - 3 Golden triangle to Luang Prabang – (approx 368 km) – 23 dangerous areas											
Focus on impacts from navigation improvement works											
Construction phase:											
Rocky materials may be released and distributed in the immediate area of obstruction removal (case study of Kheng Pai Dai estimated	0	0	0	0	2	2	0	2	0.8	1.1	0.33
Some rocky material may be deposited in deep pools downstream of obstruction removal (volume of materials deposited cannot be	0	0	0	0	0	0	2	0	0.3		
Sand from bed, banks and islands will be removed through dredging (Hat Ngao case study estimates removal of 100,000m^3 of sand)	2	1	3	3	0	0	0	3	1.5		
Sand from sand banks and islands may be deposited downstream and on adjacent banks	0	1	3	3	0	0	2	3	1.5		
Port construction will involve clearing and dredging releasing materials into the river	2	2	2	2	0	0	0	4	1.5		
Waves from obstruction removal and related large boats may lead to increased bank erosion where not bedrock	3	2	1	1	0	0	0	0	0.9		
Long term impact:											
The main river channel will be wider and less obstructed (extent of change is not known at this stage, although 2 case studies indicate a	0	0	0	0	2	2	0	0	0.5	0.6	0.20
The flow in the channel may be less restricted and consequently the flow may be slower (unless removed materials are placed within the	0	0	0	0	0	0	0	0	0.0		
Slower flows may reduce sediment generation due lower rates of bank erosion	0	2	2	2	0	0	0	0	0.8		
Sediment transport may be reduced – resulting in potential greater build of sediment upstream and decreased sediment supply	0	2	3	3	0	0	0	1	1.1		
Increased large boat traffic will cause bank erosion and pollution	3	0	0	0	0	0	0	3	0.8		

Construction phase impacts

The assessment of localised impacts upon the geomorphology in the construction phase show an overall Low impact, with Moderate impacts on the exposed and inundated sandy habitats in the dry season, and some high impacts on water quality during port construction. When the 368 km length of the study reach between the Golden triangle and Luang Prabang is accounted for, the cumulative impacts of navigation improvement works in 23 locations with an immediate impact zone of 5 km's is Very Low.

Longer term impacts

Generally, after navigation improvement works the geomorphology of the reach will stabilize and the localized impacts will be Very Low as will the Cumulative Impacts over the whole reach. The one area of concern is due to the increase in large boat traffic which may increase the rate of bank erosion and also pose a risk to water quality.

4.2.4.2 Wetland habitats

The projected impacts upon the wetland habitats of the study reach between the Golden triangle and Luang Prabang are shown in Table 4.10 for both the construction phase and the longer term impacts after river training works have been completed.

Table 4.10: Table of impacts upon the wetland habitats of the study reach between the Golden triangle and Luang Prabang

Wetland habitats	Rivers	Streams	Seasonal mudflats, pebble flats and sand bars	Seasonally inundated shrubland	Rock outcrops	Riverine rapids	Deep pools	Pools on bank	Local impact	combined local impact	Cumulative impact
ZONE 1 - 3 Golden triangle to Luang Prabang – (approx 368 km) – 23 dangerous areas											
Focus on impacts from navigation improvement works											
Construction phase:											
Rocky materials may be released and distributed in the immediate area of obstruction removal (case study of Kheng Pai Dai estimated	3	0	1	3	1	3	2	1	1.8	1.3	0.41
Some rocky material may be deposited in deep pools downstream of obstruction removal (volume of materials deposited cannot be	1	0	0	0	0	0	3	0	0.5		
Sand from bed, banks and islands will be removed through dredging (Hat Ngao case study estimates removal of 100,000m^3 of sand)	2	0	4	2	0	0	0	2	1.3		
Sand from sand banks and islands may be deposited downstream and on adjacent banks	2	1	4	3	0	0	0	2	1.5		
Port construction will involve clearing and dredging releasing materials into the river	3	2	4	4	2	0	0	2	2.1		
Waves from obstruction removal and related large boats may lead to increased bank erosion where not bedrock	2	0	2	2	0	0	0	0	0.8		
Long term impact:											
The main river channel will be wider and less obstructed (extent of change is not known at this stage, although 2 case studies indicate a	1	0	0	0	0	0	0	0	0.1	0.5	0.15
The flow in the channel may be less restricted and consequently the flow may be slower (unless removed materials are placed within the	1	0	0	0	0	0	0	0	0.1		
Slower flows may reduce sediment generation due lower rates of bank erosion	1	0	2	0	0	0	0	0	0.4		
Sediment transport may be reduced – resulting in potential greater build of sediment upstream and decreased sediment supply	1	1	2	2	0	0	0	0	0.8		
Increased large boat traffic will cause bank erosion and pollution	2	1	2	2	0	0	0	1	1.0		

Construction phase impacts

The localized impact for the navigation improvement works upon wetland habitats in the whole study reach is Low, but with High impacts upon the seasonal mudflats, pebble flats and sand bars and seasonally inundated shrublands. Port construction has the highest risk of impact. Over the whole study reach, the cumulative construction impact is Very Low.

Longer term impacts

Once navigation improvements have been completed both localized and cumulative impacts on wetland habitats over the whole study reach are Very Low, with only increased large boat traffic causing bank erosion and pollution as a Low risk.

It should be noted that the Ramsar site at Nong Bong Khai Non-Hunting Area lies in the floodplain of a small tributary of the Nam Mae Kok river and is isolated from the Mekong mainstream. It will not be affected by any of the navigation improvements being considered.

4.2.4.3 Aquatic and riparian vegetation

The projected impacts upon the aquatic and riparian vegetation of the study reach between the Golden triangle and Luang Prabang are shown in Table 4.11 for both the construction phase and the longer-term impacts after river training works have been completed.

Table 4.11: Table of impacts upon the aquatic and riparian vegetation of the reach between the Golden triangle and Luang Prabang

Aquatic and riparian vegetation	Channel Riparian trees	ChannelExtent of upper bank vegetation	ChannelExtent of lower bank vegetation	Channel: Weeds, grasses on sandbanks and sandbars	Channel Biomass freshwater algae	Local impact	Combined local impact	Cumulative impact
ZONE 1 - 3 Golden triangle to Luang Prabang – (approx 368 km) – 23 dangerous areas								
Focus on impacts from navigation improvement works								
Construction phase:								
Rocky materials may be released and distributed in the immediate area of obstruction removal (case study of Kheng Pai Dai estimated	0	0	0	1	2	0.6	1.2	0.36
Some rocky material may be deposited in deep pools downstream of obstruction removal (volume of materials deposited cannot be	0	0	0	0	2	0.4		
Sand from bed, banks and islands will be removed through dredging (Hat Ngao case study estimates removal of $100,000m^3$ of sand)	0	0	3	3	1	1.4		
Sand from sand banks and islands may be deposited downstream and on adjacent banks	0	0	1	2	1	0.8		
Port construction will involve clearing and dredging releasing materials into the river	3	3	3	1	1	2.2		
Waves from obstruction removal and related large boats may lead to increased bank erosion where not bedrock	2	2	2	1	1	1.6		
Long term impact:								
The main river channel will be wider and less obstructed (extent of change is not known at this stage, although 2 case studies indicate a	0	0	0	0	2	0.4	0.8	0.26
The flow in the channel may be less restricted and consequently the flow may be slower (unless removed materials are placed within the	0	0	0	0	2	0.4		
Slower flows may reduce sediment generation due lower rates of bank erosion	0	0	0	2	2	0.8		
Sediment transport may be reduced – resulting in potential greater build of sediment upstream and decreased sediment supply	0	0	0	3	1	0.8		
Increased large boat traffic will cause bank erosion and pollution	2	2	2	1	2	1.8		

Construction phase impacts

The localized impacts upon aquatic vegetation in the study reach are Low, with some moderate impacts upon riparian trees, upper and lower bank vegetation caused by port construction and to a lesser extent by construction boat traffic. When considered across the whole of the study reach, the cumulative impacts upon aquatic vegetation are Very Low.

Longer term impacts

In the longer term, after the navigation improvements, the impacts upon Aquatic Vegetation are Very Low for both the localized impact of the works and the cumulative impacts.

4.2.4.4 Macroinvertebrates

The projected impacts upon the macroinvertebrates of the study reach between the Golden triangle and Luang Prabang are shown in Table 4.12 for both the construction phase and the longer-term impacts after river training works have been completed.

Table 4.12: Table of impacts upon the macroinvertebrates of the reach between the Golden triangle and Luang Prabang

Indicator Groups	Insects on stones	Insects on sand	Burrowing mayflies	Snails	Diversity of snails	Bivalves	Shrimps and crabs	Macrobrachium prawns	Littoral invertebrate diversity	Benthic invertebrate diversity	Zooplankton	Benthic invertebrate biomass	Emergence	Local impact	combined local impact	Cumulative impact
ZONE 1 - 3 Golden triangle to Luang Prabang – (approx 368 km) – 23 dangerous areas																
Focus on impacts from navigation improvement works																
Construction phase:																
Rocky materials may be released and distributed in the immediate area of obstruction removal (case study of Kheng Pai Dai estimated removal of 20,500 m3	2	0	0	1	0	2	1	2	0	0	1	2	1	0.9	1.1	0.36
Some rocky material may be deposited in deep pools downstream of obstruction removal (volume of materials deposited cannot be estimated at this stage)	0	0	0	1	0	2	0	0	0	0	0	2	0	0.4		
Sand from bed, banks and islands will be removed through dredging (Hat Ngao case study estimates removal of 100,000m^3 of sand)	0	3	3	2	0	2	2	2	0	0	1	2	2	1.5		
Sand from sand banks and islands may be deposited downstream and on adjacent banks	0	3	3	2	0	3	2	2	0	0	2	2	2	1.6		
Port construction will involve clearing and dredging releasing materials into the river	2	2	2	2	0	2	2	2	0	0	2	2	2	1.5		
Waves from obstruction removal and related large boats may lead to increased bank erosion where not bedrock	0	2	2	2	0	2	2	2	0	0	0	0	0	0.9		
Long term impact:																
The main river channel will be wider and less obstructed (extent of change is not known at this stage, although 2 case studies indicate a minor change)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.5	0.17
The flow in the channel may be less restricted and consequently the flow may be slower (unless removed materials are placed within the vicinity of removal	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0		
Slower flows may reduce sediment generation due lower rates of bank erosion	0	1	1	1	0	1	1	1	0	0	0	1	0	0.5		
Sediment transport may be reduced – resulting in potential greater build of sediment upstream and decreased sediment supply downstream	0	1	1	1	0	1	1	1	0	0	0	1	0	0.5		
Increased large boat traffic will cause bank erosion and pollution	3	2	2	2	0	2	2	3	1	1	1	1	1	1.6		

Construction phase impacts

During the construction phase in the study reach the localized impacts upon macroinvertebrates are considered to be Low, though Moderate impacts may be expected on insects on sand and burrowing mayflies and bivalves, especially when sand is mobilized during the works which will be deposited downstream. The Cumulative impact on the macroinvertebrates in the whole of the study reach is Very Low.

Longer term impacts

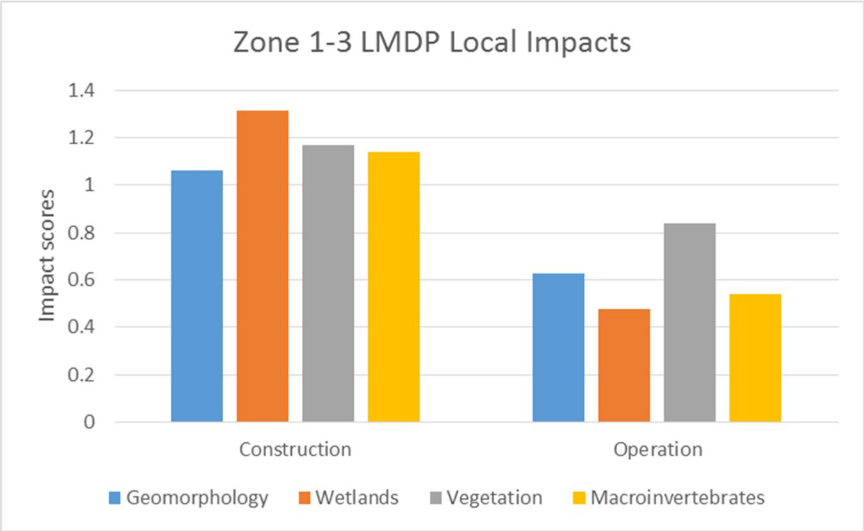
After the navigation improvements in the study reach, the longer term impacts upon macroinvertebrates are expected to be Very Low both for localized and cumulative impacts, with the only higher impacts being caused by increased large boat traffic upon insects on stones and the Macrobrachium prawns, which are more susceptible to pollution.

4.2.5 *Comparison of impacts during construction vs operation and cumulative impacts*

When the impacts on the four components of aquatic ecology are considered in the whole study reach, there are marked differences between construction and operation (Figure 4.2). During the construction phase the local impacts around the dangerous areas are similar Low impacts (with scores just over 1) for all four components.

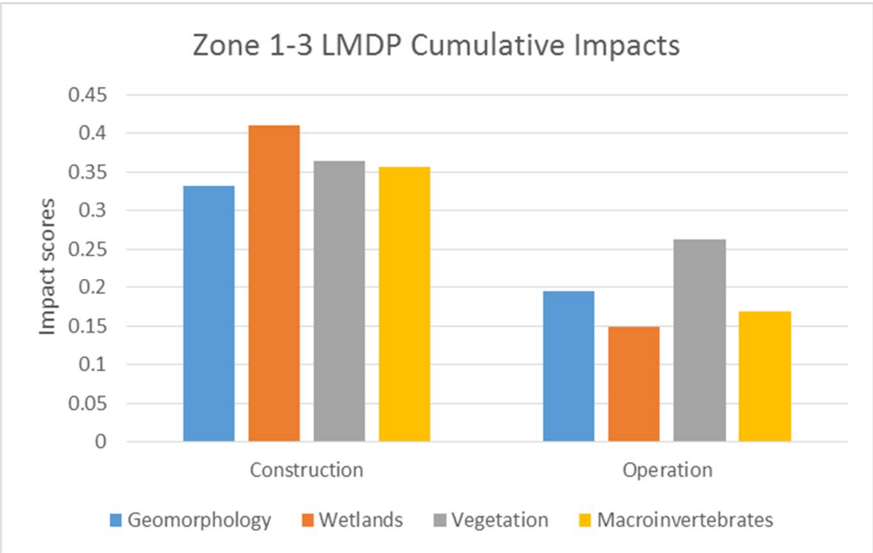
Similarly when the operational or longer term impacts are considered at the local level, study reach impacts show a Very Low level for all components.

Figure 4.2: Comparison of local impacts upon aquatic ecology in Zones 1 - 3



The cumulative impacts in the study reach is shown in Figure 4.3. The cumulative impacts reflect the fact that the navigation improvements are focused on the dangerous areas of which there are twenty three in the whole study reach. The dangerous zones occur every 15 – 20 km, and for our calculations we have assumed an impact zone of 5 kms. The cumulative impacts assessments reflect the density of the local impacts over the whole zone. It can clearly be seen from Figure 4.3, that the cumulative impacts of the construction activities on the aquatic ecology are Very Low (with impact scores of less than 0.5).

Figure 4.3: Comparison of cumulative impacts upon aquatic ecology in Zones 1 - 3



4.2.6 *Conclusions*

The assessments of impacts on the aquatic ecology show that generally the navigation improvement works have a low to very low impact if conducted to international best practice. That is especially so 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. When all the navigation improvements are assessed cumulatively for each zone, there is enough “dilution” effect to spread the impacts which are assessed as very low for all the components – geomorphology, wetland habitats, aquatic vegetation and macroinvertebrates.

While the overall impacts of the navigation improvement works are low, there are certain features which may be more sensitive to these works, especially the more labile sand and pebble flats. The rocky outcrops which make up the dangerous areas and which may have to be reduced in size or removed are less sensitive. The volume to be removed is relatively small in comparison to overall availability of this type of habitat, and the vegetation and macroinvertebrate fauna associated with these rocky outcrops will quickly re-establish themselves.

On the operational side, the increase in large boat traffic and the risks of water pollution – both organic wastes from the boats and regular oil and grease releases, will contribute to the gradually declining water quality in this stretch of the river. The risks of accidents and spillages will also increase.

Increased large boat traffic will also increase the risks of bank erosion. For much of this stretch the river is generally flowing through a rock confined channel and erosion sensitivity is low. However, there are stretches where bank erosion is already an issue e.g. in the first 30 km downstream of Chiang Saen and between Pak Ou and Luang Prabang. The right bank on the Thailand side has already been hardened significantly – 33% of the bank in Thailand has been strengthened with rip rap or concrete embankment – and this has caused loss of riparian vegetation and depletion of macroinvertebrate fauna.

4.2.7 *References*

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4.3 AMPHIBIANS AND REPTILES IMPACT ASSESSMENT

4.3.1 *Baseline summary*

A total of 25 species of amphibians and reptiles were documented during field and market surveys. An additional seven species were reported during interviews but were not directly observed by the team. Eight of the observed and reported species (six turtle species and two snake species) are globally and nationally threatened from overexploitation for food and traditional medicine.

The surveyed areas along the Mekong River were heavily impacted by human development activities, especially removal and degradation of forest for agriculture (banana plantations, rubber plantations, and rice fields), as well as infrastructure development of the Mekong (hydropower dams and embankments).

Most conservation value for amphibians and reptiles in the survey area probably lies in forested portions of the mainstream Mekong and its tributaries.

4.3.2 *Key potential impacts*

The LMDP will affect amphibians and reptiles living in areas to be cleared and ports developed through direct habitat loss. There will also be impacts through increased navigation causing water quality decline and wave action. As a notable example, breeding habitat of the Asiatic softshell turtle (*Amyda cartilaginea*) will likely be negatively impacted by such changes.

In addition to habitat loss and navigation impacts, port infrastructure development and increased trade and navigation along the study stretch with the LMDP will likely facilitate increased human access into previously inaccessible to infrequently visited portions of the survey areas, which in turn will likely cause increased harvesting of turtles, large lizards and large snakes for consumption and trade, particularly illegal wildlife trade to China.

4.3.3 *Reptile and amphibian conservation needs within the project area*

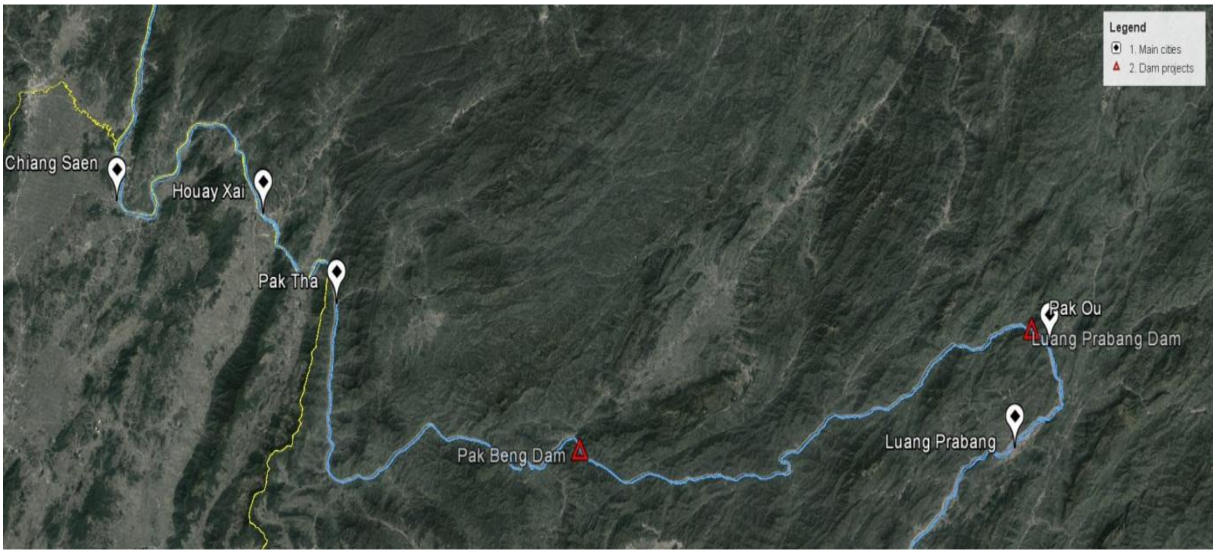
Further detailed surveys of amphibians and reptiles in the LMDP impact areas is urgently needed. Continued infrastructure development in the area needs to be accompanied by increased enforcement of wildlife hunting and trade laws by relevant governmental agencies.

4.4 FISH IMPACT ASSESSMENT

4.4.1 *Introduction*

This focus of this section is to present an assessment of the impacts of the LMDP on fish biodiversity and fisheries in the study stretch from the Golden Triangle (Chiang Saen) to Luang Prabang (Figure 4.4).

Figure 4.4: Study location map detailing cities and proposed dam projects along the Mekong between Chiang Saen and Luang Prabang



4.4.2 *Methodology*

Environmental characterization and species analysis for fish have been described in the Baseline Assessment Report. In this impact assessment, the analysis has been deepened by making use of the extensive ecological information available by species in the Mekong Fish Database (MFD 2003). This information includes in particular information about the usual position of fish species in the water column, as well as their habitats (in particular dry season and flood season habitats. That information was coded to be quantitatively analysed (Table 4.13).

Table 4.13: Ecological information extracted from the MRC Mekong Fish Database and coded

Field	Note
Species name	Updated using FishBase
Family	
Order	
Water column position	1= benthopelagic; 2=demersal; 3=pelagic-neritic;, 4=pelagic
Habitat	Plain text interpreted for the 206 species present in the study zone, and coded 1=river/rapid water/clear water/ sandy/ gravel/ rocky/ torrent habitat; 2=slow water/muddy/floodplain habitat; 3= dual habitat, 4= no information available
Pool	Field created by using the above information, in order to code the use of deep pools 1=use of pools, 2 = no information on pools
Dry Season Habitat	Used to confirm the above coding of Habitat
Flood Season Habitat	Used to confirm the above coding of Habitat

4.4.3 *Results*

4.4.3.1 Deep pools in the study section

Deep pools have long been known to provide refuge habitat for multiple fish species in the Mekong, especially in the dry season (Hill and Hill 1994, Roberts & Baird 1995, Baird et al. 1999, Chan et al. 2005, MRC 2005). In Cambodia for instance, 75 percent of the catch landed by the Cambodia *dai* fishery depends on fish populations that utilize deep pools (Halls et al. 2013).

Deep pools can be defined as "…a confined, relatively deep area within a river channel, which acts as a dry-season refuge for a number of important fish species. For some species, deep pools may also act as spawning habitats" (Poulsen et al. 2002). As detailed by Halls et al. (2013), most deep pools are 15 to 20 m deep and have areas ranging between 10 and 15 ha. The deepest pools are 80 - 90 m deep and are found in particular between Huay Xai and Vientiane.

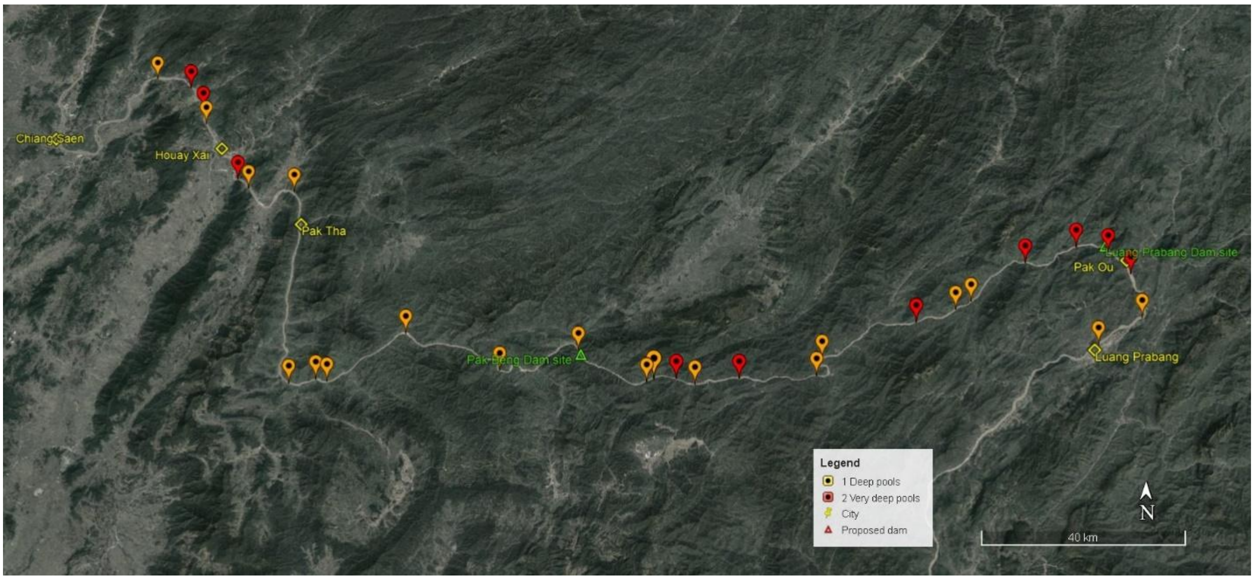
The concentration of biomass and large-size individuals in these pools (Baran et al. 2005, Viravong et al. 2006) especially during the dry season (Poulsen et al. 2002), is such that they have led to the identification of these pools as candidate Fish Conservation Zones (Baird and Flaherty 2005, Baird 2006).

Among the 450 deep pools recorded to date in the Mekong (Halls et al. 2013), the 110 pools identified in the focus zone (see Baseline report) can be considered one of the salient features relevant to fisheries and biodiversity conservation in that zone.

Changes to depth, velocity and turbulence linked to blasting of rapids will ultimately affect the nature of this essential habitat. Filling of pools with sediments is one of the main concerns in case of large-scale river modification (Conlan et al. 2008a). Deep pools are indeed dynamic morphological features, in which bedload sediment moves, under unaltered conditions, as a large "waves" mobilized upstream of the pool at the beginning of the wet season, through the pool at peak flows and then downstream out of the pool by the end of the monsoon flood (Conlan et al. 2008b). Under major hydrodynamic change, substantial alteration of the sediment dynamics is expected, with subsequent modification of the depth, substrate granulometry and ecological functioning of deep pools.

During the Baseline phase of the present assessment, the MRC Mekong bathymetric maps allowed mapping the deep pools of the main study area and classifying them into four depth categories. The pools of the two deepest categories, i.e. 19 deep pools and 10 very deep pools, are respectively highlighted in orange and red below (Figure 4.5).

Figure 4.5: Deep pools and very deep pools in the Mekong mainstream between Chiang Saen and Luang Prabang



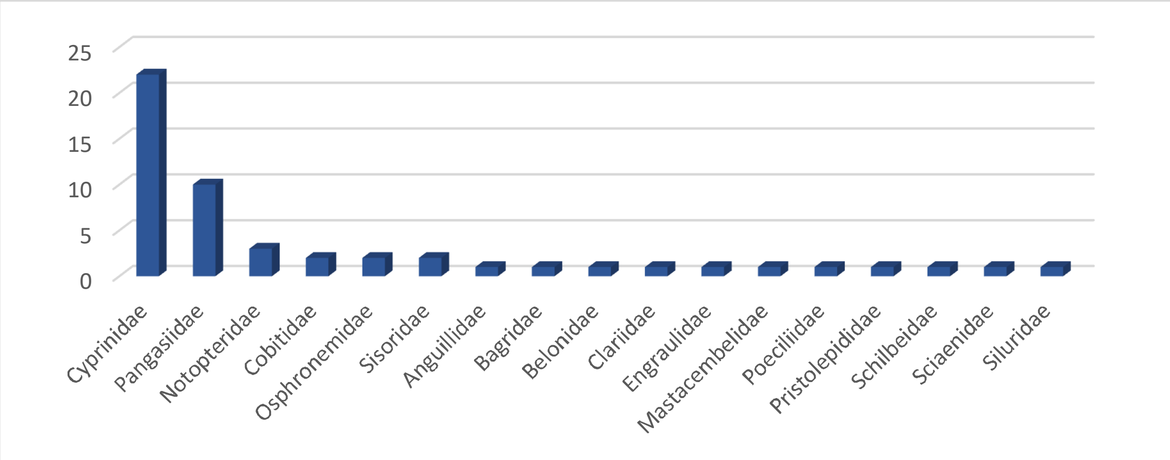
When their surface area is integrated, the map shows how extensive the presence of deep pools is in that section of the river (Figure 4.6).

Figure 4.6: Extent of deep pools (orange) and very deep pools (red) in the Mekong mainstream between Chiang Saen and Luang Prabang

4.4.3.2 Fish species using deep pools

Of the 206 species recorded in the study zone, 52 are known to make use of deep pools. Among these are 22 species of Cyprinidae (minnows and barbs), 10 species of Pangasiidae (panga catfish) and 3 species of Notopteridae (featherbacks), followed by 1 to 2 species in 14 other families (Figure 4.7).

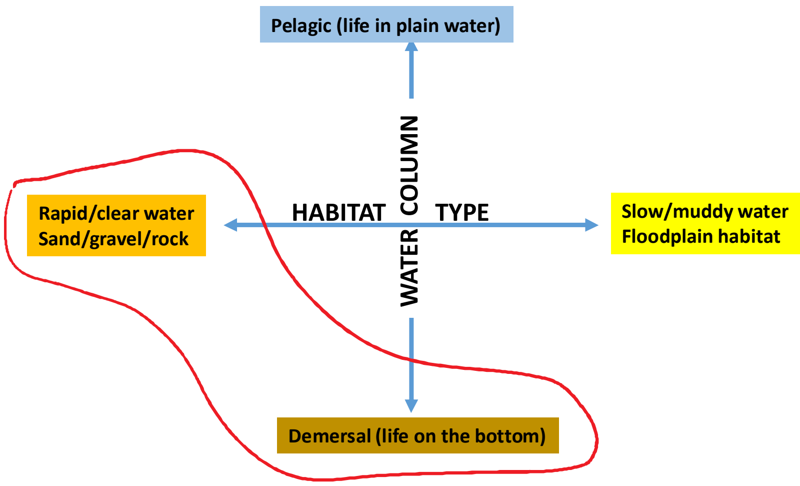
Figure 4.7: Number of species by family making use of deep pools among the 206 species identified in the study zone



Summary ecological information, extracted from the Mekong Fish Database, is detailed in Annex 1.

By coupling information about species using deep pools with ecological information by species available the Mekong Fish Database, the study team developed a 2D map of species using deep pools and their location in the water column (Figure 4.8) for 50 of the 52 species known to use deep pools.

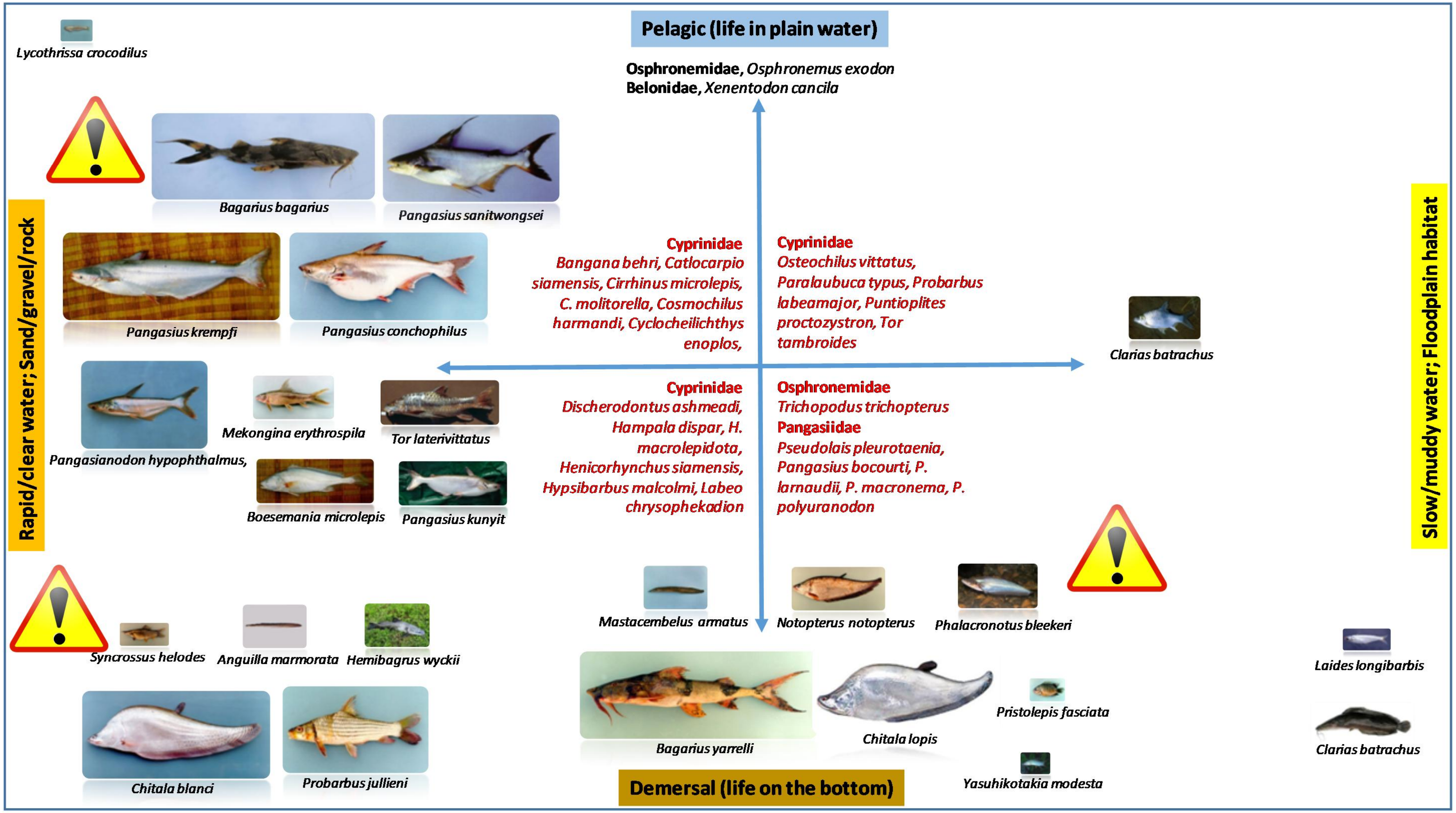
Figure 4.8: 2D map of habitats for the species known to use deep pools



This map indicates which species are likely to be most sensitive to environmental change among deep pools (red zone). Such sensitiveness is due to a combination of habitat requirements corresponding to the mainstream (running water, sandy/rocky environment) and to deep pools (demersal life subject to changes in sedimentation and bedload). See detailed species mapping in Figure 4.9.

Figure 4.9 indicates that the species most likely to be impacted by a change in hydrology and bedload in relation to deep pools (warning symbols) are primarily Pangasiidae (panga catfishes), but also a number of other catfishes (Bagridae, Sisoridae, Siluridae, etc.). Among these species for which a negative impact is expected, two are already critically endangered (*Pangasionodon gigas* and *Pangasius sanitwongsei*) and one is endangered (*Probarbus jullieni*).

Figure 4.9: Distribution of species using deep pools in the water column and in different aquatic habitats



4.4.3.3 LMDP impacts expected on fish and fish habitats

Impacts during the LMDP construction phase:

1. **The mortality of fishes due to blasting during the construction period is unavoidable.** The magnitude of loss depends on charge and distance from the detonation. Depth of water, type of substrate, and the size and species of fish are also factors influencing the number of fish killed (Keevin and Hempen 1997). Immediate mortality is followed by longer-term mortality of survivors due to internal wounds, reduced swimming ability and reduced ability to catch preys, caused in particular by damaged swim bladder and lateral line, i.e. the sensory system that fishes use to detect water motions and pressure gradients.
2. **Dredging, during either construction or operation phases, may create suspended sediment plumes surrounding the dredging area.** Dredging the river bed will directly impact macro-invertebrates, i.e. an important food source for fish resources (Chiu and Kuo, 2012). Increased suspended solid load is also damageable to fishes since the sediment can clog fish gill and alter respiration. Moreover, the sediment load can affect fish egg and larval development, resulting in massive early life mortality (Hess et al., 2015; Kjelland et al., 2015).
3. **Partial filling of the deep pools by rocky materials and sediment during the port construction phase may negatively affect these fishes** (see impacted species in the above section). As detailed earlier, deep pools act as the "dry-season" refuge for many Mekong fish species; this applies in particular to true riverine species such as Pangasids, Silurids and many Cyprinid fishes. The pelagic layer of the pool is dominated by the small to medium size fishes, whereas the larger ones inhabit in the deeper zone.

Impacts during the LMDP operation phase:

1. **Strong waves created by boats, in particular the 500t vessels, will affect small size fish (< 10 cm total length) due to their low swimming capability**. The waves flush them towards river banks, which is known to result in mass mortality of small fish but also eggs and larvae (Wolter and Arlinghaus, 2003). Mortality can also occur due to decreasing food availability following reduced zooplankton abundance in turbulent waters off the river-bank (Bohle, 1995). In addition, the submerged vegetation, where some Cyprinids lay their eggs, and nests of some species such as *Chitala* spp. will be disturbed by this waves, making the area less suitable as a nursery ground.
2. **Increased navigation can result in mortality** caused by the physical forces generated by the boats, in particular the shear stress on fish eggs and larvae as well as small sized fishes (Killgore et al., 2001; Wolter and Arlinghaus, 2003).
3. **Leaking (or disposing) of oil and grease in the river channel is expected to some extent, which may can cause of death of many living organisms**, in particular the macro-invertebrates living in the bottom, which disrupts the food chain in the area (U.S. Environmental Protection Agency, 2016, Ifelebuegu et al., 2017). This not only affects the sources of food available to fish, but also impacts their ingestion and overall survival. Another effect of "oil and grease" pollution is the prevention of photosynthesis, resulting in less productive habitats near the port.
4. **River bank stabilization for navigation purposes, usually using riprap, may interrupt the connection between the aquatic and terrestrial zones, as well as changes in channel geometry, flow rate and direction, and riparian vegetation condition**. However, river bank stabilization *per se* shows either beneficial or adverse impacts to fishes, depending on species, life stage, and season (Fischenich, 2003). In depth studies in this issue are required.

4.4.4 *References*

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4.4.5 *Annex 1: Ecological information about the fish species using deep pools*

Table 4.14: Ecological information about the fish species using deep pools

Order	Family	Valid name	Habitat main text
Anguilliformes	Anguillidae	Anguilla marmorata	Inhabits estuaries and seas as young, and migrates into freshwater areas as adults; It occurs in lowland rivers as well as upland tributaries, but it has a preference for deep rocky pools.
Beloniformes	Belonidae	Xenentodon cancila	Found in both running and standing waters; Inhabits large and medium-sized rivers where it can be found in slow-flowing pools with a rock or sand substrate; It is also found in ponds, canals, beels, and inundated fields; It is a common inhabitant of open waters on the floodplain where it is found most commonly at the surface in sluggish or standing waters; Adults occur in areas that lack floating vegetation; Juveniles always live in running water.
Clupeiformes	Engraulidae	Lycothrissa crocodilus	Usually found in brackish water in the estuaries of large rivers, but it often ascends into fresh water; Reported to inhabit deep pools in the mainstream Mekong at least part of the year.
Cypriniformes	Cobitidae	Syncrossus helodes	Found at bottom depths in flowing rivers of all sizes; However usually found in large rivers; It shows a distinct preference for bottom cover or rocks, logs, or even brush piles; It is Reported to inhabit deep pools
Cypriniformes	Cobitidae	Yasuhikotakia modesta	Usually found in large rivers with a muddy substrate; It is reported to inhabit deep pools at least part of the year; Has been reported from reservoirs.
Cypriniformes	Cyprinidae	Bangana behri	It lives in association with rocks in the Mekong mainstream and in large tributaries at least during the dry season, however it has also been reported to inhabit deep pools at least part of the year; It is not known to persist in impoundments ; It reportedly often occur inside the trunks of large flooded forest trees during the high-water season.
Cypriniformes	Cyprinidae	Barbonymus gonionotus	Found at midwater to bottom depths in rivers, streams, floodplains, and occasionally in reservoirs. However it seems to prefer standing water habitats instead of flowing waters; It stays in the flooded forest during periods of high water; It
Cypriniformes	Cyprinidae	Catlocarpio siamensis	Found in large rivers and seasonally in canals and floodplains; The adults have a preference for big

Order	Family	Valid name	Habitat main text
			pools in the Mekong at least during the dry season; Juveniles are mostly seen in swamps and small tributaries.
Cypriniformes	Cyprinidae	Cirrhinus microlepis	Found in large lowland rivers and floodplains; It has also been found in impoundments; It is reported to inhabit deep pools at least part of the year.
Cypriniformes	Cyprinidae	Cirrhinus molitorella	Found in large rivers and some impoundments; Reported to inhabit deep pools at least part of the year.
Cypriniformes	Cyprinidae	Cosmochilus harmandi	Known from midwater to bottom depths; Reported to inhabit deep pools at least part of the year.
Cypriniformes	Cyprinidae	Cyclocheilichthys enoplos	Found at midwater to bottom levels of rivers. Not found in impoundments; The bigger fish are reported to live in big pools at certain places within the Mekong. Smaller individuals occur near the river-bank, in particular in connection with flooded/sub-merged shrubs.
Cypriniformes	Cyprinidae	Discherodontus ashmeadi	Associated with streams and rivers with clear water, moderate to fast current and a gravel to stony bottom. Occurs near the bottom in pools of small to medium-sized rivers, typically near decaying plant debris.
Cypriniformes	Cyprinidae	Hampala dispar	Most commonly in slowly moving or standing water habitats; Deep ponds; It is also common in impoundments, where small individuals frequent areas of dense vegetation; It is reported to inhabit deep pools in the mainstream at least part of the year.
Cypriniformes	Cyprinidae	Hampala macrolepidota	Found in flowing and standing waters and frequently found in impoundments; Occurs mainly in clear rivers or streams with running water and sandy to muddy bottoms, it is however not found in small creeks, torrents, and shallow swamps; It is reported to inhabit deep pools at least part of the year; In rivers, canals, and ponds. Prefer running and clear water with sand and rock;
Cypriniformes	Cyprinidae	Henicorhynchus siamensis	Found often in great abundance at midwater to bottom depths in large and small rivers; It is reported to inhabit deep pools at least part of the year.
Cypriniformes	Cyprinidae	Hypsibarbus malcolmi	Found in large and medium-sized lowland rivers and floodplains, where it is known from midwater to bottom depths usually over coarse substrate; It is reported to inhabit deep pools at least part of the year
Cypriniformes	Cyprinidae	Labeo chrysophekadion	Known from rivers, streams, canals, inundated floodplains, swamps, and reservoirs; It prefers to live among aquatic plants, tree stumps, shrubs, roots and submerged parts of seasonally inundated plants during the high-water season; It is reported to inhabit deep pools in the mainstream at least part of the year; and floodplains during the rainy season.
Cypriniformes	Cyprinidae	Mekongina erythrospila	Inhabits rapidly flowing water in medium and large rivers; The species distribution pattern

Order	Family	Valid name	Habitat main text
			indicates that it prefers rocky stretches with rapids, and a fast current; It was reported that the species never migrates into small streams; Reported to inhabit deep pools at least part of the year; Duangsawasdi and Duangsawasdi (1992) claim that the species exists in a reservoir.
Cypriniformes	Cyprinidae	Neolissochilus blanci	Found in pools of clear forest streams and rivers.
Cypriniformes	Cyprinidae	Osteochilus vittatus	Occurs in running water rivers, streams, canals with slow current and muddy to sandy substrate; and standing water including swamps, oxbows, lakes, and impoundments); It has a preference for areas with dense vegetation and in rivers it is often attracted to brush piles, tree roots, and other solid objects; It spends the flood season in seasonally inundated areas, and the dry season in deep pools).
Cypriniformes	Cyprinidae	Paralaubuca typus	Found at shallow depths in large rivers; However it is reported to inhabit deep pools at least part of the year.
Cypriniformes	Cyprinidae	Probarbus jullieni	It is a freshwater species, which never enters saltwater; It inhabits large rivers with sand, pebble or hard rock substrate, and especially areas with high mollusc populations; It has been reported to inhabit deep pools at least part of the year; Juveniles cannot be seen in the mainstream in the flood season because they migrate laterally to feed in shallow areas close to shore.
Cypriniformes	Cyprinidae	Probarbus labeamajor	Occurs in large upland rivers ; where it is most common in sections of the river that are bordered by seasonally inundated forest and in areas with rapids and rocky substrate; It has been reported to inhabit deep pools at least part of the year.
Cypriniformes	Cyprinidae	Puntioplites proctozystron	It is a common species in standing and slowly moving water; Found in rivers, streams, canals, ditches, reservoirs and swamps; Usually found around submerged aquatic or inundated terrestrial vegetation; It has been reported to inhabit deep pools at least part of the year.
Cypriniformes	Cyprinidae	Tor laterivittatus	Large adults are found in deep pools; juveniles are most frequently found in shallow areas with sandy substrate.
Cypriniformes	Cyprinidae	Tor tambroides	Found in deep running waters; In rapid streams and rivers 1038304); Rocky, forested upland streams with deep pools; In small rivers and streams during the dry season, where it is found in pools and runs over gravel and cobble in rivers flowing through undisturbed forests; Juveniles are most common in or near rapids in shallow water.
Cyprinodontiformes	Poeciliidae	Gambusia affinis	Inhabits standing to slow-flowing water; most common in vegetated ponds and lakes, backwaters and quiet pools of streams; It also occurs in brackish water.
Osteoglossiformes	Notopteridae	Chitala blanci	Known from sections of large rivers with rocks or boulders in the main channel, and with fast flowing waters, deep pools and rapids; Most

Order	Family	Valid name	Habitat main text
			fishers report that the species spends all the year in deep pools in the
Osteoglossiformes	Notopteridae	Chitala lopis	It is mainly found in permanent swamps in the upland area; However it is also reported to inhabit deep pools in the mainstream at least part of the year.
Osteoglossiformes	Notopteridae	Notopterus notopterus	Found in moderately shallow waters in large rivers, streams and in standing and sluggish waters of lakes, floodplains, canals, and ponds; In the Lower Mekong it is more common in permanent lakes that in the main river channel; However in the Middle and Upper Mekong it is common in the main river as well as in tributaries, where it lives in pools with submerged woods and shrubs; In the flood season it inhabits the floodplains up to the littoral zone and areas with submerged vegetation mostly found in deep water; in the dry season it may stay in deep pools in the mainstream; It has been reported to enter brackish water.
Perciformes	Osphronemidae	Osphronemus exodon	Found in sluggish rivers and standing water habitats, including reservoirs; In particular favours marginal areas thick with aquatic and terrestrial vegetation; It can be found in deep pools of large rivers , often near the mouths of tributaries; and in flooded forests during the rainy season, where this species is sometimes found inside the trunks of large flooded forest trees;
Perciformes	Osphronemidae	Trichopodus trichopterus	Found in shallow sluggish or standing-water habitats with a lot of aquatic vegetation, and is much more common in small streams, floodplain lakes and swamps than in the main river; It is however reported to inhabit deep pools in the mainstream at least part of the year.
Perciformes	Pristolepididae	Pristolepis fasciata	Found in slow or standing waters, with logs or dead trees at the bottom; Also reservoirs; The species is more common in permanent lakes than in the main river; However it has been reported to inhabit deep pools in the main stream at least part of the year; It is frequently found in areas with a lot of aquatic and submerged terrestrial vegetation,; It is mainly benthic, but also occupies the pelagic zone while feeding.
Perciformes	Sciaenidae	Boesemania microlepis	The species is a persistent dry-season inhabitant of deep-water pools in the Mekong River in southern Laos and north-eastern Cambodia; Especially large individuals tend to prefer the deep parts of pools, and spend little time in shThe species is a persistent dry-season inhabitant of deep-water pools in the Mekong River in southern Laos and north-eastern Cambodia; Especially large individuals tend to prefer the deep parts of pools, and spend little time in shallow areas.
Siluriformes	Bagridae	Hemibagrus wyckii	Lives in large rivers, where it is reported to inhabit deep pools at least part of the year.

Order	Family	Valid name	Habitat main text
Siluriformes	Clariidae	Clarias batrachus	Found in standing or sluggish flowing water including floodplains and flooded forests with dense vegetation; It is much more common in floodplain habitats than in the main river; Mainly occurs in swamps, ponds, ditches, rice paddies, and pools left in low spots after rivers have been in flood and is usually confined to stagnant, muddy water.
Siluriformes	Pangasiidae	Pangasianodon hypophthalmus	Found in large rivers; Can live in both standing and running water; It is reported to inhabit deep pools at least part of the year.
Siluriformes	Pangasiidae	Pangasius bocourti	Found in rapids, and deeper slower reaches; It is reported to inhabit deep pools at least part of the year.
Siluriformes	Pangasiidae	Pangasius conchophilus	Found in large rivers, where it inhabits both rapids and deep slow reaches; It probably stays in the mainstream Mekong River throughout the year and it is reported to inhabit deep pools at least part of the year.
Siluriformes	Pangasiidae	Pangasius krempfi	Spends the dry season in deep pools within the mainstream; Sometimes caught in salt-water many km from shore; It is unclear which part of the life cycle is spent in the sea.
Siluriformes	Pangasiidae	Pangasius kunyit	Reported to inhabit deep pools at least part of the year.
Siluriformes	Pangasiidae	Pangasius larnaudii	Known to occur in large rivers and floodplains; It is reported to live in deep pools within the mainstream.
Siluriformes	Pangasiidae	Pangasius macronema	Found in large and medium-sized rivers, however the principal habitat for this species seems to be the Mekong mainstream, and it remains common in the Middle Mekong along the Thai-Lao border during the dry season;
Siluriformes	Pangasiidae	Pangasius polyuranodon	Found in the lower courses of major and deep rivers, where it is reported to inhabit deep pools at least part of the year.
Siluriformes	Pangasiidae	Pangasius sanitwongsei	Found in large rivers, where it is reported to inhabit deep pools at least part of the year; Does normally not enter the flooded forest; larvae are usually found near riverbanks and in tributaries of lar
Siluriformes	Pangasiidae	Pseudolais pleurotaenia	Found in large and medium-sized rivers and possibly also inhabits flooded forests; Occurs both in rapids and deeper slower reaches; It is reported to inhabit deep pools at least part of the year.
Siluriformes	Schilbeidae	Laides longibarbis	Occurs in large rivers with turbid and slow or standing waters; It is reported to inhabit deep pools at least part of the year.
Siluriformes	Siluridae	Phalacronotus bleekeri	Found in rivers, streams, and lakes as well as impoundments, with a preference for rapids and faster flowing waters; Deep pools constitute the dry season habitat.
Siluriformes	Sisoridae	Bagarius bagarius	Known from rapids and rocky pools of large and medium-sized rivers.
Siluriformes	Sisoridae	Bagarius yarrelli	It is found in large rivers where it likes to stay near the bottom in rocky areas with strong

Order	Family	Valid name	Habitat main text
			current, where it is found among boulders, often in the white water of the rapids, it inhabits seasonally inundated riverine habitats in the high-water season, but probably does not go far into the flood zone; It is reported to inhabit deep pools in the mainstream at least part of the year.
Synbranchiformes	Mastacembelidae	Mastacembelus armatus	Found in running streams near waterfalls where the bottom is sandy; It has very strict habitat requirements (at least to its dry season habitat). In the dry season it is only found in the main river in areas with a rocky bottom, where it lives in crevices and under rocks, but it enters canals, lakes and other floodplain areas during the flood season; It is reported to inhabit deep pools at least part of the year; Occasionally found in reservoirs.

Source: MRC Mekong Fish Database (2003)

4.5 BIRDS IMPACT ASSESSMENT

4.5.1 *Introduction*

Table 4.15 summarises the likely effects of the various potential causal factors of change to the study stretch's avifauna (from the Golden Triangle to Luang Prabang) associated with the LMDP. The potential threats are elaborated below.

Table 4.15: LMDP impact factors potentially affecting the avifauna of the study stretch

Impact factor	Impact significance
Construction phase	
Channel used as base by itinerant people	Damaging if it occurs
Increased mercantile attitude and opportunity	Negligible effect
Increased dry-season sediment flow	Likely to occur and be problematic
Long-term	
Increased accessibility for hunting	Negligible effect
Loss of habitat through blasting	Negligible effect
Loss of habitat to infrastructure	Negligible effect
Decrease in food supply consequent upon blasting	Material effects seem unlikely
Water pollution from boats and associated infrastructure	Could occur at damaging levels
Vegetation change	Negligible effect
Sediment flow change	Negligible effect
Relocation of solid material	Negligible effect
Water-flow speed change	Negligible effect

The sole safely predictable serious negative effect of the LMDP on the project stretch's avifauna is presented in bold face.

4.5.2 *Potential solely or overwhelmingly construction-phase impacts*

The channel serving as a base by itinerant people: seasonally exposed channel is used often as a living area by non-local, and to some extent local, people. If large numbers of people live during LMDP construction in the seasonally exposed channel, their presence (including presumably also dogs and, through refuse, increased rat numbers) may reduce breeding success of channel nesters for the relevant year(s). This is typically a transitory effect but could well be locally devastating to reproductive output for the year in question, if large numbers of people are involved and they are spread across many channel features.

However, a long-term effect is also plausible, given levels of human activity along the project stretch to date: temporary habitation of a stretch of channel bed that happens to support the last pair of a much declined species (e.g. Great Thick-knee, if not already gone) in the project stretch could result in that pair's breeding failure and coincide with the death of one or other of the birds. While this may seem contrived, I have seen both the last resident River Tern in the Lao Mekong north of Vientiane, and the last resident Black-bellied Terns anywhere in the Mekong. One year these birds were there; the next, they were not. This is the era of the final loss of once-abundant species from all or large sectors of the Mekong. However, it is probably fair to say that even if high project-induced pressure from itinerant people in the channel coincided with the breeding failure in the last year of a key pair's existence, even had the project not existed, the 'baseline' local people package would probably also have been sufficient to deliver the same result. Project-induced people coming to base themselves temporarily in the river channel may be not (only) those officially employed in construction, but a whole host of itinerant 'camp followers': traders, hunters, fishers, purveyors of recreational services, and so on.

It is possible that current residential use of the seasonally exposed channel bed in the project stretch is already so high (and damaging) that the additional people brought, directly or indirectly, by the LMDP could have no meaningful incremental effect. Without assessment of current such use it is not possible responsibly to suggest how serious this factor will be.

Increased mercantile attitude and opportunity: large infrastructure projects typically bring in, during the construction phase, a huge pulse of non-local personnel with knowledge of non-local markets, transport opportunities to these markets, and a mental outlook to seek and exploit additional money-making opportunities. The project stretch has supported for a long time one of the main concentrations of traders in Lao PDR, by virtue of its being a trading route. The LMDP is not likely to increase this factor materially.

Increased dry-season sediment flow during construction: although much of the bird conservation interest of the project stretch depends upon the presence and seasonal mobility of huge quantities of unconsolidated sediment of a variety of sizes from silt to boulder, navigation improvement work in such a river typically releases a pulse of small sediment into downstream flow. This is unlikely to be particularly problematic in the high-flow season, but during low water levels it may be severely detrimental to some species. Water can become so turbid that kingfishers and other visual hunters need to relocate to areas of clearer water to forage efficiently; if there are not sufficient backwaters and tributary mouths, dispersal away from the project stretch may be necessary. 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.

4.5.3 *Potential long-term impacts*

Increased accessibility for hunting: one of the most severe effects on wildlife of any large infrastructure project in Lao PDR and neighbours is often the increase in accessibility to an area, meaning that a host of species become economically sensible to extract whereas they had not been before. The project stretch is already fully accessible along its length by boat and increasing the maximum size of boat that can pass (LMDP) cannot therefore increase accessibility. The mosaic stretches of the seasonally exposed channel bed are challenging to enter compared with sandbars, and this is believed to explain their less-depleted communities. The LMDP is not likely to materially increase accessibility to the mosaic areas.

Loss of habitat through blasting: the sections of the channel with the exposed bedrock, which provides the basis for channel mosaic habitat, contain the majority of the habitat for the declining study species. Wide areas (more than 100 m, especially more than 300 m) of seasonally exposed channel mosaic are particularly important. The total loss of these two-dimensional areas would be catastrophic to the remaining avifaunal interest of the study stretch. It is apparently unlikely that more than 20% of any bedrock 'reef' will be removed, and in many cases it is likely to be very much less: the increase in maximum boat size is minor compared with the width of the seasonally exposed channel mosaic in wide areas. It is likely that in some areas the exploded rock will result in the loss of territories of some study species, either those dependent upon rocks themselves for nest-sites (e.g. Wire-tailed Swallow) or those using chiefly the wider stretches of channel mosaic (e.g. River Lapwing). But given that these latter expanses of rock are already over 100 m wide, mostly much more so, the proportionate loss of rock and thus bird territories is low. If there are any bedrock stretches to be blasted that are narrow enough for more than a quarter of their width to be lost, it is likely they are already of low importance to declining birds because of the existing local people package.

Loss of habitat to infrastructure: some areas will be converted from natural or near-natural habitat to ports and other structures relevant to the increased shipping for the LMDP. These comprise such a tiny proportion of the total length that a material effect on study species populations is difficult to conceive. This is the more so because for LMDP such spots seem likely to be expansions of existing ports, and thus of low importance to habitat specialists that breed in the project stretch.

Decrease in food supply consequent upon blasting: while the loss of bird habitat to blasting is so proportionately low that material direct effects on bird populations are unlikely, the effects underwater on habitat suitability for fish and invertebrates could in theory lead to bird population declines through reductions in food supply. The diet of study species is too poorly known to be sure that any species does not have a tight dietary link to an aquatic prey species that could in theory be affected badly by the LMDP. Most of the study species occur (as foragers if not nesters) in stretches of river lacking channel mosaic suggesting that, in terms of diet effects, blasting-generated prey depletion might be unlikely. The only study species strongly associated with channel mosaic, including in areas of tropical Asia with lower human pressures (and so an association in the Upper Lao Mekong with channel mosaic is not plausibly a secondary effect of the local people package) are Jerdon's Bushchat (riverine populations: other populations occur in highland anthropogenic scrub and floodplain grassland) and White Wagtail (resident race, during the breeding season at least); one further species. Crested Kingfisher, would also have shown such an association but seems now to have been extirpated from the study stretch. The blasting is so spatially restricted it seems very unlikely that it could have a study-stretch-wide effect on food resources for these species: both the wagtail and the bushchat are abundant in areas that will not be blasted, and it seems implausible that some (hypothetical) highly specialised prey species requiring the very narrow, fast stretches that will be modified by the LMDP is/are responsible for sustaining these two species' populations the length of the study stretch.

Pollution: a wide range of chemicals is used in association with boats and their attendant infrastructure, and in the construction and running of a hydropower project. Many of these are damagingly polluting to river wildlife. A poorly managed pollution incident could have severe effects locally and temporarily. Such a risk exists today and while the increased shipping that the LMDP will facilitate will increase the risk, this is not a new threat nor even a transformational increase in risk.

Vegetation change: changes in vegetation in the seasonally exposed channel bed and underwater could affect the bird community including populations of project species. With the LMDP there clearly will be change in the areas blasted but, as with a number of potential threats, the amount of exposed channel mosaic that will not be blasted is much higher than that which will be. This is so even for existing water-channel-side areas, which might plausibly hold vegetation that would not, immediately, colonise rock faces newly exposed by blasting. A material effect on the channel bird community seems, therefore, unlikely.

Water-level change: the LMDP will not, materially, change water levels at any time of year or in the pattern of water level change through the year.

Sediment flow and distribution change: the blasting of some stretches of exposed rock will result in local changes to sediment flow and deposition around the blasted areas, but at the scale of the full project stretch the LMDP has no obvious mechanism to cause a major change in amount of sediment transported during high-flow periods or the amount dropped in the low-flow season. The precise spatial pastern of unconsolidated sediment will change somewhat but it is implausible that this will drive any material change in bird populations.

Relocation of solid material: the LMDP will remove a large amount of shattered rock and no doubt some amount of unconsolidated sediment. Mostly, it is unlikely to be problematic for the avifauna wherever this is relocated, unless it is (i) used for filling in plains wetlands (which are seriously threatened habitats, but outside the scope of this study) or (ii) ends up in deep pools within the river channel which might well result in reduced food supply for some river bird species. Much of the remaining avifaunal value of this stretch of the Mekong comes from the areas with lots of unconsolidated sediment of various sizes, which is subject to major redistribution each high-flow period. This instability is the natural situation for the specialist avifauna. In many places there is already large-scale removal of sediment for use in construction, without obvious change to the specialist bird communities. While there may well be some short-term, localised, negative impacts on birds (most plausibly, through food supply and/or accessibility changes) of blasting, dredging and other activities releasing extra sediment into the river (see above), it is unlikely that creation and removal of sediment for LMDP is going to have major long-term effect on bird populations.

Water-flow speed change: for most of the project stretch, the LMDP will have no effect on water flow speeds. Around the exact places where the channel has been widened, water speed will decrease (as a consequence of increased cross-sectional area but constant volume moved per unit time). This is unlikely to have any effect on birds directly, but could conceivably do so through changes in food supply, as it could lead to significant change (at the very spatially localised scale) in fish and aquatic invertebrate communities. The only project species strongly associated with fast-flowing water (and thus most plausibly at risk from this factor) is Crested Kingfisher, which appears already to have been extirpated from the project stretch.

4.5.4 *Scenarios*

Baseline: no LMDP

This is covered in the 'forward projection' section of the baseline report. Basically, the catastrophic collapse of the project-stretch avifauna has, largely, occurred already, and all species left are by definition relatively resilient on a river of this width. Nonetheless, many are probably still in decline and this is likely to continue. Some extirpated species may recolonise, reflecting factors operating outside the project stretch. But overall, the future avifaunal community is likely to be shaped by the continued loss of species and decline in numbers of those study species that still occur.

With the LMDP

There are no obvious likely material long-term effects of the LMDP on the conservation value of the study stretch's avifauna except at the most local of scales. It is possible, but seems unlikely, that such effects could occur via changes in food supply consequent upon blasting, or via pollution. During construction, there could be severe but probably only transitory negative effects from two factors: unregulated use of the dry-season exposed channel as a living base by itinerant people, and increased dry sediment flow. The most likely 10–20 year future scenario is indistinguishable from the baseline scenario. This benign prediction reflects entirely the very small proportion of seasonally exposed habitat that will be removed. A much larger scale of removal would be catastrophic for the channel avifauna. It may be that previously expressed views, that the LMDP would be a serious threat to riverine birds, failed to appreciate its small scale relative to the habitat extent. Alternatively, or additionally, various parties may have vested interests in alarmist prognostications, prioritising aspects other than veracity.

4.6 SOCIO-ECONOMICS AND LIVELIHOODS IMPACT ASSESSMENT

4.6.1 *Introduction*

When considering the environmental impacts of a development plan, socio-economics is the point at which environmental impacts interact people. Conserving the environment, as well as the flora and fauna within it, is important. However, the rationale behind development plans, including the LMDP, is to improve livelihoods. Thus, it is important to assess the directly bio-physically induced socio-economic impacts as well as changes that occur because the biophysical changes lead to different usages of an area.

This chapter documents the potential impacts on local peoples' socio-economic situation that could result from clearing "dangerous areas" in the river as well as from constructing ports in the section of the Mekong River between the Golder Triangle (confluence of the Mekong and Ruak rivers near Chiang Saen) and Luang Prabang.

4.6.2 *Summary of Baseline Conditions*

The socio-economic baseline study was completed to give the reader a picture of the socio-economic situation and conditions for the people living on or near the Mekong River over the 360 km stretch that forms the study area. The baseline report provided an overview of the physical aspects of the river. As part of this overview, it was shown that of the 23 dangerous areas on the Mekong mainstream in the study area, only five (5) do not have communities living in the immediate area. Following the physical description of the river, detail was provided about the people in the study area and a poverty and livelihoods assessment was conducted covering a variety of areas. A summary of the people and the poverty and livelihoods sections is provided here:

4.6.2.1 People (including ethnic minorities)

There is a total population of just over 100,000 people who will be affected by the LMDP. Approximately 19,000 of these people live in Thailand and the remainder in Laos, and of the 100,000 people, over 75% (76,000) live within the first 100 km below the Ruak-Mekong confluence (Zone 1 of the study area). Data on ethnicity was only able to be sourced for the Laos side of the border, and it shows that about 36% of the Lao population in the area are likely to be from the majority Lao-Tai ethnic family, around 33% from the Mon-Khmer peoples, and around 15% from each of the Hmong Lewmien and Sino-Tibetan peoples.

4.6.2.2 Poverty and livelihoods

The agricultural sector in Laos remains a very important part of the economy, and it is being used as a tool by government to generate foreign investment in the country. While this is laudable, some negative impacts associated with this policy have been observed for the poorest segments of society, whose food security is at risk. Some of the risk is associated with outsiders who hold land concessions, but who log illegally outside the concession boundaries. In addition to logging, wildlife trafficking is big business in Laos, although most illegal wildlife products are sourced internationally.

There will be business opportunities associated with implementation of the LMDP such as those associated with an increasing tourism trade. However, business opportunities like this are much more likely to benefit the wealthy, while ethnic minority groups and other poor people shoulder many of the negative impacts. Poverty rates in the study area are high, and while fishing is not a full-time occupation for many people in the study area, most households do fish during the year. This gives them access to a critical source of protein and micronutrients in their diet. Most fish caught is for household consumption, and provides an important food security buffer, particularly for ethnic minority and other poor communities.

4.6.2.3 Summary of likely impacts in narrative form

There are three main existing trends that will affect the lives of those living in the study area over the coming years. Understanding these trends helps to situate the impacts of the LMDP in the broader development context. The main trends are:

1. Population growth rates. Population growth rates are decreasing in both Thailand and Laos, and in Chiang Rai the growth rate (0.38%) is already well below the Southeast Asian average annual population growth rate of 1.06% (http://www.worldometers.info/world-population/south-eastern-asia-population/). In Laos, the growth rates are higher than the Southeast Asian average, except in Luang Prabang, which has an annual population growth rate of 0.6% p.a.
2. The total population within the study area can be expected to grow by around 12,000 people over the 7 years from 2018 to 2025, from the current 100,000 people to about 112,000 people.
3. An extra 12,000 people over 7 years means a moderate level of provincial and town planning will need to take place, however this is normal population growth, and so the vast majority of the new residents will still be young children in 2025.
4. In contrast, the implementation of the LMDP, particularly the construction of ports, will bring in migrants: those looking for construction jobs, those looking for business and other opportunities in towns, as well as those looking for land concessions and other opportunities in the surrounding areas. The migrant population is likely to be far smaller than 12,000 people by 2025, however their impact on the towns where the ports will be built will be far greater, and to avoid risks of negative socio-economic impacts, will require much more short to medium term planning by local authorities to accommodate them. The impacts are considered in detail below, assuming no mitigation or planning is done ahead of time.
5. The Lao government is promoting agri-business development across the country. Combined with this, northern Lao has already seen a very rapid growth in the amount of land being used to cultivate rubber. The implementation of the LMDP is likely to magnify the impact of the government policies in support of agri-business. This is because the LMDP will improve access to the main towns along the river, as well as directly improving the port facilities, and indirectly improving services, such as mechanics, in these towns. The construction of port facilities is also very likely to be accompanied by infrastructure upgrades, particularly for roads in the region. With all the added infrastructure, as well as the improved transportation on the river itself, plantations are likely to expand in the area much more rapidly than they would if the LMDP were not implemented. The impacts of this nature are detailed below.
6. Illegal logging is continuing to expand in Laos. Satellite imagery of northern Laos shows a variety of large areas, up to 20km across that have been denuded of forest. While official statistics report that forested areas are growing, scientific studies suggest that all provinces in the country are showing a year on year decline in forest cover. The four Lao study area provinces all show a lower than national average rate of forest loss. The government does not have reliable information on logging quotas or on registered timber shipped out of the country. For example, Chinese and Vietnamese data on imports of timber from Laos are an order of magnitude greater than what appears in Lao export data. For the same reasons that the implementation of the LMDP will magnify expansion of plantations in Laos, it will also almost certainly result in more logging, both legal and illegal. Particularly as China is a major destination for Lao logs and timber, the improved navigation on the Mekong, and improved port facilities will make the area much more enticing for logging. Additionally, logging in Laos is very often done in association with Chinese and Vietnamese companies investing in plantations among other areas, often with upwards of 75% of the logging happening illegally. Thus, improved roads associated with the port constructions will bring foreign investors

seeking concessions for plantations such as rubber, and logging will occur alongside the land concessions.

In addition to the three points above, there are a six other trends and factors that also influence the way that LMDP impacts should be interpreted.

1. Laos has the fastest growing illegal wildlife trade in the world, and it is centred in northern Laos, with a large amount of this happening, for example, at the Golden Triangle, where the Ruak and Mekong rivers converge. There is the potential for upgraded roads and port infrastructure to facilitate further growth in this trade, however, Laos is largely a hub of the trade and is neither a big source of wildlife products nor large destination country. Thus, the biggest change to the illegal wildlife trade as a result of implementing the LMDP is likely to be that the upgraded Mekong makes a new route available for wildlife products from, for example, Africa.
2. Tourism is already a large foreign income earner in Luang Prabang with its more than 300 hotels and guesthouses. There is also a constant flow of boats that take tourists up and down the Mekong River between Luang Prabang and Houay Xay. Most tourists travel on the river by slow boat, and stay for one night in Pak Beng town on the way, and this accounts for about 65% of all the tourism in Oudomxay province. The implementation of the LMDP could either enhance or diminish tourism business opportunities along the Mekong River. The ambiguity is because, firstly, improved navigation will mean bigger boats, which will mean the number of tourists travelling along the river is likely to grow. However, the other consideration is that the larger vessels will likely make the trip from Luang Prabang to Houay Xay in a single day, obviating the need for places to stay in, for example, Pak Beng. The Oudomxay tourism management plan recognises the need for the province to become a tourism destination in order for tourism to flourish there. Thus, the effect of the LMDP on tourism along the river is likely to depend in large part on whether or not Oudomxay tourism authorities succeed in transforming their province into a tourist destination. If they are successful, it is also likely to that expanding tourism will have flow on effects in neighbouring areas.
3. Fishing is likely to remain an important part of rural peoples' food security buffer for many years to come. It may become more important to the food security needs of vulnerable populations if they are forced to relinquish their customary lands because of expansions of logging and plantation areas the LMDP. Despite this possibility, fish stocks in the Mekong River and its tributaries have the potential to be negatively affected by the LMDP because of changes to deep and very deep pools as rocky sections of the river are blasted, and because of dredging and urban run-off associated with port developments that could affect habitats as well as breeding sites.
4. Agriculture will be affected in two distinct ways by the implementation of the LMDP. First, improved access will incentivise expansion of plantations, which will primarily benefit those who come from outside the area to develop them (the impact for local populations is discussed above). Second, the implementation of the LMDP will result in riverbank erosion, which is likely to impact on riverbank vegetable gardens, grazing lands as well as rice and other agricultural crops grown on the riverbanks. From a socio-economic perspective this will primarily impact on the poor and near poor who rely on the river bank gardens and fields for their food security.
5. The main drivers of deforestation and forest degradation in Laos are investments in commercial plantations, logging, and shifting agriculture. The implementation of the LMDP, is very likely to cause an expansion of logging and plantations in the region. Conversely, it will likely reduce the amount of shifting agriculture, as those who customarily practice shifting agriculture are pressured to allow plantations and logging in their traditional lands.

6. From a Thai perspective there are five dangerous areas that will be altered, and two ports that will be constructed (ie. in the 100km immediately downstream from the convergence of the Mekong and Ruak rivers). The LMDP may increase the level of illegal logged timbers entering Thailand, although Thailand's pursuit of a Voluntary Partnership Agreement (VPA) with the EU may mitigate this. While around 12% of Thailand's forest cover is made up of rubber plantations, these are managed by smallholder farmers. As Thailand is an importer of illegal timber rather than an exporter, and because plantations in Thailand are managed by smallholders, rather than big companies, it is unlikely that Thai communities along the river and road networks will face pressure to relinquish their lands as a result of the LMDP being implemented. Thailand is likely to see more tourists arriving in the country via Houay Xay, and there could be opportunities for development of areas within Chiang Rai province as tourist destinations.

4.6.2.3.1 Socio-economic impacts by theme in the study area

The study of socio-economic systems differs substantially from other aspects of this study into the impacts of the LMDP. Physical changes to the river and its banks will derive directly from the removal of rocks and sandbanks, and changes to fish and bird populations relate to how their habitats will be affected by the changes in the river. By contrast, while there will be direct socio-economic impacts, the majority of the socio-economic impacts depend on people’s behaviours and the change management decisions that are made. This realisation that final outcomes are mediated by socio-economic responses underlies, for example, public health paradigms. Urban planners incorporate cycle paths and green spaces into cities, not just because they make cities feel nicer, but because they wish to encourage active transport and physical activity, and in so doing reduce future burdens on the medical system (see e.g. Giles-Corti et al. 2016). In the case of the LMDP, building a new port will change both the numbers and types of people in the town where the port is built because there will be construction crews, crews from river vessels as well as people who come to set up businesses to provide construction, mechanical, provisioning and other services. These extra people change the social dynamic within the town, and so the impacts have multiple layers and dependencies.

Because of the multiple layers that of effects between the physical LMDP implementation and final socio-economic impacts, this section of the impact report is formatted to clearly show the different layers as well as the assumptions that have been made in each case. Each root-cause is identified and then linked through a series of steps to final impacts. For example, increased freight capacity on the river (because of larger boats) links to probable growth in trade in towns where new ports are built. This in turn means probable increased rates of construction in these towns, and because of this there will likely be construction-related employment opportunities. Because of employment opportunities migrants will probably come looking for work, and the increase in migrant population (not all of whom will find work) will mean a probable rise in negative social issues such as substance abuse and prostitution.

In this impact assessment, expert judgement has been applied to predict likely changes in the numbers and types of people along the river, as well as the likely impacts on activities in towns as well as to rural activities like logging and farming. The judgements that have been applied are based on expert experience both in and outside of Southeast Asia of indirect impact flows. It should be noted that the probable and potential impacts identified here are not certain to occur, and forward planning can minimise the likelihood of negative impacts occurring, while at the same time encouraging positive impacts such as increased employment opportunities. Management options to minimise negative impacts and foster positive impacts are described in the following mitigation report.

Socio-economic impacts here are broken down into two over-arching themes. First are the direct socio-economic impacts associated with biophysical impacts that result from the LMDP implementation. Second are more indirect, and relate to likely usage changes in the river following implementation of the LMDP, and the socio-economic impacts that may result. The purpose of this document is to highlight potential and likely impacts so that management plans can be developed to mitigate negative impacts and enhance positive impacts. The impacts are divided on a probability spectrum, as per Table 4.16 below.

Table 4.16: Probabilities of impacts occurring, and corresponding descriptive terms

Probability of the impact (in the absence of mitigation)	Terminology used
It will definitely occur	**will**
It is almost certain to occur	**very likely to**
It will probably occur	**likely to**
There is a possibility it will occur	**potential to**

Of course, the impacts (both direct impacts and those that follow changes in how the river is used) of the LMDP will not occur in a vacuum. For example, the baseline socio-economic report highlighted that population growth is one of the causal factors in deforestation and forest degradation. As a desk-based study, this socio-economic assessment is primarily qualitative in nature, but where possible does take into account the existing trends in the study area. In the sections below, impacts in the study area are presented where those impacts are likely to differ significantly in magnitude or direction from the existing baseline trends.

4.6.2.3.2 Biophysical impacts

4.6.2.3.2.1 Bank Erosion

1. Dredging of channels **will** lead to river-bank erosion
   1.1. There is **likely** to be a loss of riparian farmland. *(Q: What is the socio-economic situation for riparian farmland users/owners?)*
      1.1.1.If riparian farmers are poor or near poor, the shock of loss of farmland to erosion has the **potential to** drive their households into poverty.
      1.1.2.If the riparian farmers are poor or near poor, the loss of farmland is **likely to** undermine household food security.
2. Wakes from increased large vessel traffic **will** cause bank erosion
   2.1. There is **likely** to be a loss of riparian farmland. *(Q: What is the socio-economic situation for riparian farmland users/owners?)*
      2.1.1.If riparian farmers are poor or near poor, the shock of loss of farmland to erosion has the **potential to** drive their households into poverty.
      2.1.2.If the riparian farmers are poor or near poor, the loss of farmland is **likely to** undermine household food security.
3. Port development and embankments **will** cause bank erosion across-stream & downstream
   3.1. There is **likely** to be a loss of riparian farmland. *(Q: What is the socio-economic situation for riparian farmland users/owners?)*
      3.1.1.If riparian farmers are poor or near poor, the shock of loss of farmland to bank erosion has the **potential to** drive their households into poverty.
      3.1.2.If the riparian farmers are poor or near poor, the loss of farmland is **likely to** undermine household food security.

4.6.2.3.2.2 Fresh water algae

4. Where large amounts of sediment are being dredged/moved (ie. dredging sections and port developments), fresh water algae growth is **likely** to be impacted in the short-term. (Q: What is the socio-economic situation for those who harvest kai?)

4.1. There is **likely** to be a detrimental impact on local economy as "kai" is the main harvest from the Mekong in the Chiang Khong area of the river (impact will be centred on Chiang Khong and is likely to be **low in severity**).

4.2. If those who harvest kai are poor or near poor, a short term loss of harvestable kai is **likely to** undermine household food security.

4.2.1. There is a **potential** for households to fall into, or back into, poverty.

4.6.2.3.2.3 Water Pollution

5. More ships crews and passengers are **likely** to lead to more organic pollutants (waste water) entering the river.

5.1. This has the **potential to** lead to some increase in instances of water- and food-borne diseases along the length of the river. As background, Kunming Engineering Corporation Limited (2015) observed that stomach and diarrhoeal complaints are already the most common morbidity complaints among 25 surveyed villages in the dam affected area, with 30% of complaints being for acute watery diarrhoea.

6. Expansion of towns around port developments will increase domestic waste-water runoff into the river.

6.1. This 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.

7. Increased water pollution is **likely to** have a negative impact on the desirability of this stretch of the Mekong River as a tourist destination.

4.6.2.3.2.4 Impact on Fish and Other Aquatic Animals

As per the baseline section of this study, most of the dangerous areas along the river have riparian communities living within 1 -2 km of them. It is likely that these settlements have been established at least partly because the rapids areas of the river make good fishing grounds. This could be confirmed through field surveys.

8. Some rocky material from channel clearing has the **potential to** be deposited in deep pools down river.

8.1. This is **likely to** have a negative impact on fish habitats, including for endangered species such as the giant *Pangasius* catfish, and other larger fish. This has the **potential to** reduce fish stocks in these areas.

8.1.1. This has the **potential to** undermine food security for those living adjacent to or in the near downstream of rocky zones for which blasting is planned. *(Q: What are the socio-economic situations for communities who live and/or fish in or near the rapids for which channel improvements are planned?)*

9. Construction of ports is **very likely to** be accompanied by loss of river bank vegetation and disturbances to the river bed.

9.1. This is **likely to** degrade fish habitats in nearby downstream areas.

9.1.1. This has the **potential to** undermine the food security for the poor and near poor living in or near the towns where the ports will be developed (Houay Xai, Chiang Khong, Pak Beng and Luang Prabang).

10. Because riffles increase the oxygen levels in river water (Connolly *et al.* 2004), removal of rock from the dangerous areas has the **potential to** lower the dissolved oxygen content of the nearby water.

10.1. This has the **potential to** negatively impact on aquatic life in the vicinity.

10.1.1. This has the **potential to** undermine food security for those living adjacent to or in the near downstream of rocky zones for which blasting is planned.

11. Port constructions:

11.1. ***<u>Zone 1:</u>***

11.1.1. **Houay Xai:** in a sandy area of the river, **likely to** be substantial disturbances in the short term as a result of dredging for the port as well as oil and diesel contamination in the water.

11.1.1.1. Dredging is **likely to** impact on kai harvesting, particularly as Houay Xai is in the Chiang Khong area, where kai represents the main river produce.

11.1.1.1.1. This is **<u>likely to</u>** cause a detrimental impact on local economy as "kai" is the main harvest from the Mekong in the Chiang Khong area of the river (impact will be centred on Chiang Khong and is likely to be **low in severity**);

11.1.1.1.2. If those who harvest kai are poor or near poor, a short term loss of harvestable kai is **likely to** undermine household food security.

11.1.2. Port development in Houay Xai is **likely to** link to significant infrastructure upgrades in the region, such as the roads to Louang Natha and Xieng Dao (near the Myanmar border), where satellite imagery suggests there is already logging or mining taking place.

11.1.2.1. Infrastructure upgrades of this nature is **very likely to** encourage the expansion of logging and/or plantations in the area because of better access to the river and transport on the river (see impact 12 and 13 for more details)

11.1.2.2. Road upgrades are also **likely to** lead to more injuries and fatalities from traffic accidents, because traffic can travel faster.

11.1.3. **Chiang Khong:** in a sandy area of the river, there is likely to be substantial disturbances in the short term due to dredging as well as contaminants entering the river.

11.1.3.1. Kai harvesting, is **very likely to** be negatively impacted, particularly as Chiang Khong is an area where kai represents the main river produce.

11.1.3.1.1. This is **likely to** cause a detrimental impact on local economy as "kai" is the main harvest from the Mekong in the Chiang Khong area of the river (impact will be centred on Chiang Khong and is likely to be **low in severity**);

11.1.3.1.2. If those who harvest kai are poor or near poor, a short term loss of harvestable kai is **likely to** undermine household food security.

11.2. ***<u>Zone 2:</u>***

11.2.1. **Pak Beng:** is "*narrower, more incised, straighter and rockier than"* Zone 1. There are deep pools in the near downstream area (see Figure 4.5 for locations of deep and very deep pools). Disturbances related to the Pak Beng port development are **likely to** disturb dry season habitats for endangered species such as the giant *Pangasius* catfish, and may impact on breeding habitats (the information in the literature on the use of deep water pools as breeding sites is not robust).

11.2.1.1. This has the **potential to** undermine food security for the poor and/or near poor who live in the vicinity of the port development and any downstream deep water pools. *(Q: what are the socio-economic conditions for the people living near 18 of the 23 dangerous areas? Q2: what socio-economic data is available from local authorities about poor segments on the population in the towns of Chiang Khong, Houay Xai, Pak Beng and Luang Prabang?)*

11.2.2. Port development in Pak Beng is **very likely to** link to significant infrastructure upgrades in the region, such as the road to Muang Ngeun (near the Thai border), where satellite imagery suggests there is logging or mining already taking place, as well as to Muang Xay, the provincial capital of Oudomxay Province.

11.2.2.1. Infrastructure upgrades of this nature is **very likely to** encourage the expansion of logging and/or plantations in the area because of better access to the river and transport on the river (see impact 12 and 13 for more details)

11.3. **Zone 3**

11.3.1. **Luang Prabang:** The river widens as it approaches Luang Prabang, and the riparian areas become more developed. *(Q: where will the port be located? Q2: will the addition of a port significantly impact the economy in Luang Prabang? (e.g. is it likely that there will there be road upgrades associated with port facilities in Luang Prabang?))*

4.6.2.3.3 Socio-economic Changes and Potential Impacts on Peple's lives

4.6.2.3.3.1 Increased traffic: both more and larger vessels

12. It is **very likely** that companies will seek to take advantage of the Lao government's interest in agribusiness as part of a strategy to move towards modern and industrialised forms of production

12.1. It is **very likely** that additional land concessions will be sought (and granted) following improvements in the channel (better transport) and development of port facilities (faster, easier and cheaper loading and unloading of vessels)

12.1.1. It is **likely that** poor communities (and particularly ethnic minority communities) will be pressured to give up their autonomy and customary title to the land they farm in exchange for waged employment on plantations

12.1.1.1. There is **potential** for loss of traditional life-style practices

12.1.1.2. There is **potential** for loss of food security as households become dependent on mono-crops and the fluctuations of world price markets

12.1.1.3. There is **potential** for communities to improve their lives because they have a more consistent income and can enhance their engagement with the market economy (but this is more likely if they are not pressured to give up their lands)

13. It is **very likely** that logging companies (legal and otherwise) will begin or expand operations in the region (particularly as China is a major destination for Lao timber)

13.1. It is **very likely** that additional land concessions will be sought and granted following improvements in the channel (better transport) and development of port facilities (faster, easier and cheaper loading and unloading of vessels)

13.1.1. It is **likely** that poor communities (and particularly ethnic minority communities) will be pressured to give up their autonomy and customary title to the land they farm in exchange for waged employment on plantations

13.1.1.1. There is **potential** for loss of traditional life-style practices

13.1.1.2. There is **potential** for loss of food security as households become dependent on mono-crops and the fluctuations of world price markets

13.1.1.3. There is **potential** for communities to improve their lives because they have a more consistent income and can enhance their engagement with the market economy (but this is more likely if they are not pressured to give up their lands)

14. There is **likely to** be a growth in general trade in the four towns where ports will be built

14.1. It is l**ikely** that towns will expand as new traders establish themselves

14.1.1. There is **likely** to be an increased rate of construction of new buildings

14.1.1.1. There are l**ikely** to be employment opportunities in construction and services sectors

14.1.1.1.1. There are **likely** that more 'outsiders' (construction workers, traders, boat crews) will come to towns and villages in the study area.

14.1.1.1.1.1. There is **likely to** be more gambling, and more alcohol/substance abuse

14.1.1.1.1.2. It is **likely** that levels of violence/civil disturbances will increase

14.1.1.1.1.3. It is **likely** that gangs will form

14.1.1.1.1.4. It is **likely** that there will be a growth in prostitution

14.1.1.1.1.5. It is **likely** that there will be increased rates of sexually transmitted diseases

14.1.1.2. It is l**ikely** that there will be increased instances of respiratory illnesses because of dust due to construction

14.1.1.3. It is l**ikely** that mosquito populations will grow (e.g. construction materials left where they can collect water, thus providing breeding sites for mosquitos)

14.1.1.3.1. There is l**ikely** to be an increase in vector-borne disease rates (predominantly dengue in more urban areas, and predominantly malaria in more forested areas)

14.1.1.4. 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)

14.1.2. It is l**ikely** that a wider range of products will become available at local markets

14.1.3. There is **potential** for people along the river to trade more produce with each other

14.1.3.1. There is **potential** for social networks to become stronger

15. It is **very likely** that more 'outsiders' (construction workers, traders, boat crews) will come to the towns where ports are developed in the study area (Luang Prabang, Pak Beng, Houay Xai and Chiang Khong).

15.1. There is **very likely to** be more gambling, and more alcohol/substance abuse

15.1.1. It is **very likely** that levels of violence/civil disturbances will increase

15.1.2. It is **very likely** that gangs will form

15.1.3. It is **very likely** that there will be a growth in prostitution

15.1.4. It is **very likely** that there will be increased rates of sexually transmitted diseases

16. There are **likely to** be increasing opportunities in the tourism sector

16.1. There are **likely to** be new tour operator business opportunities

16.2. 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)

16.3. There are **likely to** be new hotels/guesthouses established

16.3.1. There is **likely to** be an increased rate of construction of new buildings

16.3.2. There are **likely to** be new employment opportunities in construction

16.3.3. There are **likely to** be increased instances of respiratory illnesses because of construction-induced dust.

16.3.4. It is l**ikely** that mosquito populations will grow (e.g. construction materials left where they can collect water, thus providing breeding sites for mosquitos).

16.3.4.1. There is l**ikely** to be an increase in vector-borne disease rates (predominantly dengue in more urban areas, and predominantly malaria in more forested areas)

16.3.5. 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 housing or municipal sanitation facilities as well as poor living conditions for new arrivals)

16.4. There are **likely to** be enhanced opportunities for ethnic minority communities to showcase their culture and way of life

16.4.1. This also has the **potential to** cause ethnic communities to lose their autonomy/have their culture(s) commercialised/trivialised.

16.5. It is **likely** that the income gap between the wealthy and poor will widen further (because the wealthy will be able to take advantage of opportunities, while the poor will tend to bear the brunt of negative impacts)

17. Increased large boat traffic has the **potential to** result in more accidents on the river, particularly as people rely on small boats on the river for transport.

Most of the negative impacts described will be predominantly borne by poorer segments of society such as ethnic minority groups (e.g. vector-borne disease increases are more likely to affect those living in poorer quality housing). Conversely, many of the opportunities will be primarily available to the wealthier (e.g. only the wealthier will be able to access funds to build hotels to cater to increased tourist trade).

4.6.3 *Conclusions*

This report highlights that the predominant negative impacts will fall upon ethnic minorities and other vulnerable groups. Whereas a wealthy household may be able to cope with the loss of 100 m^2 of land, a household that is just barely surviving would be severely affected by the same impact. Thus, the socio-economic impacts do not relate only to the biophysical impacts, but also to the circumstances and the contexts in which affected people are living. Statistically ethnic minorities have a tendency to be less well educated, less likely to speak Lao, to live in more remote locations, and more likely to be subsistence farmers. All these factors make ethnic minorities more vulnerable in general than the dominant Lao-Thai peoples.

The negative impacts noted in this section of the report can be managed and mitigated, while at the same time enhancing the positive impacts. The next section of this report outlines strategies to do this. Planning ahead, and building the mitigation strategies into the LMDP prior to beginning implementation will be both more effective and more efficient in monetary terms.

4.7 LMDP IMPACT ASSESSMENT CONCLUSIONS

Hydrology and sediment: are river characteristics that have major implications for ecology and biodiversity. For example, flooding enables connectivity to the floodplain and rising water levels can serve as a trigger for fish spawning. Changes in sediment transport can provide new habitat for fish species, or alternatively can smother existing habitats or fill in pools. 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. When all the navigation improvements are assessed cumulatively for each zone, there is enough "dilution" effect to spread the impacts which are assessed as very low for all the components – geomorphology, wetland habitats, aquatic vegetation and macroinvertebrates. 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, there should be a note of caution attached to positive changes such as this. Using consumption as a proxy indicator of changes in people's socio-economic status, the World Bank's (2014, p. 5) graph (for Lao PDR nationally) shows that over the ten year period 2003 – 2013, poorer people's socio-economic status improved much less than wealthier people's socio-economic status did (see socio-economic baseline report). Similarly, in the study area, it is 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. Other positive impacts will include employment growth, not just for port facilities construction (and to a lesser extent for the work on the navigation channel), but also as construction workers building hotels, and in the service sector in restaurants, cafes and hotels. The most likely positive impacts will be:

- Increased trade in primary industries, transport and tourism, and hence potential for local economic growth;
- Employment opportunities in construction of housing, hotels, and tourism related services;
- Opportunity for new businesses – tourism, restaurants, shops, handicrafts.

As with the distribution of positive impacts being weighted towards wealthier segments of the Mekong communities, the distribution of negative impacts will tend to fall hardest on those who are poorer and less well educated. The main negative socio-economic impacts identified in this study were:

- The potential for dredging and increased boat traffic to erode river banks, causing families to lose riparian farmland that they rely on for food security.
- Expansion of towns will lead to greater urban run-off, including of untreated domestic waste. This will increase levels of organic pollutants leading to a likelihood of increased instances of water-borne as well as food-borne diseases.
- Construction of ports will lead to loss of riverbank vegetation as well as significant disturbances to the river bed. This is likely to degrade fish habitats and possibly breeding area, thus reducing the number of fish and other aquatic animals in the areas near these towns. Loss of aquatic biodiversity because of breeding site degradation and degradation of the water near expanding towns may impact on food security, particularly for those already living under or near the poverty line.
- Better access to remote areas of the Mekong will make it more likely that investors will seek land concessions in the area for activities such as plantations (e.g. rubber, palm oil) and logging. This is likely to result in local populations, particularly poorer and ethnic minority villages, being pressured to give up their customary title to the land they farm, and with this their ability to directly provide food for their households (e.g. McAllister 2015, Kenney-Lazar 2016).

5 PAK BENG IMPACT ASSESSMENT RESULTS

5.1 HYDROLOGY AND SEDIMENT IMPACT ASSESSMENT

5.1.1 *Introduction*

Hydrology and sediment transport are river characteristics that have major implications for ecology and biodiversity. For example, flooding enables connectivity to the floodplain and rising water levels can serve as a trigger for fish spawning. Changes in sediment transport can provide new habitat for fish species, or alternatively can smother existing habitats or fill in pools.

In this chapter we document the potential impacts on hydrology and sediment transport from construction of the run-of-river Pak Beng HPP in the section of the Mekong River between Luang Prabang and Chiang Saen.

5.1.2 *Impacts in the Thai-Lao border to Pak Beng Dam reach*

5.1.2.1 Hydrology

5.1.2.1.1 Construction phase impacts

Table 5.1: Construction phase impacts on hydrology

Impact description	Likelihood	Consequence	Risk
Temporary constriction of river for construction causes high velocities in immediate area of the construction	Likely	Moderate	High

Temporary constriction of river causing high velocities

Plans for building the Pak Beng dam involves two stages (KECL, 2015). In the first stage, half the river is blocked entirely to provide a dry area for dam construction. Once construction on half the dam is completed, water is allowed to fill and overtop the completed section, whilst the other half of the bed is dried to allow for construction. During these periods the river flow will be forced through approximately half the normal cross-sectional area, thus leading to higher velocities. This increase in velocities will be isolated to a small section of the river immediately at and below the construction site.

5.1.2.1.2 Longer term impacts

Table 5.2: Longer term impacts on hydrology

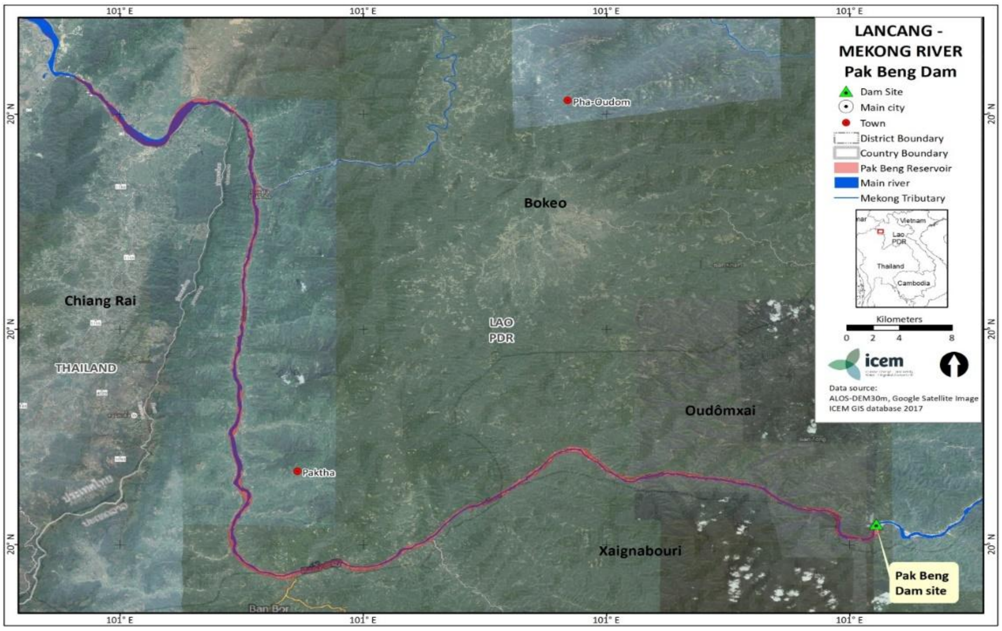
Impact description	Likelihood	Consequence	Risk
Increased water levels and flooding of existing habitats	Almost certain	Significant	Very high
Decreased flow velocities	Almost certain	Extensive	Very high
Changes in water quality	Almost certain	Moderate	high

Increased water levels and flooding of existing habitats

During filling of the Pak Beng reservoir, water levels will increase as the reservoir fills behind the 69m high dam wall. The dam developers have estimated that the backwater effect will reach 97km upstream of the dam (KECL, 2015) meaning that a total 27.5km^2 of river area will increase in depth (Figure 5.1). Water level increases will range from a maximum 30m increase at the dam wall to normal water levels at the upstream extent of the reservoir. For example, the dam developers have estimated an increase in mean monthly water level of up to 3.87m in the wet season (in November) and down to 1.23m in the dry season (in December) at Keng Pha Dai (KECL, 2015). Further upstream at Chiang Khong the largest increase in mean monthly water level is estimated at 0.18m (in August) and no change is predicted in February and March (KECL, 2015).

Increasing water levels will lead to flooding of existing riparian and terrestrial habitats. The reservoir will permanently flood approximately 11.0 km^2 of riverbank that is currently only sometimes flooded (Figure 5.1).

Figure 5.1: Pak Beng reservoir extent



Decreased flow velocities

Flow velocities in the reservoir area will significantly decrease compared to the naturally flowing river. Whilst an impoundment reservoir would lead to a lentic environment with high residence times and low velocity, it is planned that the Pak Beng dam will be operated as a run-of-river which matches inflow and outflow on a daily time-step. Residence times will therefore be lower, and velocities higher compared to an impoundment reservoir. With the information available to the study team it is not possible to estimate the changes in velocity, which will depend on how the reservoir is operated, but it is certain that some decrease in velocity will happen, and small changes in velocity can lead to major impacts for sediment transport and aquatic species.

Changing water quality

The submerging of riparian areas and establishment of lower velocities in the reservoir area, may lead to changes in water quality. An area of approximately 11.0 km^2 will be newly submerged by the Pak Beng reservoir. The decomposition of vegetation and soils in this newly submerged zone will likely deplete the levels of oxygen in the water, and can also lead to release of greenhouse gases methane and carbon dioxide.

Longer term, there are several water quality issues that commonly arise in reservoirs. For example, accumulation of Nitrogen and Phosphorus in a reservoir can trigger algal growth and decrease dissolved oxygen in slower moving water (Santos et al 2017). In addition, the large amount of slow moving water in a reservoir can be subjected to reservoir stratification (Mehta et al 2012).

The extent of deterioration in water quality is related to the retention time of the reservoir — its storage capacity compared to the amount of water flowing into it. In the case of Pak Beng, the retention time is quite low as it is designed as a run-of river. The capacity of Pak Beng will be 560 million m^3, which is equivalent to approximately three to six days flow at Luang Prabang[3] during the dry season, and half a day to two days flow during the wet season (compared than the months or years retention time in a large reservoir). Therefore, the water quality impacts downstream of the reservoir should be relatively limited compared to those of reservoirs with longer residence times.

5.1.2.2 Sediment transport

5.1.2.2.1 Construction phase impacts

Table 5.3: Construction phase impacts on sediment transport

Impact description	Likelihood	Consequence	Risk
Sediments mobilised and distributed in immediate area of dam site	Likely	Negligible	Moderate

Sediments mobilised and distributed in immediate area of dam site

Dam construction involves use of a wide number of vehicles including heavy machinery, drying of the river bed to allow for construction works and construction of roads to access the site. These changes often lead to increased sediment mobilisation in the immediate area around the dam site.

5.1.2.2.2 Longer term impacts

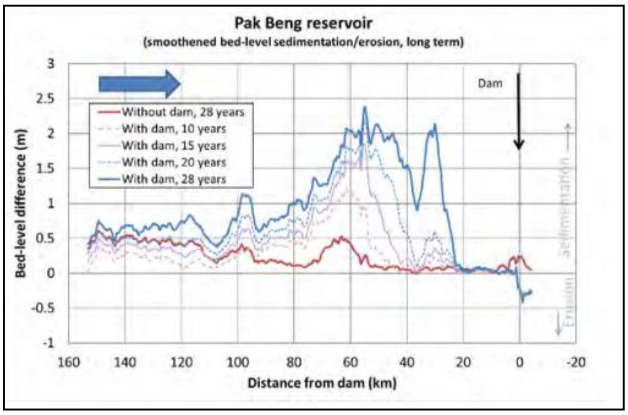
Table 5.4: Longer term impacts on sediment transport

Impact description	Likelihood	Consequence	Risk
Reservoir traps sediment	Almost certain	Significant	Very high
New deltas forming at the bottom of tributaries	Almost certain	Extensive	Very high

Reservoir traps sediment

Sediment transport capacity is the capacity of a river to move sediments along the channel, and is a function of flow velocity, channel cross-sectional area, channel slope and sediment grain-size distribution. With the establishment of a reservoir, the flow velocity will decrease, leading to lower sediment transport capacity. The reservoir design also includes a sediment barrier designed to divert the bedload to a sand-sluicing gate, to avoid it reaching the dam wall. The MRC ISH study estaimtes that the bed-level in the reservoir will increase by up to 2.5m in some places (Figure 5.2).

Figure 5.2: Modelled bed level changes in Pak Beng reservoir from years 10 to 28 from construction (MRC 2018)



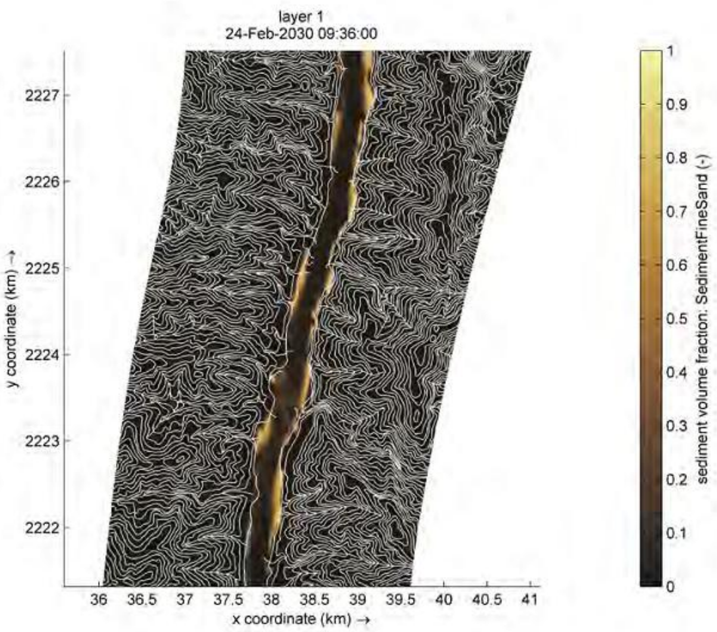
[3] It is noted that Luang Prabang is at the downstream end of the study reach, where flow volumes will be highest. Flow volumes at the upper end of the study reach can be assumed to be lower but the study team could not obtain discharge information at the dam site.

There are currently several sediment bars within the river stretch that the Pak Beng HPP reservoir will occupy (Figure 5.3, Figure 5.4, Figure 5.5).

Figure 5.3: Lateral sediment bars in the Pak Beng reservoir stretch, km 2274-2278 (MRC 2018)

Figure 5.4: Typical sand bar in Pak Beng reservoir stretch, km 2286 (MRC 2018)

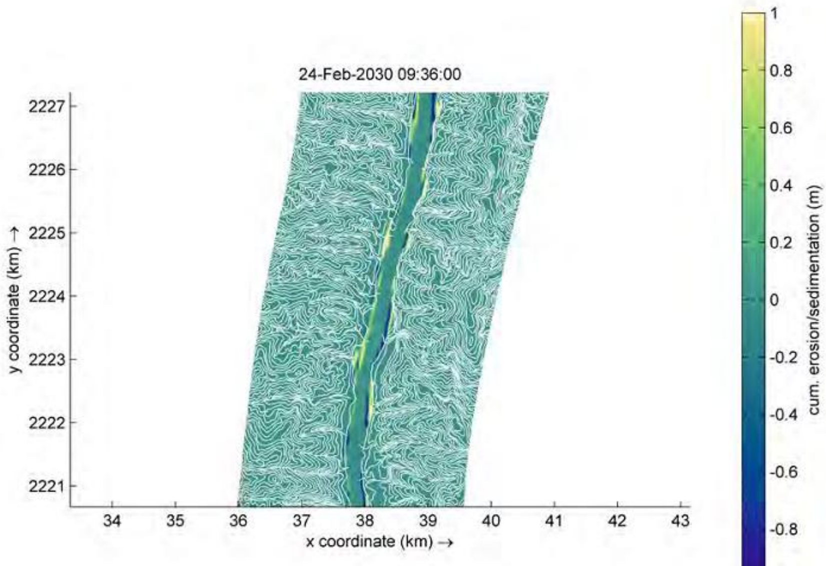
Figure 5.5: Fine sand fraction in river bed of Pak Beng reservoir stretch without the dam, km 2274-2278 (MRC 2018)



In the study reach, the suspended load is comprised of silt and clay, and bedload is dominated by sand and gravel (Bravard and Goichot, 2013). The larger bedload grain sizes will settle out first, likley causing a delta at the upstream end of the reservoir comprised of coarse sand and gravels. Any bedload that is transported through the reservoir will be blocked by the sediment barrier or dam wall. Whether the smaller suspended silt and clay suspended load will also settle out within the reservoir will depend on the reduction in velocity. The 2018 MRC ISH study modelled the impact of the Pak Beng dam on cumulative erosion and sedimentation in the reservoir showing developmmnent of lateral sediment bars (Figure 5.6).

Figure 5.6: Cumulative erosion and sedimentation in the Pak Beng reservoir

showing developmmnent of lateral sediment bars, km 2274-2278. Yellow zones indicate areas with deposition - sand bar growth (MRC 2018)



The MRC ISH study estimates that if Pak Beng HPP dam is operated as a run-of-river without any sediment mitigation, the annual sediment load will be decreased from 12.2 Mt/yr to 2.7 Mt/yr. T (Table 5.5 - MRC, 2018). There is also a substantial shift in the grain-size distribution of the transported sediment with virtually all gravel, coarse and medium sand, and most of the fine sand captured within the impoundments (MRC, 2018).

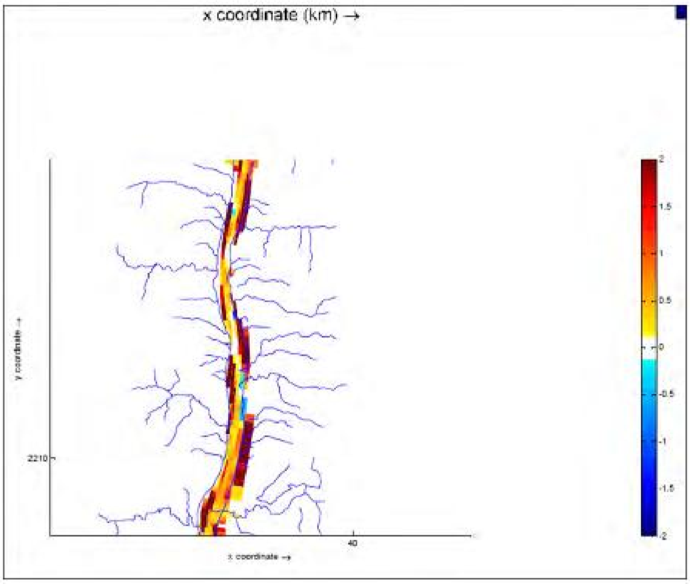
Table 5.5: Sediment load and composition before and after Pak Beng Dam with no sediment mitigation (MRC, 2018)

Indicator	Run-of-river with no sediment mitigation
Annual Sediment Load upstream of Pak Beng (Mt/yr) Km 2347	**12.2 Mt/yr** Gr: 2% C Sand: 8% M Sand: 22% F Sand: 63% Silt+Clay: 5%
Annual Sediment Load at Pak Beng Damsite (Mt/yr) Km 2188	**2.7 Mt/yr** Gr: <1% C Sand: <1% M Sand: 1% F Sand: 16% Silt+Clay: 84%

The longitudinal distribution of coarse, medium and fine sand within the Pak Beng reservoir (Figure 5.7) demonstrates that finer material is deposited farther downstream as compared to coarse sediment, but most material is trapped in the upper half of the reservoir over the 7-years of the model run (MRC 2018).

Figure 5.7. Distribution of sediment deposition within the Pak Beng reservoir

Colour bar shows deposition (red) and erosion (blue in meters (MRC 2018) – output of a Delft 3D model run over 7 years



New deltas form at the bottom of tributaries

Three main tributaries enter the river in this reach, the Nam Tha, Nam Ngao and Nam Mae Ing. The supply of sediment from each of these tributaries could not be quantified as no literature could be found and the study team could not obtain sediment or hydrological data for the tributaries. The study team therefore took a qualitative approach using satellite imagery to identify which tributaries are likely to be supplying large amounts of sediment.

Three key tributary characteristics were assessed through analysis of satellite imagery including catchment size, catchment land use and sediment deposits visible in the lower tributary. In general, a tributary with a large catchment containing large amounts of agriculture or mining is likely to have high sediment loads which would be visible as sediment deposits in the lower tributary. The three characteristics were assessed for the three tributaries with confluences within Pak Beng impoundment area (Table 5.6).

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. Delta's comprised of sand and gravel are therefore likely to form where these two tributaries meet the slower flowing water of the Pak Beng impoundment, smothering existing habitats in these areas.

Table 5.6: Tributary characteristics

Name	Catchment size	Catchment land use	Sediment deposits visible in lower tributary
Nam Tha	Medium	Forest/Agriculture	Yes
Nam Ngao	Medium.	Agriculture/Urban/Forest	Yes
Nam Mae Ing	Large	Agriculture	No

5.1.3 *Downstream Impacts of the Pak Beng Dam to Luang Prabang*

5.1.3.1 Hydrology

5.1.3.1.1 Construction phase impacts

Table 5.7: Construction phase impacts on hydrology

Impact description	Likelihood	Consequence	Risk
Altered flow downstream as the reservoir fills (Pak Beng dam impact)	Almost certain	Negligible	Moderate

Limited or no flow downstream as the reservoir fills

Downstream flows and water level will be impacted during filling of the Pak Beng reservoir, although the impact on flow is likely to be minimal due to the small reservoir volume compared to flow volumes. The capacity of Pak Beng HPP will be 560 million m^3, which is equivalent to approximately three to six days flow at Luang Prabang[4] during the dry season, and half a day to two days flow during the wet season.

Assuming the filling of the reservoir is extended over a year, the impact would be negligible. The total storage volume of the reservoir is only 0.5% of the total annual flow volume (120,000m^3 at Luang Prabang[1]), and is significantly less than the natural variation in annual flows. The impact would be increased if the filling was completed more quickly, and lessened if the filling is spread over several years.

[4] It is noted that Luang Prabang is at the downstream end of the study reach, where flow volumes will be highest. Flow volumes at the upper end of the study reach can be assumed to be lower but the study team could not obtain discharge information at the dam site. The developers estimate the mean annual flow volume at the dam site to be 99,600 million m^3, which means the total storage volume of the reservoir is only 0.78% of the total annual flow volume at the dam site.

5.1.3.1.2 Longer term impacts

Table 5.8: Longer term impacts on hydrology

Impact description	Likelihood	Consequence	Risk
Changes in the flow regime due to dam operations (Pak Beng HPP dam impact)	Almost certain	Negligible*	High
Changes in water quality due to dam releases (Pak Beng HPP dam impact)	Likely	Negligible*	Moderate

** Assuming that Pak Beng is operated as run-of-river*

Changes in the flow regime due to dam operations

If Pak Beng is operated as a proper run-of-river, the impact on downstream hydrology would be limited. Reservoirs alter downstream flows as they store water and release it to produce electricity. The Pak Beng dam is planned to be operated as a run-of-river, with a daily regulation. This means that the volume of water entering the reservoir over a 24hour period should equal the volume being released. This approach avoids issues with peaking hydropower (where water is stored and released during high energy demand periods, creating spikes and troughs in the hydrograph) and inter-seasonal storage (where water is stored in the wet season to be released in the dry season which flattens the annual hydrograph).

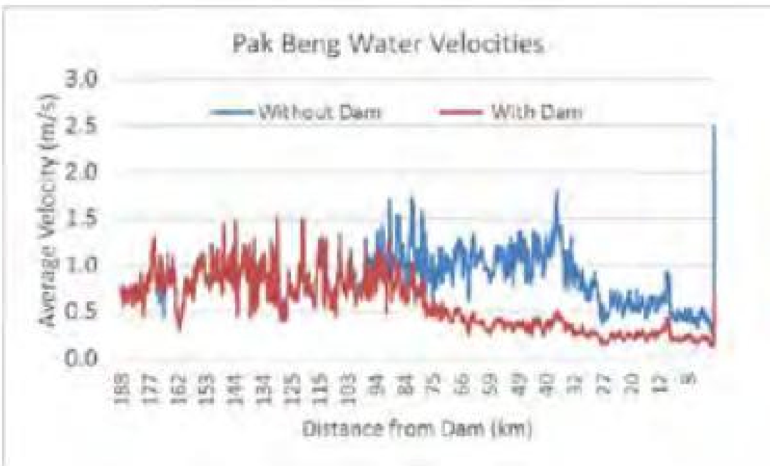
Changes in water quality due to dam releases

Water released from a reservoir may have reduced water quality. Water quality issues of the released water may include reduced Dissolved Oxygen levels due to decomposing vegetation in the reservoir area and lower temperatures due to deeper water levels.

Water velocities in the impoundment will decrease relative to pre-dam conditions, with velocities reducing to well below 0.5 m/s during the dry season (Figure 5.8- MRC 2018).

Figure 5.8: Average velocity in the Pak Beng HPP reservoir for the months of Dec-April.

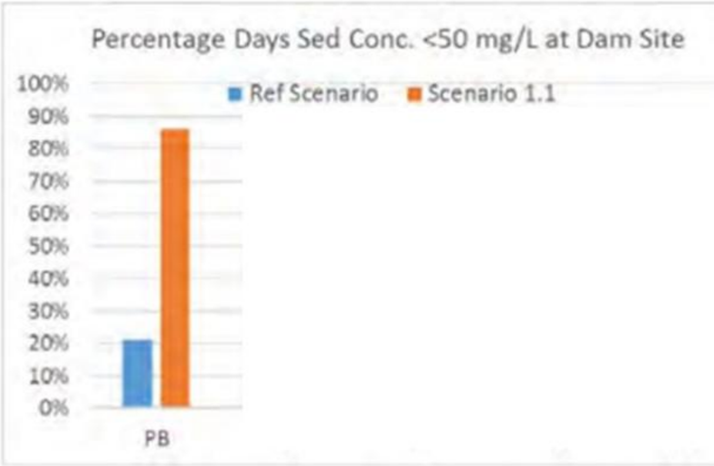
Based on cross-sectional averaged velocities from the Delft 3D model (MRC 2018)



Modelling investigations into the hydraulic conditions that promote algal blooms have found that the risk of growth increases when water velocities decrease below 0.4 m/s (Huang, 2008), which extend for tens of kilometres within the impoundment (MRC 2018).

Based on available information it was assumed that light penetration will extend into the water column on days when the average daily suspended sediment concentration falls below 50 mg/L (MRC 2018). The number of days this condition is met was determined for Pak Beng dam site using the daily averaged sediment model results (Figure 5.9).

Figure 5.9: Percentage of days the suspended sediment concentration in the average daily discharge at each of the dam sites was below 50 mg/L based on the results of the sediment model (MRC 2018)



There is evidence that sufficient nutrients are present in the Mekong to promote algal growth given the right physical conditions based on the presence of an algal bloom 'pond' upstream of the Xayaburi dam in March 2015. (this bloom was present even though residence times were low relative to the future operating conditions of the impoundment (water level was 18 m below full supply level), and the water had not been subjected to storage upstream) (MRC 2018).

Mitigation measures to address algal blooms are largely dependent on catchment management approaches that limit nutrient input to impoundments. In some instances, operating procedures can be used to lessen the severity of bloom events.

5.1.3.2 Sediment transport

5.1.3.2.1 Construction phase impacts

Table 5.9: Construction phase impacts on sediment transport

Impact description	Likelihood	Consequence	Risk
Sediment released during dam construction (Pak Beng impact)	Possible	Moderate	Moderate

Sediment released during dam construction

Increased vehicular traffic around dam construction sites may increase sediment loads downstream. The construction of dam with be accompanied by deforestation and road construction in the catchment. With the increased development activities around the dam, vehicular traffic will increase as well (Ed. Meynell 2003). The increasing deforestation and vehicular traffic at and around the dam site during the construction phase may increase fine sediment loads in the reaches downstream of the dam.

5.1.3.2.2 Longer term impacts

Table 5.10: Longer term impacts on sediment transport

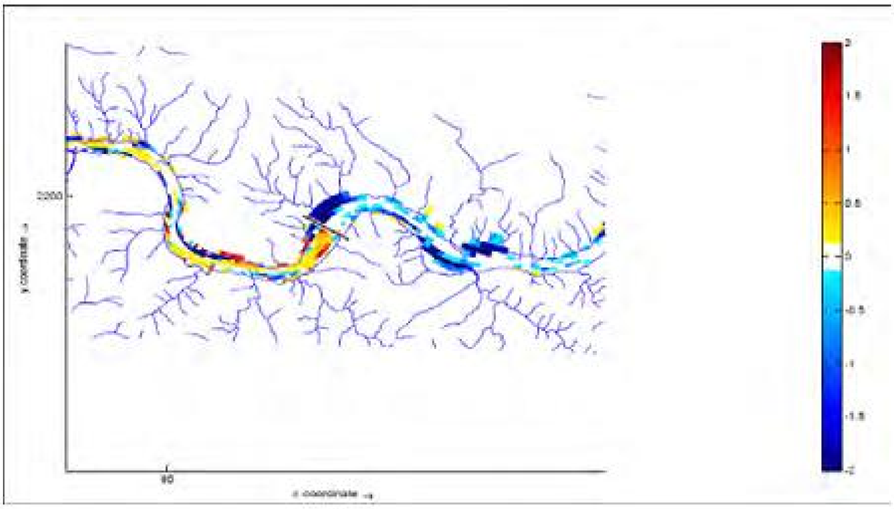
Impact description	Likelihood	Consequence	Risk
Decrease in sediment load leading to bed and bank erosion (Pak Beng dam impact)	Almost certain	Moderate	High

Decrease in sediment load leading to bed and bank erosion

Reservoirs are effective sediment traps, with high percentages of sediment being retained within the reservoir leading to a marked decrease in sediment loads below a dam. Assuming that the downstream discharge is not greatly altered, as should be the case with the run-of-river Pak Peng, a common response to the release of low-sediment load water from reservoirs is degradation of the channel bed. The degradation occurs as the river has excess sediment transport capacity and therefore erodes the bed and banks to obtain more sediment. The degradation is largest close to the dam wall, and progressively declines in intensity downstream which leads to a flatter channel slope (Knighton, 1998). Degradation may lead to "armouring" of the channel bed which is when finer bed materials are eroded leaving a bed which is dominated by larger gravel or rocks. This leads to a significant change in habitat available for fish and other aquatic species. Depending on the Pak Bang operation mode, the bed and bank erosion process may be exacerbated by increased variability in water levels (Figure 5.10).

Figure 5.10: Bed elevation changes in the vicinity of Pak Beng HPP dam

Showing deposition upstream of the dam (red) and erosion on the outside bends downstream (blue) (MRC 2018) – output of a Delft 3D model run over 7 years



The potential for decreasing sediment loads downstream of the dam has been recognised by the Pak Beng HPP developers, and plans for sediment flushing facilities are included in the Pak Beng HPP design. The MRC ISH study evaluates the effect of sediment flushing operations at Pak Beng and other planned dams in the mainstream cascade – and shows that is has some potential to mitigate sediment trapping depending on timing and other conditions.

5.1.4 *Conclusions*

Based on the impacts analysis presented in this report, the highest risk impacts identified for each section are as follows:

- **Highest risk impacts in the Lao border to Pak Beng HPP Dam section** 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;
- **Highest risk impacts in the Pak Beng HPP Dam to Luang Prabang section are** flow regime altered due to operation of Pak Beng dam; reduced water quality of water released from 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;

The extent and scale of the impacts will depend on the dam design and how well the dam construction works are undertaken according to best practice. The Mitigation Recommendations Report outlines what mitigation opportunities are available, and what elements of best practice will be most important to implement.

Table 5.11: Summary of hydrological impacts across the two zones

Impact description	Construction/ long term	Likelihood	Consequence	Risk
Lao border to Pak Beng HPP Dam section (Zone 2)				
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
Pak Beng HPP Dam to Luang Prabang section (Zone 3)				
Altered flow downstream as the reservoir fills	Construction	Almost certain	Negligible	Moderate
Changes in the flow regime due to dam operations	Long	Almost certain	Negligible*	High
Changes in water quality due to dam releases	Long	Likely	Negligible*	Moderate

Table 5.12: Summary of sediment impacts across the two zones

Impact description	Construction/ long term	Likelihood	Consequence	Risk
Lao border to Pak Beng HPP Dam section (Zone 2)				
Sediments mobilised and distributed in the immediate area of dam site	Construction	Likely	Negligible	Moderate
Reservoir traps sediment	Long	Almost certain	Significant	Very high
New deltas form at the bottom of tributaries	Long	Almost certain	Extensive	Very high
Pak Beng HPP Dam to Luang Prabang section (Zone 3)				
Sediment released during dam construction	Construction	Possible	Moderate	Moderate
Decrease in sediment load leading to bed and bank erosion	Long	Almost certain	Moderate	High

5.2 AQUATIC ECOLOGY AND WETLANDS IMPACT ASSESSMENT

5.2.1 *Introduction*

The impacts on aquatic ecology and wetlands from Pak Beng HPP arise from the direct damages that will occur during the works, and the longer-term changes in the aquatic ecology that will develop due to changes in hydrology and sediment. In the baseline report, the aquatic ecology was disaggregated into four components – the geomorphology and habitats, water quality, aquatic and riparian vegetation, and macroinvertebrates.

In this section, we document the potential impacts on the aquatic ecology and wetlands from construction of the run-of-river Pak Beng hydropower scheme in the section of the Mekong River between Luang Prabang and Chiang Saen.

5.2.2 *Method of assessing local and cumulative impacts*

The different indicators of change used in the BioRa method of the MRC Council study have been assessed for each of the aspects considered in this report – geomorphology, wetland habitats, aquatic and riparian vegetation and macroinvertebrates. The scale of impacts is assessed based upon professional judgment of what is likely to occur with the different expected changes during construction and longer-term operation of Pak Beng dam.

- 0 – No Impact,
- 1 - Very Low Impact,
- 2 - Low Impact,
- 3 - Moderate Impact,
- 4 - High Impact, and
- 5 - Very High Impact

The construction impacts of the Pak Beng HPP in Zone 2 are considered to have direct impacts on 10 km on each side of the dam site, i.e, 20 km of the reach, but when the reservoir is filled the impacts will extend to include the whole reservoir area.

In Zone 2, the cumulative impact of dam construction and operation is assessed by taking the localized score for dam construction, factoring the length of the direct impact zone (20 km) and dividing by the total length of Zone 2. For longer term impacts when the reservoir is filled and operational, the length of the reservoir (90 km) is divided by the total length of the reach (94 km). Each of the localized and cumulative impacts are then graded on the ranges above.

5.2.3 *Impacts in the Thai-Lao border to Pak Beng Dam reach (Zone 2)*

5.2.3.1 Geomorphology and habitats

The projected impacts upon the geomorphology of the reach between the Thai-Lao border to Pak Beng Dam are shown in Table 5.13 for both the construction phase and the longer term impacts after dam construction has been completed. The assessment (for all components) focuses on the upstream impacts of Pak Beng Dam i.e. the reservoir.

Table 5.13: Table of impacts upon the geomorphology of the reach between the Thai-Lao border to Pak Beng Dam

Geomorphology	Erosion	Average bed sediment size in dry season	Availability of exposed sandy habitat in dry season	Availability of inundated sandy habitat in dry season	Availability of exposed rocky habitats in dry season	Availability of inundated rocky habitats in dry season	Depth of pools in bedrock in dry season	Water quality	Local impact	Combined local impact	Cumulative impact
ZONE 2 From the Thai-Lao border to Pak Beng Dam – (approx 94 km) – 6 dangerous areas; dam = 62 m, reservoir =90 km long											
Focus on impacts from construction and operation of Pak Beng Dam reservoir											
Construction phase:											
Rocky materials will be released and distributed in the immediate area of the dam site	0	0	0	0	2	2	0	3	0.9	1.9	0.41
Increased vehicle traffic around dam construction site may increase sediment loads downstream	3	3	1	1	0	0	0	3	1.4		
Limited or no flow downstream as the reservoir fills	0	0	3	3	3	3	3	0	1.9		
Increasing water levels and decreasing flow velocity upstream of dam as the reservoir fills	3	3	4	4	4	4	4	3	3.6		
Long term impact:											
Change from lotic to lentic environment upstream of the dam	2	2	5	5	5	5	5	4	4.1	2.5	2.39
Sediment transport will reduced – resulting in sediment build up at the upstream end of the reservoir	1	1	5	5	3	3	3	3	3.0		
Existing riverine habitats will be flooded	0	0	5	5	5	5	5	0	3.1		
Anaerobic conditions in the reservoir, down to a certain depth (regardless of vegetation, because of reduced circulation)	0	0	0	0	0	0	0	4	0.5		
New delta's forming at the bottom of tributaries (likley located further upstream of tributary)	1	1	5	5	3	3	3	3	3.0		
Barrier to sediment and fish passage	5	5	0	0	0	0	0	0	1.3		

Construction phase impacts

The construction phase of the Pak Beng Dam will have a significant impact upon the geomorphology at the dam site, but in terms of the indicators chosen for this assessment, the main changes which will have moderate impacts will be increased construction vehicle traffic around the dam site, and the changes in flows upstream as the reservoir fills. The localized impacts on these indicators are Low and cumulative impact over the whole of Zone 2 is Very Low.

Longer term impacts

The longer term localized impacts to geomorphology of the Pak Beng Dam are considered to be moderate, but with Very High impacts on exposed and inundated sandy and rocky habitats as the reservoir fills, changing from a flowing river to a lake type habitat, flooding of riverine habitats and the formation of deltas around the head of the reservoir and where tributaries enter the reservoir. The dam will be a major long-term barrier to sediment transport which will lead to sediment build up in the reservoir. Water quality may be highly impacted in the change from a lotic to lentic environment in the reservoir and with risks of anaerobic water being released downstream at certain stages of operation. When these impacts are extended over the whole length of Zone 2, there will be Very High impacts upon the geomorphology.

5.2.3.2 Wetland Habitats

The projected impacts upon the wetland habitats of the reach between the Thai-Lao border to Pak Beng Dam are shown in Table 5.14 for both the construction phase and the longer term impacts after dam construction has been completed.

Table 5.14: Table of impacts upon the wetland habitats of the reach between the Thai-Lao border to Pak Beng Dam

Wetland habitats	Rivers	Streams	Seasonal mudflats, pebble flats and sand bars	Seasonally inundated shrubland	Rock outcrops	Riverine rapids	Deep pools	Pools on bank	Local impact	combined local impact	Cumulative impact
ZONE 2 From the Thai-Lao border to Pak Beng Dam – (approx 94 km) – 6 dangerous areas; dam = 62 m, reservoir =90 km long											
Focus on impacts from construction and operation of Pak Beng Dam reservoir											
Construction phase:											
Rocky materials will be released and distributed in the immediate area of the dam site	2	0	2	2	3	3	0	0	1.5	2.3	0.49
Increased vehicle traffic around dam construction site may increase sediment loads downstream	2	0	1	1	0	0	0	0	0.5		
Limited or no flow downstream as the reservoir fills	3	0	3	3	3	3	2	2	2.4		
Increasing water levels and decreasing flow velocity upstream of dam as the reservoir fills	5	3	5	5	5	5	5	5	4.8		
Long term impact:											
Change from lotic to lentic environment upstream of the dam	5	2	5	5	5	5	5	5	4.6	2.3	2.15
Sediment transport will reduced – resulting in sediment build up at the upstream end of the reservoir	2	0	3	3	0	0	0	0	1.0		
Existing riverine habitats will be flooded	5	2	5	5	5	5	5	5	4.6		
Anaerobic conditions in the reservoir, down to a certain depth (regardless of vegetation, because of reduced circulation)	2	0	0	0	0	0	4	0	0.8		
New delta's forming at the bottom of tributaries (likley located further upstream of tributary)	2	4	2	2	0	0	0	2	1.5		
Barrier to sediment and fish passage	5	3	0	0	0	0	0	0	1.0		

Construction phase impacts

The construction impacts of the Pak Beng dam upon wetlands are considered to be Low, but with moderate risks for any rocky outcrops and rapids, and the seasonal mudflats, pebble flats and sand bars, especially when sand is removed for construction and especially when the reservoir fills and inundates the different types of wetland upstream when the impacts will be Very High, and moderate with reduced water released downstream when the reservoir is filling. The cumulative impacts of the construction phase on wetlands over the whole 94 kms of Zone 2 are considered to be Very Low.

Longer term impacts

With the reservoir in place, most of the wetlands lying within the old channel and on the banks will be inundated and lost completely, especially with the change from a lotic to lentic environment. The localized impact is Moderate, but when this is extended over the whole reservoir area – the whole of Zone 2, the cumulative impacts upon wetland habitats are Very High.

5.2.3.3 Aquatic and riparian vegetation

The projected impacts upon the aquatic and riparian vegetation of the reach between the Thai-Lao border to Pak Beng Dam are shown in Table 5.15 for both the construction phase and the longer-term impacts after dam construction has been completed.

Table 5.15: Table of impacts upon the aquatic and riparian vegetation of the reach between the Thai-Lao border to Pak Beng Dam

Aquatic and riparian vegetation	Channel Riparian trees	ChannelExtent of upper bank vegetation	ChannelExtent of lower bank vegetation	Channel: Weeds, grasses on sandbanks and sandbars	Channel Biomass freshwater algae	Local impact	Combined local impact	Cumulative impact
ZONE 2 From the Thai-Lao border to Pak Beng Dam – (approx 94 km) – 6 dangerous areas; dam = 62 m, reservoir =90 km long								
Focus on impacts from construction and operation of Pak Beng Dam reservoir								
Construction phase:								
Rocky materials will be released and distributed in the immediate area of the dam site	0	0	0	1	2	0.6	2.1	0.44
Increased vehicle traffic around dam construction site may increase sediment loads downstream	0	0	2	2	2	1.2		
Limited or no flow downstream as the reservoir fills	0	0	2	3	2	1.4		
Increasing water levels and decreasing flow velocity upstream of dam as the reservoir fills	5	5	5	5	5	5.0		
Long term impact:								
Change from lotic to lentic environment upstream of the dam	0	0	0	4	5	1.8	2.2	2.11
Sediment transport will reduced – resulting in sediment build up at the upstream end of the reservoir	0	0	0	5	0	1.0		
Existing riverine habitats will be flooded	5	5	5	5	5	5.0		
Anaerobic conditions in the reservoir, down to a certain depth (regardless of vegetation, because of reduced circulation)	0	0	5	5	5	3.0		
New delta's forming at the bottom of tributaries (likley located further upstream of tributary)	0	0	5	5	2	2.4		
Barrier to sediment and fish passage	0	0	0	0	0	0.0		

Construction phase impacts

During the construction phase of the Pak Beng Dam the localized impacts upon aquatic and riparian vegetation are Low, but with moderate impacts on lower bank vegetation and shrubs, weeds and grasses on sandbanks. Within the immediate vicinity of the dam site and along access roads riparian vegetation will be removed. The highest impact upon vegetation occurs when the reservoir upstream is filled, which will inundate all the different types of aquatic and riparian vegetation. Despite this the cumulative impact of the dam construction phase in Zone 2 is Very Low.

Longer term impacts

However, the longer term impacts of the Pak Beng Dam, shows a Moderate localized impact upon aquatic vegetation around the dam site, but when assessed cumulatively the impacts on aquatic vegetation are Very High, since all the riverine vegetation habitats are flooded and the major change from lotic to lentic environment.

5.2.3.4 Macroinvertebrates

The projected impacts upon the macroinvertebrates of the reach between the Thai-Lao border to Pak Beng Dam are shown in Table 5.16 for both the construction phase and the longer-term impacts after dam construction has been completed.

Table 5.16: Table of impacts upon the macroinvertebrates of the reach between the Thai-Lao border to Pak Beng Dam

Indicator Groups	Insects on stones	Insects on sand	Burrowing mayflies	Snails	Diversity of snails	Bivalves	Shrimps and crabs	Macrobrachium prawns	Littoral invertebrate diversity	Benthic invertebrate diversity	Zooplankton	Benthic invertebrate biomass	Emergence	Local impact	combined local impact	Cumulative impact
ZONE 2 From the Thai-Lao border to Pak Beng Dam – (approx 94 km) – 6 dangerous areas; dam = 62 m, reservoir =90 km long																
Focus on impacts from construction and operation of Pak Beng Dam reservoir																
Construction phase:																
Rocky materials will be released and distributed in the immediate area of the dam site	2	0	0	1	0	2	1	2	0	0	1	2	1	0.9	2.4	0.50
Increased vehicle traffic around dam construction site may increase sediment loads downstream	2	3	3	2	0	2	2	3	0	0	1	1	1	1.5		
Limited or no flow downstream as the reservoir fills	3	3	3	2	0	2	3	3	0	0	2	3	2	2.0		
Increasing water levels and decreasing flow velocity upstream of dam as the reservoir fills	5	5	5	5	5	5	5	5	5	5	5	5	5	5.0		
Long term impact:																
Change from lotic to lentic environment upstream of the dam	5	5	5	5	5	5	5	5	5	5	5	5	5	5.0	3.5	3.36
Sediment transport will reduced – resulting in sediment build up at the upstream end of the reservoir	5	3	3	3	0	3	3	5	2	2	2	3	3	2.8		
Existing riverine habitats will be flooded	5	5	5	5	5	5	5	5	5	5	5	5	5	5.0		
Anaerobic conditions in the reservoir, down to a certain depth (regardless of vegetation, because of reduced circulation)	5	5	5	5	5	5	5	5	5	5	5	5	5	5.0		
New delta's forming at the bottom of tributaries (likley located further upstream of tributary)	5	3	3	3	0	3	3	5	2	2	2	3	3	2.8		
Barrier to sediment and fish passage	0	0	0	0	0	0	0	5	0	0	0	0	0	0.4		

Construction phase impacts

During the construction phase of the Pak Beng dam, the local impacts upon macroinvertebrates will be Low, except when the reservoir is being filled, which will affect all the different types of macroinvertebrate. This is the change that will not only affect the populations of littoral and benthic macroinvertebrates, but also their diversity. The cumulative impacts of the construction phase over the whole Zone 2 is considered to be Very Low.

Longer term impacts

With the reservoir in place and the change from a lotic to lentic environment and the inundation of macroinvertebrate habitats, all types will be affected, although some new habitats may emerge with the formation of deltas at the top end of the reservoir and at the confluences with tributaries and small seasonal streams. The localized impact of the Pak Beng Dam on macroinvertebrates is considered to be Moderate, but when assessed cumulatively the impact is Very High.

5.2.4 *Impacts in the Pak Beng Dam to Luang Prabang reach (Zone 3)*

5.2.4.1 Geomorphology and habitats

The projected impacts upon the geomorphology of the reach between the Pak Beng Dam to Luang Prabang are shown in Table 5.17 for both the construction phase of Pak Beng Dam and longer term impacts after construction has been completed. The assessment (for all components) focuses on the downstream impacts of Pak Beng Dam.

Table 5.17: Table of impacts upon the geomorphology of the reach between the Pak Beng Dam to Luang Prabang

	Geomorphology	Erosion	Average bed sediment size in dry season	Availability of exposed sandy habitat in dry season	Availability of inundated sandy habitat in dry season	Availability of exposed rocky habitats in dry season	Availability of inundated rocky habitats in dry season	Depth of pools in bedrock in dry season	Water quality	Local impact	Combined local impact	Cumulative impact
ZONE 3 Pak Beng Dam downstream to Luang Prabang (approx 176 km) – 12 dangerous areas												
Focus on impacts from construction and operation of Pak Beng Dam downstream												
Construction phase:												
Rocky materials may be released and distributed in the immediate area of the dam construction		0	0	0	0	2	2	0	2	0.8	1.3	0.46
Some rocky material may be deposited in deep pools downstream of dam construction		0	0	0	0	0	0	2	0	0.3		
Sand from sand banks and islands may be deposited downstream and on adjacent banks		0	1	3	3	0	0	2	3	1.5		
Limited or no flow downstream as the reservoir fills		0	0	4	4	4	4	4	3	2.9		
Long term impact:												
On balance, the reduced sediment supply from PK is expected to have a greater effect than removal of barriers, so erosion of bed and		4	4	4	4	0	0	0	0	2.0	0.8	0.26
Increased temperature variability downstream		0	0	0	0	0	0	0	1	0.1		
Reduced water quality due to anaerobic conditions of lake		0	0	0	0	0	0	0	3	0.4		
Depending on operation mode, water level variability downstream may cause bank erosion		3	0	0	0	0	0	0	3	0.8		
Depending on operation mode, there may be small or large scale changes in the flow regime. Likley to be some flattening of the hydrograph		0	0	0	0	0	0	0	0	0.0		
Change in the sediment size distribution of the channel bed		0	4	3	3	0	0	0	0	1.3		

Construction phase impacts

During the construction of the dam, the overall localized impact upon geomorphology is likely to be low, but moderate impacts are to be expected upon the availability of exposed and inundated sandy habitats. During the filling of the Pak Beng Reservoir, when low flows downstream are to be expected, this could have high impacts upon the geomorphology. The cumulative impacts over the whole reach from Pak Beng Dam site to Luang Prabang are considered to be Very Low.

Longer term impacts

Over the long term, after the Pak Beng dam has been constructed and starts to operate, the reduced sediment coming down the river and the sediment trapping of Pak Beng is likely to have High impacts upon bed and bank erosion in the reach, size of bed sediments, and availability of exposed and inundated sandy habitats in the dry season. The changes in sediment size distribution will also have high to moderate impacts upon these sandy habitats. Overall the long term impacts, both localized and cumulative, are Very Low.

5.2.4.2 Wetland Habitats

The projected impacts upon the wetland habitats of the reach between the Pak Beng Dam to Luang Prabang by Pak Beng Dam are shown in Table 5.18 for both the construction phase and the longer term impacts after construction has been completed.

Table 5.18: Table of impacts upon the wetland habitats of the reach between the Pak Beng Dam to Luang Prabang

Wetland habitats	Rivers	Streams	Seasonal mudflats, pebble flats and sand bars	Seasonally inundated shrubland	Rock outcrops	Riverine rapids	Deep pools	Pools on bank	Local impact	combined local impact	Cumulative impact
ZONE 3 Pak Beng Dam downstream to Luang Prabang (approx 176 km) – 12 dangerous areas											
Focus on impacts from construction and operation of Pak Beng Dam downstream											
Construction phase:											
Rocky materials may be released and distributed in the immediate area of the dam construction	3	0	1	3	1	3	2	1	1.8	1.3	0.45
Some rocky material may be deposited in deep pools downstream of dam construction	1	0	0	0	0	0	3	0	0.5		
Sand from sand banks and islands may be deposited downstream and on adjacent banks	2	1	4	3	0	0	0	2	1.5		
Limited or no flow downstream as the reservoir fills	2	0	2	2	2	2	2	0	1.5		
Long term impact:											
Reduced sediment supply from PK is expected to cause erosion of bed and banks where not bedrock	2	0	3	2	0	0	0	2	1.1	0.8	0.26
Increased temperature variability downstream	2	0	0	0	0	0	0	0	0.3		
Reduced water quality due to anaerobic conditions of lake	2	0	2	2	2	2	2	0	1.5		
Depending on operation mode, water level variability downstream may cause bank erosion	2	0	2	2	0	0	0	1	0.9		
Depending on operation mode, there may be small or large scale changes in the flow regime. Likley to be some flattening of the hydrograph	2	0	0	0	0	0	0	0	0.3		
Change in the sediment size distribution of the channel bed	0	0	2	2	0	0	1	0	0.6		

Construction phase impacts

The local impacts of the dam construction on wetlands in the reach from Pak Beng to Luang Prabang are considered to be Low, but with High impacts upon seasonal mudflats, pebble flats and sandbars, and moderate impacts upon riverine rapids. The cumulative impacts during the construction phase are likely to be Very Low upon the wetland habitats.

Longer term impacts

The longer term impacts upon wetlands in Zone 3 are locally Very Low and cumulatively Very Low, though the reduced sediment coming down the river as a result of sediment trapping in the Pak Beng reservoir will have a moderate impact upon the seasonally inundated mud, pebble flats and sand bars.

5.2.4.3 Aquatic and riparian vegetation

The projected impacts upon the aquatic and riparian vegetation of the reach between the Pak Beng Dam to Luang Prabang are shown in Table 5.19 for both the construction phase and the longer-term impacts after construction is completed.

Table 5.19: Table of impacts upon the aquatic and riparian vegetation of the reach between the Pak Beng Dam to Luang Prabang

Aquatic and riparian vegetation	Channel Riparian trees	ChannelExtent of upper bank vegetation	ChannelExtent of lower bank vegetation	Channel: Weeds, grasses on sandbanks and sandbars	Channel Biomass freshwater algae	Local impact	Combined local impact	Cumulative impact
ZONE 3 Pak Beng Dam downstream to Luang Prabang (approx 176 km) – 12 dangerous areas								
Focus on impacts from construction and operation of Pak Beng Dam downstream								
Construction phase:								
Rocky materials may be released and distributed in the immediate area of the dam construction	0	0	0	1	2	0.6	0.8	0.27
Some rocky material may be deposited in deep pools downstream of dam construction	0	0	0	0	2	0.4		
Sand from sand banks and islands may be deposited downstream and on adjacent banks	0	0	1	2	1	0.8		
Limited or no flow downstream as the reservoir fills	0	0	2	3	2	1.4		
Long term impact:								
Reduced sediment supply from PK is expected to cause erosion of bed and banks where not bedrock	3	3	4	4	2	3.2	1.2	0.40
Increased temperature variability downstream	0	0	0	0	3	0.6		
Reduced water quality due to anaerobic conditions of lake	0	0	0	1	2	0.6		
Depending on operation mode, water level variability downstream may cause bank erosion	2	2	2	1	0	1.4		
Depending on operation mode, there may be small or large scale changes in the flow regime. Likley to be some flattening of the hydrograph	0	0	0	0	1	0.2		
Change in the sediment size distribution of the channel bed	0	0	1	2	2	1.0		

Construction phase impacts

In the construction phase in Zone 3, the local impacts upon aquatic vegetation are considered to be Low, and cumulatively over the whole reach, Very Low.

Longer term impacts

In the longer term, the combined effects of Pak Beng operation on the downstream aquatic and riparian vegetation are expected to be locally Low and cumulatively over the whole of Zone 3, Very Low. Of particular concern are the impacts of the reduced sediment supply and changes in the sediment size, especially high impacts upon the lower bank vegetation and the vegetation on sand banks and sand bars. The changes in temperature variability downstream of Pak Beng dam may also have an impact upon freshwater algae. Many of the changes may alter the dynamics of freshwater algae, especially the Mekong weed, Cladophora spp, which harvested by local people along this stretch of the Mekong in the dry season low flow months.

5.2.4.4 Macroinvertebrates

The projected impacts upon the macroinvertebrates of the reach between the Pak Beng Dam to Luang Prabang are shown in Table 5.20 for both the construction phase and the longer-term impacts after construction has been completed.

Table 5.20: Table of impacts upon the macroinvertebrates of the reach between the Pak Beng Dam to Luang Prabang

Indicator Groups	Insects on stones	Insects on sand	Burrowing mayflies	Snails	Diversity of snails	Bivalves	Shrimps and crabs	Macrobrachium prawns	Littoral invertebrate diversity	Benthic invertebrate diversity	Zooplankton	Benthic invertebrate biomass	Emergence	Local impact	combined local impact	Cumulative impact
ZONE 3 Pak Beng Dam downstream to Luang Prabang (approx 176 km) – 12 dangerous areas																
Focus on impacts from construction and operation of Pak Beng Dam downstream																
Construction phase:																
Rocky materials may be released and distributed in the immediate area of the dam construction	2	0	0	1	0	2	1	2	0	0	1	2	1	0.9	1.2	0.42
Some rocky material may be deposited in deep pools downstream of dam construction	0	0	0	1	0	2	0	0	0	0	0	2	0	0.4		
Sand from sand banks and islands may be deposited downstream and on adjacent banks	0	3	3	2	0	3	2	2	0	0	2	2	2	1.6		
Limited or no flow downstream as the reservoir fills	3	3	3	2	0	2	3	3	0	0	2	3	2	2.0		
Long term impact:																
Reduced sediment supply from PK is expected to cause erosion of bed and banks where not bedrock	2	2	2	2	0	2	2	2	0	0	0	2	0	1.2	1.6	0.56
Increased temperature variability downstream	3	3	2	2	0	2	3	3	0	0	2	1	2	1.8		
Reduced water quality due to anaerobic conditions of lake	3	3	3	2	0	2	3	3	0	0	3	2	2	2.0		
Depending on operation mode, water level variability downstream may cause bank erosion	3	3	3	3	0	3	3	3	0	0	2	4	4	2.4		
Depending on operation mode, there may be small or large scale changes in the flow regime. Likley to be some flattening of the hydrograph	1	1	1	1	0	1	1	1	0	0	1	1	1	0.8		
Change in the sediment size distribution of the channel bed	2	3	3	1	0	2	2	2	0	0	1	3	2	1.6		

Construction phase impacts

The construction phase impacts of Pak Beng Dam on macroinvertebrates in Zone 3 are considered to be Low for localized impacts and Very Low cumulatively over the whole zone. Diversity of littoral or benthic invertebrate species in the zone is unlikely to be affected, though impacts may affect the balance of populations. The changing flows during the filling of the reservoir may have temporary moderate impacts upon some species.

Longer term impacts

The localised long term impacts on macroinvertebrates are considered to be Low, and the cumulative impacts over the whole of Zone 3 are considered to be Very Low. In the longer term, the operation of the dam is likely to have impacts, especially if there are daily flow and water level variations, which will affect the biomass of populations of macroinvertebrates and may also affect the times and seasons of emergence of insects from their larval stages in the river. The discharge of poor water quality from the reservoir will increase the risks of water pollution, which may cause decreases or losses of populations of sensitive macroinvertebrates, such as the stoneflies, some mayflies and Macrobrachium prawns.

5.2.5 *Comparison of impacts in different zones and cumulative impacts*

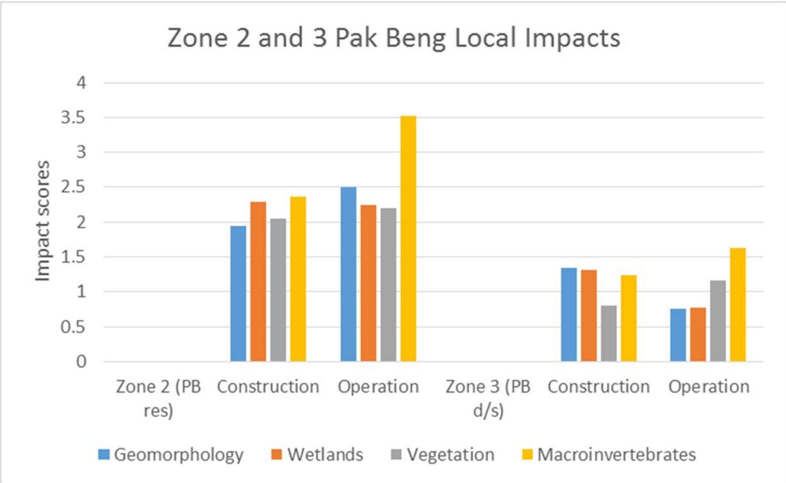
When the impacts on the four components of aquatic ecology are considered for each zone, there are marked differences between the two zones (Figure 5.1). During the construction phase the impacts in Zone 3 are slightly higher because of the effects of construction of the Pak Beng Dam.

In Zone 2, construction impacts are all significantly higher than in Zone 3, and nearing the threshold between Low and Moderate Impacts (with scores between 1.6 and 1.8).

Similarly when the operational or longer term impacts are considered at the local level, Zone 3 shows Very Low Impacts for geomorphology and wetland habitats, and a slightly higher, but still Low Impact for aquatic vegetation and macroinvertebrates.

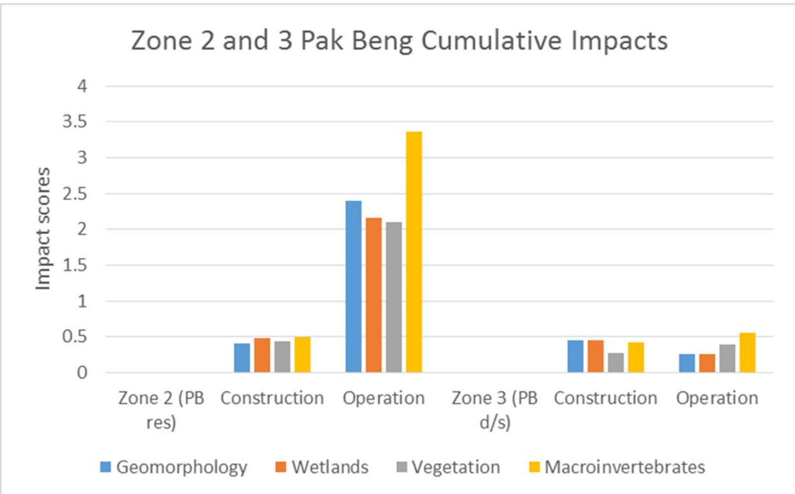
By contrast, in Zone 2 the local impacts in the operation phase are generally Moderate (above 2), but High for macroinvertebrates (score of 3.5). This reflects the inundation of the reservoir in the local areas.

Figure 5.11: Comparison of local impacts upon aquatic ecology in Zones 2 - 3



The cumulative impacts in each of the two zones is shown in Figure 5.2. The six dangerous areas in Zone 2 will be inundated by the reservoir and so action to improve them for navigation will not be necessary. The cumulative impacts assessments reflect the density of the local impacts over the whole zone. It can clearly be seen from Figure 45, that the cumulative impacts of the construction activities on the aquatic ecology of each zone are Very Low (with impact scores of less than 0.5).

Figure 5.12: Comparison of cumulative impacts upon aquatic ecology in Zones 2 - 3



For Zone 2 the construction of the dam is considered to have local impacts in a 20 km impact zone, which when assessed cumulatively also results in a Very Low score. However, when the reservoir is filled and Pak Beng Dam operating, the longer term cumulative impacts in Zone 2 are Very High especially for macroinvertebrates. This reflects the complete change from a riverine to a reservoir environment, affecting the geomorphology, the flooded wetlands and the aquatic vegetation and macroinvertebrate species.

5.2.6 *Conclusions*

The assessments of impacts on the aquatic ecology show that the operational and longer term impacts on aquatic ecology are very different for the Zone 2 with the construction and operation of the Pak Beng Dam. The long term impacts over the whole reservoir area are Very High and reflect a complete change in the aquatic ecology in the reservoir.

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. If sediment loads are retained with the reservoir, this will change the downstream sediment balance, resulting in bed and bank erosion and changes in the geomorphology, wetland habitats etc. If there is sediment flushing this could also have downstream impacts depending upon how it is done. If the plant is operated in a peaking mode, there will be much more intense impacts upon the downstream aquatic ecology in Zone 3, especially on the macroinvertebrate fauna.

5.2.7 *References*

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5.3 AMPHIBIANS AND REPTILES IMPACT ASSESSMENT

5.3.1 *Baseline summary*

A total of 25 species of amphibians and reptiles were documented during field and market surveys. An additional seven species were reported during interviews but were not directly observed by the team. Eight of the observed and reported species (six turtle species and two snake species) are globally and nationally threatened from overexploitation for food and traditional medicine.

The surveyed areas along the Mekong River were heavily impacted by human development activities, especially removal and degradation of forest for agriculture (banana plantations, rubber plantations, and rice fields), as well as infrastructure development of the Mekong (hydropower dams and embankments).

Most conservation value for amphibians and reptiles in the survey area probably lies in forested portions of the mainstream Mekong and its tributaries.

5.3.2 *Key potential impacts*

The Pak Beng HPP will inundate habitat and affect the hydrology of the river, impacting amphibians and reptiles along the river bank. As a notable example, breeding habitat of the Asiatic softshell turtle (*Amyda cartilaginea*) will likely be negatively impacted by such hydrological changes.

In addition to habitat loss, infrastructure development and hydrological changes to the Mekong with Pak Beng HPP will facilitate increased human access into remote portions of the survey areas, which in turn will likely cause overharvesting of turtles, large lizards and large snakes for consumption and trade, particularly illegal wildlife trade to China.

5.3.3 *Reptile and amphibian conservation needs within the project area*

Further detailed surveys of amphibians and reptiles in the Pak Beng HPP impact areas is urgently needed. Continued infrastructure development in the area needs to be accompanied by increased enforcement of wildlife hunting and trade laws by relevant governmental agencies.

5.4 FISH IMPACT ASSESSMENT

5.4.1 *Introduction*

This focus of this section is to present an assessment of the impacts of Pak Beng HPP on fish biodiversity and fisheries in Zone 2 and Zone 3 of the study stretch.

5.4.2 *Pak Beng HPP impacts expected on fish and fish habitats*

5.4.2.1 From Thai-Lao border to Pak Beng Dam site (Zone 2)

Key impacts include:

1. Impacts during the construction phase from release of rocky material, increased vehicle traffic and changes in water level and flow will all affect fishes found near the dam site. High turbidity in the water caused by construction activities will affect fishes (in particular their breathing and reproduction) both at construction site and downstream.
2. Blockage of fish migratory routes is often a major impact of dams in the Mekong. Most migratory Mekong fishes are found in this section of the river and/or in the deep pools between Chiang Saen to Luang Prabang (Poulsen et al. 2002, and above sections). From there, they migrate to upstream tributaries, e.g. Nam Kok and Nam Ing (Valbo-Jørgensen et al., 2009). Therefore, they will be inevitably effected by the Pak Beng HPP during their upstream spawning migration. However, the impact may be somewhat reduced by the presence and effectiveness of the fish passage of the Pak Beng HPP (depending also on its design and operation).
3. The slow flowing water created by the reservoir is expected to modify fish assemblages, with strong reduction or disappearance of migratory species in the area. However, sedentary species are expected to become more abundant and somewhat replace them, as experienced elsewhere in the LMB (Jutagate et al., 2011; Phomikong et al., 2015). The rheophilic species that exclusively live in fast flowing conditions such as *Glyptothorax* spp., *Garra* spp. and loaches are expected to disappear from the reservoir area because they cannot cope with lacustrine conditions (Jutagate et al., 2011).
4. The very high water level in the reservoir is expected to result in oxygen depletion in deep water, the consequence being lower productivity in the whole area modified (Bernacsek, 2001). In contrast, entrapment of nutrients in the reservoir typically will lead to high

productivity during a few years (usually 5 to 10 years), after which the productivity usually reaches a stable but low level.

5.4.2.2 From Pak Beng Dam site to Luang Prabang (Zone 3)

Key impacts include:

1. Change in natural flow conditions through dam regulation is a major concern as natural flows normally maintains downstream biological activity. Changes in the annual flow regime will disrupt fish behaviour related to flow, particularly reproduction (Dyson and Bergkamp, 2003).
2. Downstream floodplains along river banks, are expected to become smaller as they will not get sufficiently and adequately inundated during the wet season – reducing habitat. Changes in timing, depth, duration and seasonality of flooding can lead to significant losses in fish stocks as floodplains act as important spawning and nursery grounds for many fish species (Jackson and Marnulla, 2001), in particular in the Mekong. In the study area considered, however, the extent of floodplains is small – so the impacts will be limited.
3. Given the height of Pak Beng Dam and its location, water stratification is expected, with a warm surface layer overlying a cold bottom layer. If, as often, the water turbined is the bottom layer water, then water much colder than the natural river temperature is released and can cause death in downstream fishes (this is called cold water pollution).
4. For the same dam height and location reasons, this deep water layer from the reservoir (hypolimnion) is expected to be deoxygenated, and discharge of such water after passing through the turbines adds up to the cold water pollution downstream of the dam (Bernacsek, 2001).
5. In that water volume released downstream, a high sediment load is expected, in particular if sediment flushing is performed at dam site. This massive sediment inflow impacts fishes and the environment downstream. In addition to flushing events, the constant sediment and nutrient reduction created permanently downstream by sedimentation at the dam site will also affect fish growth/productivity and overall river productivity downstream. Reduction in sediment load downstream will also impact fish reproductive success, in particular for species that lay their eggs on the riverbed and species whose buoyant eggs are adjusted to a certain sediment density (Baran et al., 2015).

In conclusion, the Pak Beng HPP will inevitably impact fishes, both in terms of diversity and production, as well as their habitats. This is expected to contribute to degraded fisheries resources, and ultimately will have an impact on the livelihood of the people in the project-area. The major strategic issues to be concerned about are changes in habitat and hydrological patterns.

5.5 BIRDS IMPACT ASSESSMENT

5.5.1 *Introduction*

Table 5.21 summarises the likely effects of the various potential causal factors of change to the study stretch's avifauna by two sub-stretches (from the Thai – Lao border to the projected site of the Pak Beng HPP dam (including this dam's reservoir); and the Pak Beng dam to Luang Prabang). The potential threats are elaborated below. Two other factors related to the Pak Beng HPP may have severe detrimental effects upon the avifauna but these will be outside the channel and so beyond the scope of this review: changes in habitat and human activity along the route(s) of any power line(s) and in any resettlement area(s) for displaced people (it is also possible, depending on the detail of what the two projects will involve, that neither of these factors will have any material effects on the avifauna).

Table 5.21: Factors potentially affecting the avifauna of the project stretch.

Factor	Thai–Lao border to Pak Beng dam (94 km)	Downstream of Pak Beng dam (176 km)
	Construction phase	
Channel used as base by itinerant people	Damaging if it occurs	Damaging if it occurs
Increased mercantile attitude and opportunity	Negligible effect	Negligible effect
Increased dry-season sediment flow	Negligible effect	**Likely to occur and be problematic**
Dam closure effects on downstream water flow and level	Negligible effect	Low to negligible effect
	Long-term	
Increased accessibility for hunting	Negligible effect	Negligible effect
Loss of habitat to infrastructure	Negligible effect	Negligible effect
Water pollution	Could occur at damaging levels	Could occur at damaging levels
Vegetation change	Negligible effect	Negligible effect
Water-level change – reduction in annual amplitude	**Locally devastating**	**Potentially damaging**
Water-level change – large transitory dry-season rises	Unlikely to be serious	Material effects are possible
Sediment flow change	Cannot be predicted	Cannot be predicted
Relocation of solid material	Negligible effect	Negligible effect
Water-flow speed change	Probably low effect	Negligible effect

The sole safely predictable serious negative effect of Pak Beng HPP on the project stretch's avifauna is presented in bold face.

5.5.2 *Potential solely or overwhelmingly construction-phase impacts*

The channel serving as a base by itinerant people: seasonally exposed channel is used often as a living area by non-local, and to some extent local, people. If large numbers of people live during Pak Beng HPP construction in the seasonally exposed channel, their presence (including presumably also dogs and, through refuse, increased rat numbers) may reduce breeding success of channel nesters for the relevant year(s). This is typically a transitory effect but could well be locally devastating to reproductive output for the year in question, if large numbers of people are involved and they are spread across many channel features.

However, a long-term effect is also plausible, given levels of human activity along the project stretch to date: temporary habitation of a stretch of channel bed that happens to support the last pair of a much declined species (e.g. Great Thick-knee, if not already gone) in the project stretch could result in that pair's breeding failure and coincide with the death of one or other of the birds. While this may seem contrived, the last resident River Tern in the Lao Mekong north of Vientiane, and the last resident Black-bellied Terns anywhere in the Mekong was observed. One year these birds were there; the next, they were not. This is the era of the final loss of once-abundant species from all or large sectors of the Mekong. However, even if high project-induced pressure from itinerant people in the channel coincided with the breeding failure in the last year of a key pair's existence, even had the project not existed, the 'baseline' local people package would probably also have been sufficient to deliver the same result. Project-induced people coming to base themselves temporarily in the river channel may be not (only) those officially employed in construction, but a whole host of itinerant 'camp followers': traders, hunters, fishers, purveyors of recreational services, and so on.

It is possible that current residential use of the seasonally exposed channel bed in the project stretch is already so high (and damaging) that the additional people brought, directly or indirectly, by the Pak

Beng HPP could have no meaningful incremental effect. Without assessment of current such use it is not possible responsibly to suggest how serious this factor will be.

Increased mercantile attitude and opportunity: large infrastructure projects typically bring in, during the construction phase, a huge pulse of non-local personnel with knowledge of non-local markets, transport opportunities to these markets, and a mental outlook to seek and exploit additional money-making opportunities. The project stretch has supported for a long time one of the main concentrations of traders in Lao PDR, by virtue of its being a trading route. Neither project is likely to increase this factor materially.

Increased dry-season sediment flow during construction**:** although much of the bird conservation interest of the project stretch depends upon the presence and seasonal mobility of huge quantities of unconsolidated sediment of a variety of sizes from silt to boulder, construction work in such a river typically releases a pulse of small sediment into downstream flow. This is unlikely to be particularly problematic in the high-flow season, but during low water levels it may be severely detrimental to some species. Water can become so turbid that kingfishers and other visual hunters need to relocate to areas of clearer water to forage efficiently; if there are not sufficient backwaters and tributary mouths, dispersal away from the study stretch may be necessary. 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.

Reduced downstream flow and lower downstream water levels upon dam closure: the quickest way to fill a reservoir is to close its outflow until it is full, thereby leaving the bed dry until downstream tributaries enter. There are a host of social reasons why this will not occur for the Pak Beng HPP. Given the established human uses of the river, it seems unlikely that downstream flow would be reduced to levels so low as to threaten, materially, this stretch's avifauna even temporarily.

5.5.3 *Potential long-term impacts*

Increased accessibility for hunting: one of the most severe effects on wildlife of any large infrastructure project in Lao PDR and neighbours is often the increase in accessibility to an area, meaning that a host of species become economically sensible to extract whereas they had not been before. The project stretch is already fully accessible along its length by boat and damming the river (Pak Beng HPP) cannot therefore increase accessibility. The mosaic stretches of the seasonally exposed channel bed are challenging to enter compared with sandbars, and this is believed to explain in at least large part their less-depleted communities. The Pak Beng HPP is not likely materially to increase accessibility to the mosaic areas (as distinct from reducing their extent by Pak Beng Dam reservoir).

Loss of habitat to infrastructure: some areas will be converted from natural or near-natural habitat to the dam and accessory features for the Pak Beng HPP. These comprise such a tiny proportion of the total length that a material effect on project species populations is difficult to conceive.

Pollution: a wide range of chemicals is used in association with construction and running of a hydropower project. Many of these are damagingly polluting to river wildlife. Pak Beng HPP could potentially cause problematic pollution but there is little precedent to believe that this is going to make a major change in level of risk over that currently.

Vegetation change: changes in vegetation in the seasonally exposed channel bed and underwater could affect the bird community including populations of project species. Vegetation change with the Pak Beng HPP will be substantial in areas affected by water-level change (see below) but rather little of significance to birds is likely to occur in zones still exposed seasonally.

Water-level change**:** the Pak Beng HPP may have major effects on bird community through changes in water level. The absolute water levels are less significant than are their annual amplitude, the seasonal timing of change between low water and high water, and any short-term fluctuations within the mid- and late dry season. Many of the project species depend upon the special habitats generated by a predictable annual pattern, that of inundation for several months then rapid change to exposure for several months. Without annual exposure as the water drops, these habitats would be lost to birds: the vastly richer birdlife in areas of channel mosaic and sedimentary features compared with river stretches comprising simply water between two banks indicates that, for large rivers, seasonally exposed channel bed is of more value to river birds than is the equivalent area of water.

Without annual inundation the bare and sparsely vegetated habitats would come to resemble those of the adjacent plains and the specialist river species would be replaced by those of dryland habitats. Even the seasonally inundated bushland of river channels is not equivalent, in bird community terms, to the bushland of bank-tops and adjacent plains: most notably, Jerdon's Bushchat is abundant in the channel bushland but seems never to have been recorded in Lao PDR (despite considerable search effort close to areas of occupied channel) in lowland dryland bushland (although, it is also resident in high-altitude anthropogenic bushland).

As well as the seasonal amplitude in water level (which determines how much such habitat will exist) the timing of water-level switch between low and high is also critical. If, for operational or other reasons, a dam retains water well above pre-impoundment levels into the late dry season but then rapidly lets it out so that by the end of the dry season water levels are similar to those pre-impoundment at that time of year, this may be insufficient to prevent the area being unsuitable for ground-nesting channel birds. These require a period of some months (the precise period varies between species, with, in general, larger birds having longer periods) of low water to work through the cycle of territory establishment and pairing, laying, incubation, and rearing of chicks to flying stage (when, if necessary, they can evade rising water levels). Moreover given the likely high rates of nesting failure for these species, a low water period sufficient for just one cycle is likely to result in overall stretch-level productivity much lower than the current situation, where the dry period is so long that multiple re-nesting attempts can be made if eggs or chicks are lost.

It might seem that because so many river channel birds are clearly at somewhat to greatly reduced linear densities, a lot of their habitat could be lost without this driving further population declines. However, this is not a fair prediction even for bird species way below what would be the carrying capacity in the absence of human activity. Under the current local people package, whatever is the precise balance of its threats, it may be that huge areas are necessary (through hindering the finding of nests by people, dogs and rats, hampering the setting of traps for adults, 'diluting' the chance of buffaloes trampling nests and people setting up camps right beside nests, etc.) for populations to persist.

Thus, a loss of two-thirds of the area of seasonally exposed, seasonally inundated, channel bed will quite plausibly cause a loss to similar level of ground-nesting bird species: it may even cause a greater proportionate loss in bird populations than in habitat if it reduces the width of the waterside band seasonally exposed habitat to below that typically occupied by a whole range of specie from Jerdon's Bushchat to Little Pratincole. The likely relationship for cliff- (rock and sand) nesting species (swallows, martins, bee-eaters, kingfishers, White Wagtail) is even less predictable but again it should not be assumed that there is any 'slack' in the current habitat extent for today's numbers even if these are way below what they would be were there no local people package.

Depending on how much the seasonal amplitude in water level will decrease and/or timing will change, this factor has the potential to devastate the remaining bird community of the Pak Beng reservoir stretch (particularly its lower part) and the stretch downstream of the dam to the next major tributary inflow, or to have only minimal effects. On current plans, the dam developers have estimated that the backwater effect will reach 97 km upstream of the dam; alternative sources indicate it may be as far as 110 km upstream. This stretch seemed, in 2000, to be of merely average importance to project species. The most important areas were all upstream of this, and here, if the developer's predictions of water-level change are correct, there will be no significant such effects. The seasonally inundated, seasonally exposed parts of the channel in the lower part of stretch 5 will be lost almost entirely: a 27 m increase dry-season water levels is predicted at the dam wall. Overall, on these plans, and if the spatial pattern of avifaunal importance within the project stretch remains similar now to the situation in 2000, the water-level changes from the Pak Beng dam will have a material, but not catastrophic, effect on the full project stretch's bird conservation importance.

A second component of water level change is within-season predictability of water levels. The excellent strategy of nesting on the ground in river channels during falling water levels in a climate with high seasonal predictability in rainfall and snow-melt becomes an absolute liability in a situation of occasional high releases from upstream dams causing a surge in water levels even if only for a day or two. This effect is likely to be particularly strong on river-bed nesters (because eggs and pre-flight chicks are unlikely to survive immersion for even a few hours), but less marked on sand- and rock-cliff nesters. It is close to irrelevant for non-breeding visitors and for residents outside the nesting and dependent-young periods. Given the level of human activity downstream of the dam and the risk to human life and livelihoods from water surges, it seems possible that these will not occur at levels (magnitude and frequency) threatening to the avifauna. Moreover, the Mekong immediately downstream of the Pak Beng dam site, where such surges, if occurring at all, will be most marked, was in 2000 of rather little import to the project species.

Sediment flow and distribution change: for the Pak Beng HPP, there is the possibility of sediment build-up in the bottom of the reservoir; all of this will be lost from the dynamic seasonally exposed, seasonally inundated habitat layout which supports the majority of the project species. Furthermore, water exiting dams is typically low in sediment and therefore erodes downstream sedimentary features. At the scale of the entire project stretch, this loss may be offset by the increased deposition of sediment as each stream (including the Mekong mainstream) slows on entering the reservoir, if there is sufficient seasonal variation in water level of the dam to expose these new sediment banks during the dry season. There could even be a net positive effect, depending on the relative sizes of areas lost and gained. It is not possible to predict with any justifiable confidence the magnitude or even the polarity of the effects on the project stretch's avifauna of sediment flow changes occasioned by the Pak Beng HPP.

Relocation of solid material: While there may well be some short-term, localised, negative impacts on birds (most plausibly, through food supply and/or accessibility changes) of dam construction activities releasing extra sediment into the river (see above), it is unlikely that this is going to have major long-term effect on bird populations.

Water-flow speed change: For the Pak Beng HPP, radical changes in water flow will occur. On current information, effects will extend (the further from the dam, lower in magnitude) about 100 km upstream from the dam. Major changes in fish and aquatic invertebrates (i.e. bird food) will follow. However, the effects on birds are difficult to predict. No serious study has been undertaken of the before and after avifauna of any comparable dam in Lao PDR or neighbours, and little information is available from anywhere in tropical Asia. However, basic observations of reservoirs considerably more lentic than the Pak Beng HPP's is likely to be, in India and Thailand, show that almost all the 'river' specialities such as River Tern, Great Thick-knee, Little Pratincole and River Lapwing use them for both feeding (even in the dry season) and nesting. The circumstances in which such use occurs compared with those where it does not, for each species, remain unknown. While reservoirs in Lao PDR are almost legendarily lacking in birds of conservation significance except during migration periods, this may be because they are heavily used and typically lack areas of barely accessible habitats comparable to 'channel mosaic'; and thus human pressure, rather than inherent habitat unsuitability, prevents much use by study stretch species.

Of the project species still known to be, or potentially still, extant in the study stretch, those which seem most likely (based upon their use of waterbodies and watercourses of various types across northern South-east Asia) to eschew slow-flowing parts of the reservoir because of change in water-flow speed (rather than other factors such as change in hunting pressure or decreased area of seasonally exposed, seasonally inundated land) are White-eyed River Martin, Blue-tailed Bee-eater, Asian Plain Martin, Long-billed Plover, Little Pratincole, Jerdon's Bushchat, Wire-tailed Swallow and White Wagtail. The confidence of this prediction is low, and the result for at least some species may be somewhat to greatly decreased numbers in, rather than full extirpation from, the affected part of the study stretch.

5.5.4 *Scenarios*

Baseline: no Pak Beng hydropower project

This is covered in the 'forward projection' section of the baseline report. Basically, the catastrophic collapse of the project-stretch avifauna has, largely, occurred already, and all species left are by definition relatively resilient on a river of this width. Nonetheless, many are probably still in decline and this is likely to continue. Some extirpated species may recolonise, reflecting factors operating outside the project stretch. But overall, the future avifaunal community is likely to be shaped by the continued loss of species and decline in numbers of those project species that still occur.

With Pak Beng HPP

The Pak Beng Hydropower Project has a major guaranteed (on current plans) serious long-term negative impact: the reduction in the area of seasonally exposed – seasonally inundated channel bed reflecting typically higher low-water levels. Fortunately, the reach most affected by this factor is not among those (in 2000) most important for study stretch species; but nor is it of low importance to them either. Study-stretch-level population declines in many project species can confidently be predicted. Less likely, but also conceivable, long-term negative impacts could come through pollution, dry-season water surges from dam release, changes to sediment flow and distribution, and change in water flow speed. As with the LMDP, during construction there could be severe but probably only transitory negative effects from unregulated use of the dry-season exposed channel as a living base by itinerant people, and increased dry sediment flow.

5.6 SOCIO ECONOMIC IMPACT ASSESSMENT

5.6.1 *Introduction*

This socio economic impact assessment builds on the social impact assessment (SIA) that was conducted in 2015 for the Pak Beng Dam. As such, it does not attempt to repeat the earlier work, but adds impacts that the original SIA did not consider. In particular, the SIA focused on direct impacts of the dam construction and operation, whereas this socio economic assessment considers the additional longer-term and indirect impacts. For example, there are a variety of impacts that are likely to occur because of project-induced road improvements in the area.

An overview of the impacts identified in the SIA are provided initially, and is then followed by a cascading list of impacts that are not considered in the SIA. For a full critique of the SIA, please see Appendix 1.

5.6.2 *Overview of SIA identified impacts*

The SIA provides some detail on impacts to the local communities. While there is a section on downstream impacts, there is also a note indicating that these impacts are provided in a separate report. The SIA also briefly considers some broader implications of the project, including positive changes associated with rural electrification and increased foreign direct investment. A summary of the impacts on local communities is provided below.

5.6.2.1 Upstream impacts (Zone 2)

5.6.2.1.1 Construction related

For the upstream and dam construction area, the SIA identifies seven negative construction related impacts and one positive construction related impact that are likely to occur during the construction phase. In addition they have noted three construction related effects in the same area that will have both positive and negative effects. For example, they note that there will be obstacles relating to navigation and tourism because of factors such as increased vehicular traffic on roads and coffer dams, but that people will still be attracted to the area to view progress.

For the positive impacts, the SIA observes that access to schools will be improved as part of the overall dam construction project, including the resettlement component. Thus education levels in the area are likely to rise. There will also be improved access to markets for livestock and other farm produce, thus producing positive economic impacts.

The primary negative impacts that the SIA identifies 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.

5.6.2.1.2 Operation related

For the upstream area, during the operation phase of the dam, the SIA lists 6 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.

1) Impacts on health and education

For health and education, the negative impacts are related to potential for drowning in the reservoir, while the positive impacts relate to improved health and education infrastructure at the dam site and the village relocation/resettlement sites.

2) Impacts on tourism

The higher water level in the reservoir is anticipated to make it more convenient for tourists to access tourism sites, and that the dam itself will attract tourists for education and sightseeing reasons. On the other hand, there will be the loss of rapids and river bank scenery that tourists find attractive.

3) Impacts on land transportation

For project purposes there will be construction of new roads as well as upgrading of existing roads. These will later be maintained, and local communities will have better market access and better communication.

4) Impacts on fishing

The diversity of fish in the upstream area is expected to decrease because not all species of fish will be able to use the fish ladder. However, the SIA predicts that with the inclusion of a fish management program, the reservoir will become a rich fishing resource.

5) Impacts on navigation

The only impact listed relating to navigation is that the dam will make it more convenient for tourists who use boats, to cross from one side of the Mekong River to the other during the dry season.

6) Impacts on livelihood restoration

The details of impacts on livelihood restoration are not provided in detail, but are expected to of long-term duration.

5.6.2.2 Downstream impacts (Zone 3)

5.6.2.2.1 Construction related

In the SIA, there are a total of five construction related impacts listed. Two of these are negative, and one positive. The negative impacts are 1) Impacts on water quality, and 2) Impacts on fishing. The positive impacts are: 3) Impacts relating to employment, 4) Impacts on household investment, and 5) Impacts on food supply.

1) Impacts on water quality

These impacts will be driven by A) Concrete contamination (altered pH of the water), B) Increase in Biological Oxygen Demand because of untreated waste-water and insufficiently treated sewage, and C) Oil contamination from accidental spills as well as machine maintenance.

2) Impacts on fishing

The SIA notes that impacts on fishing and fish culture will be impacted in the short term.

Positive impacts

The three positive impacts are grouped together in the SIA, which notes that there will be positive impacts relating to employment, household investment and food supply in some downstream villages.

5.6.2.2.2 Operation related

The SIA notes that there will be long-term negative impacts relating to water variation, fishing and livelihoods, but does not provide detail on what these impacts will be. It also notes that there is potential for both positive and negative impacts on tourism, but does not provide any detail.

5.6.3 *Summary analysis of the SIA identified impacts*

The impacts identified in the SIA are primarily of a direct nature, and are also considered only superficially. For example, the improvement of land transport component of the impacts does not consider any potential impacts relating to traffic travelling at higher speeds, whether there will be a large number of inexperienced road users, or whether land transport improvements will include separate spaces for cyclists and/or pedestrians. The purpose of this section on socio economic impacts associated with the Pak Beng dam is to consider those impacts that have either not been considered, or not fully considered, in the SIA.

5.6.4 *Additional impacts not identified in the SIA*

In addition to the impacts identified in the SIA, an analysis of likely flow-on effects indicated that these need to be considered in order to safeguard the livelihoods and well-being of those living in the study area. This is particularly the case for poor and vulnerable populations such as ethnic minority groups. The indirect impacts presented here are divided up according to the underlying causes, rather than the geographic location in which they will occur.

The causal areas of indirect impacts that were not covered in the SIA are: 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. The impacts described below assume that no attempt has been made to mitigate negative impacts or to enhance positive impacts. The impacts are divided into the three causal areas:

5.6.4.1 Increased number and size of boats on the river

The construction of Pak Beng dam is planned to be accompanied by the implementation of the LMDP, as can be seen by the size of the ship lock that has been included in the dam design. The lock will be capable of facilitating transport of boats of 500 tons, up to a total of 1.5 million tons of shipping each year. This volume and size of boat traffic will have a number of implications:

1. The Pak Beng dam is **likely** to be associated with the LMDP navigation upgrades:
    - 1.1. Increased large vessel traffic has the **potential** to result in more boat accidents, particularly as those living in the area currently rely on small boats for transport.
    - 1.2. Wakes from increased large vessel traffic **will** lead to river-bank erosion, and hence a likely loss of riparian farmland:
        - 1.2.1. This is **likely** to impact on food security, especially for ethnic minority and other poor communities who rely on river bank areas for vegetable gardening or subsistence farming.
2. More ships crews and passengers are **likely** to lead to more organic pollutants (waste water) entering the river:
    - 2.1. The increased pollutants have the **potential** to result in increasing levels of food- and water-borne illnesses such as acute watery diarrhoea, which is already a chief complaint in the area:
        - 2.1.1. Increases in food- and water-borne diseases are **likely** to disproportionately affect poor and vulnerable people:
            - 2.1.1.1. There is the **potential** for poor and vulnerable households to be driven into poverty because of a need to pay for medical care as well as degraded ability to work.
3. Increased large vessel traffic provides a larger capacity for carrying produce from plantations, as well as logs and other timber:
    - 3.1. This makes it **likely** that there will be increased pressure on poor and ethnic minority communities to relinquish their customary lands, as outside investors apply for land concessions in the area:
            - 3.1.1.1. There is **potential** for loss of traditional life-style practices.
            - 3.1.1.2. There is **potential** for loss of food security as households become dependent on mono-crops and the fluctuations of world price markets.
            - 3.1.1.3. There is **potential** for communities to improve their lives through more consistent income streams and enhanced engagement with the market economy (but this is more likely if they are not pressured to give up their lands).

5.6.4.2 Associated infrastructure upgrades

A project the size of Pak Beng dam will almost certainly be associated with improved infrastructure such as roads that link the site to other areas. This will facilitate transport of construction materials and personnel for the dam itself, as well as supporting likely growth in nearby towns such as Pak Beng and Pak Ngeui. For example, it is very likely that existing roads to towns including Muang Xay, Muang Ngeun and Pak Tha will be upgraded. This is particularly the case because the Lao government is promoting modern industrialised agriculture as part of the country's national development planning (MAF 2010), and road upgrades will support moves away from traditional shifting agriculture, by providing farmers with access to agricultural inputs and markets, thus facilitating the integration of remote rural populations into modern market-oriented ways of living.

4. Construction of the dam will be **very likely** lead to road upgrades spreading out from the dam site:
   4.1. It is **likely** that there will be large numbers of inexperienced users of the roads, particularly when they are first upgraded/constructed:
      4.1.1. There is a **potential** for higher rates of traffic accidents resulting in injuries and fatalities.
   4.2. With improved roads, as well as the improved port facilities and improved navigation of the river, the study area **will** become significantly more attractive to foreign investors, for agricultural, logging and other types of land concessions:
      4.2.1. Thus, there it is **very likely** that there will be further expansion of logging and plantation concessions, as well as wildlife trade:
         4.2.2. Along the river as well as the upgraded roads leading away from the Pak Beng dam site, it is **likely** that poor and ethnic minority communities will face increasing pressure to relinquish their customary lands, as outside investors apply for land concessions in the area:
            4.2.2.1. There is **potential** for loss of traditional life-style practices.
            4.2.2.2. There is **potential** for loss of food security as households become dependent on mono-crops and the fluctuations of world price markets.
            4.2.2.3. There is **potential** for communities to improve their lives through access to more consistent income, and can enhance their engagement with the market economy (but this is more likely if they are not pressured to give up their lands).
   4.3. Improved roads are **likely** to benefit farmers who sell part of all of their produce, through better access to inputs as well as to markets.
   4.4. Improved roads has the **potential** to improve communications between riparian villages, and thus strengthening social networks.

5.6.4.3 Social dynamics creating follow-on impacts

The influx of 3,000 – 4,000 workers, as well as other job seekers will have major impacts on the nearby towns including Pak Beng and Pak Ngeui.

5. The large number of paid workers **will** attract entrepreneurs as well as criminals, thus the population growth **very likely** to be significantly higher just those attracted directly by dam-related employment opportunities:
   5.1. There is **likely to** be more gambling, and more alcohol/substance abuse.
   5.2. It is **likely** that levels of violence/civil disturbances will increase.
   5.3. It is **likely** that gangs will form.
   5.4. It is **likely** that there will be a growth in prostitution.
   5.5. It is **likely** that there will be increased rates of sexually transmitted diseases.
6. New accommodation, restaurants/eateries and shops **will** be constructed to house and feed both those directly employed by the project, as well as entrepreneurs who have come to take advantage of the money making opportunities:
   6.1. There are l**ikely** to be employment opportunities in construction and services sectors.
7. 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)

5.6.5 *Conclusion*

The SIA does not consider indirect impacts, and neither does it consider cumulative impacts. For example, while it notes the potentially negative effects of land loss on vulnerable groups, and also notes that fishing may be disrupted, it does not consider that facing these two shocks at the same time is likely to be far more damaging to vulnerable groups than either would be on its own. There will be a variety of indirect socio economic impacts associated with the construction and operation of the Pak Beng dam, as indicated here. This report considered the impacts presented in the SIA, and built on these to form a picture of likely indirect socio economic impacts.

These indirect impacts are not limited to just the dam site and the immediate up and downstream areas. For example, 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. 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 that is a basis for 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.

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5.7 PAK BENG IMPACT ASSESSMENT CONCLUSIONS

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 the 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. If sediment loads are retained with the reservoir, this will change the downstream sediment balance, resulting in bed and bank erosion and changes in geomorphology and wetland habitats. If there is sediment flushing this could also have downstream impacts depending upon how it is done. If the plant is operated in a peaking mode, there will be much more intense impacts upon the downstream aquatic ecology in Zone 3, especially on the macroinvertebrate fauna. 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: There will be a variety of direct and indirect socio economic impacts associated with the construction and operation of the Pak Beng dam. The indirect impacts are not limited to just the dam site and the immediate up and downstream areas. For example, 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 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.

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7 APPENDIX 1: EVALUATION OF THE PAK BENG DAM SOCIAL IMPACT ASSESSMENT

7.1 INTRODUCTION

The purpose of this appendix is to critically examine the social impact assessment (SIA) that was conducted in 2015 for the Pak Beng dam planning and construction. It was a full SIA, and was conducted by Kunming Engineering Corporation.

This examination of the SIA begins with a brief background on the Pak Beng dam, following which, the SIA report is evaluated against the nine areas that were used to compile the baseline socio-economic report on the Lancang-Mekong Development Plan (LMDP). The choice to assess the SIA against these criteria was made because: 1) Both the LMDP and the Pak Beng dam are proposed developments in the same area of the Mekong mainstream; 2) Both the Pak Beng dam SIA and the LMDP socio-economic report concern themselves with the socio-economic conditions and impacts of people living in the riparian communities; and 3) There are significant interlinkages between the two development projects (e.g. the ship lock will not be useful for 500 tonne vessels unless the LMDP is implemented).

These nine areas, grouped into two categories, are as follows:

1. People
    - 1.1. Population data
    - 1.2. People in the impact zone from the dam
    - 1.3. Ethnic minorities
2. Poverty and livelihoods
    - 2.1. Agriculture
    - 2.2. Trade and economic situation
    - 2.3. Fishing
    - 2.4. Wildlife trade and trafficking
    - 2.5. Deforestation and forest degradation
    - 2.6. Land tenure and titling

This critique shows that while some aspects of the SIA are thorough and well thought through, more detail needs to be provided in some areas, and that important indirect impacts are not considered. The following sections provide more detail on both the areas of the SIA that should be considered in more depth, and the areas where the SIA provides useful data, information and recommendations that will help to safeguard and enhance people's livelihoods and well-beings in the face of changes that would come with the construction of the dam. The final section of this critique is used to make recommendations about how gaps in the SIA could be rectified.

7.2 BACKGROUND

According to the SIA, building the Pak Beng dam, when compared with not building the dam, rates positively in terms of anticipated socio economic impacts on the population. The basis of the argument made in the SIA is that the fishing, and environment quality, in the area will degrade over time because of population growth, and because of the management capacities of relevant agencies are limited. The implication is that fishing and the quality of the environment will be able to be better maintained in the case where the dam is constructed.

The dam that is planned for construction has a design height of 69m, with a dam wall length of 895m. The water level in the reservoir is planned at an operating height of 340 metres above sea level (masl). The dam is planned to include a fish passage as well as a ship lock for vessels up to 500 tonnes. The ship lock will allow passage of 1.5 million tonnes of shipping per annum (3,000 ships of 500 tonnes each). The design of the dam will create a reservoir with a surface area of about 7,660 Ha. that will hold 780 million m^3 of water, and that will inundate an area extending 90 km upstream. It is expected that preparation and construction will together take around 95 months (just under 8 years).

The dam is being planned to meet the Lao government's development objectives, which include increasing their sales of electricity to Thailand to 7,000 megawatts (MW) by 2020. In this context, the Pak Beng dam is one of five currently planned hydropower dams on the Mekong mainstream in Lao territory that together have a combined design capacity of around 5,500MW. The Pak Beng dam has a design capacity of 912 MW, and most of the produced electricity will be exported to Thailand via high voltage power lines.

The SIA has a number of background components, including description of legislative arrangements and development donor policies that impact on the project. Once the SIA begins discussing impacts and mitigation options, it breaks them down into pre-construction related impacts and mitigation options, construction related impacts and mitigation options, and operation related impacts and mitigation options.

The following sections of the report provide a brief summaries of the SIA content broken down into the nine areas described in the introduction. Following this is a discussion of the positive aspects of the SIA, as well as the areas where it could be improved by inclusion of more detail, or by filling existing gaps. This critique concludes with some recommendations about how to best fill gaps and develop more detail, in order that those who will be affected both directly and indirectly by the construction and operation of the Pak Beng dam, and particularly poor and vulnerable populations, have their interests considered and voices heard.

7.3 PEOPLE

This first section focuses on people, and is broken into three subsections. These are: 1) Information from the SIA focusing on population data; 2) More detailed information from the SIA on the people in the dam impact zones; and 3) Information from the SIA on ethnic minorities. The inclusion of ethnic minorities as a separate sub-section is because ethnic minority groups in Laos are statistically worse off than people from the majority Lao-Tai ethnic family.

7.3.1 *Population data*

Population data refers to the type of data that would be collected in a census, such as numbers of people, the main occupations and the gender breakdown.

The SIA provides a lot of detail about the population living along the river. The SIA makes the observation that, generally, people living along the river rely on basic agriculture such as rice or maize cropping for their livelihoods, and livestock are treated in much the same was as a bank account. In the area upstream of the dam site, the SIA provides data on the populations of the villages that will be directly affected by the reservoir, including six villages that will need to be resettled uphill, but in the same general location, and one village that will need to be re-located. The SIA reports that people living upstream of the dam site live well below the poverty line on average, with an average income equivalent to US$0.49/person/day. The SIA also includes survey data of 18 upstream villages briefly describing community history, cultural sites and an overview of the different ethnicities living in each community.

For the area downstream of the dam site, the SIA provides a table of data showing each community by name, how many kilometres the community is from the dam site, whether it is located on the left or right bank, and how many women and men live in the community. The average income for those in the downstream communities is described as being in the range of US$300-400/person/year (significantly more than the US$0.49/person/day reported for the upstream communities). In addition, the SIA data includes the populations, number of households and gender breakdown for each downstream community. The data does not include detailed information on the ethnicities within each community.

7.3.2 *People in the dam impact zones*

The broader population data overlays the lived experiences of the people who will be affected by the construction of the Pak Beng dam. The perspectives of those who will be affected are important, and the SIA highlights that livelihoods need to be maintained from the perspective of the local people. For example, in the introduction this is pointed out explicitly, and later in the SIA it is observed that affected people, including women and vulnerable groups, must be involved in the development of the action plan for resettlement (for those in communities that will be inundated by the reservoir).

The SIA provides details of communities that will be directly affected by the dam construction and operation. This includes separate discussions of upstream communities (8 pages), and downstream communities (9 pages). The separation is appropriate, since the direct impacts of the dam are different depending on location. For example, the discussion of upstream communities focuses on those villages that will be partially or mostly inundated by the reservoir, whereas the discussion of downstream communities provides a descriptive narrative of 20 downstream communities within 100km of the dam site. Location maps for 3 of the downstream villages are supplied. The discussion of the upstream villages includes half a page of text and a page of photos about the housing within these communities, including the approximate costs for construction.

Within the scope of the SIA, an HIA was also conducted, based on surveys completed in 2011. The SIA reports that health service facilities in the dam impact zones are basic. The main health complaints are diarrhoea, respiratory illnesses and dengue fever, and improvements in health outcomes in the area have been limited. The HIA includes a section on access to health care facilities for communities upstream of the dam site. It also describes endemic intestinal infections among the surveyed peoples. Diarrhoeal and intestinal infections are associated with inadequate disposal of human faecal waste. The SIA reports that across 25 upstream villages that 68% of households had improved sanitation facilities such as latrines. An additional health concern was food security.

Focusing primarily on the upstream communities, the SIA discusses a variety of cultural aspects of the peoples who will be directly impacted by the dam and its construction. It discusses the sites of cultural significance in 18 upstream villages including temples, cemeteries and spirit sites. Spirit sites are not explicitly described in the SIA, however it does note that the villagers in the area believe there are territorial spirits that originate from village founders or other historically grand people. The villagers make offerings to the spirits at the beginning of the agricultural season. The offerings are generally buffalos, chickens, pigs or alcohol, and are based on a belief that in exchange the territorial spirit will offer protection and even intervene in case of disaster or some other need. The focus on culture in the SIA is on the villages that face partial inundation because of the dam, including noting the temples and spirit sites that will require relocation.

The SIA notes that the government requires a portion of the project's income be set aside to support any dislocated communities. Thus, those being resettled can expect benefits including access to electricity, improved roads, as well as hospitals and schools. They can also expect to exchange existing rain-fed rice fields for irrigated rice and cash crops.

The experiences of the affected people provide the context for how well and easily they will be able to adjust to and cope with the changes that the dam construction and operation will bring. The SIA acknowledges this in its assessment of the significance of impacts.

7.3.3 *Ethnic minorities*

Ethnic minority groups in Lao tend to be particularly vulnerable, and the Pak Beng SIA refers to the World Bank's (2005) operational manual on safe-guarding the rights of indigenous people, acknowledging World Bank requirements in regard to this and other operational manuals. The SIA also states in its introduction that the SIA will analyse the existing social conditions, including for ethnic groups in the project area. Ethnic minority groups are categorised under the broader term 'vulnerable groups', which it defines as, "groups of people who by fate of gender, ethnic group or indigenous status, age, disability and other predicaments have much less capability to adapt to the changes caused from the project development" (Kunming Engineering Corporation Limited 2015, p. 1-12) .

The SIA provides some general information regarding the ethnicities in the region. For example, in relation to communities upstream of the dam site, it is noted that "only Luangtong and Pakped villages are overwhelmingly Lao while the remaining villages [that will be partially inundated by the reservoir] are a mixture of Lao, Khmou and Lue" (Kunming Engineering Corporation Limited 2015, p. 5-2). Similarly, in the downstream area, the SIA observed that the ethnicity in the 20 downstream villages surveyed was 70% Khmou, 25% Lao, and 5% Hmong households.

The SIA also observes that health outcomes for ethnic minority groups in northern Laos tend to be significantly worse than for the majority population. The reasons cited include that: 1) Ethnic minority groups tend to live in more remote locations, and so do not have good access to health facilities; 2) Ethnic minority groups tend to have lower educational levels, particularly the women; and 3) Ethnic minority groups often do not speak the national language, which makes communicating public health messages more challenging. This last point links to a tendency in ethnic minority communities for there to be lower sanitation and hygiene standards.

Despite government proclamations about national solidarity, ethnic groups in Lao PDR appear to have a tendency to remain separate from each other. For example, Kunming Engineering Corporation Limited (2015, p. 5-24) reported that in 2008 three villages in the study area merged into a single administrative unit, comprising 77 households of ethnically Khmou people, and 21 households of ethnically Lao people. Seven years after the combined town became a single administrative unit, the population was "still separated *culturally and ethnically*" [emphasis in original]. One of the Khmou populations holds a rock in the Mekong River as part of their folklore – a rock that in the dry season is visible above water, and which resembles the head and tail of a crocodile. Surprisingly, the SIA reports this, and then five lines down lists the village as having no sites of cultural significance.

7.4 POVERTY AND LIVELIHOODS

This section of the critique focuses on livelihoods and issues around poverty related to the dam's impact zones. It is broken up into the following six sections: 1) Agriculture; 2) Trade and economics; 3) Fishing; 4) Wildlife trade and trafficking; 5) Deforestation and forest degradation; and 6) Land tenure and titling.

7.4.1 *Agriculture*

Agriculture forms a very important aspect of the lives of those communities who will face the direct impacts of the dam construction. The SIA observed a reliance on basic agriculture, with many households relying on subsistence farming.

Agricultural land concessions are already active in the area, with the SIA reporting that a Chinese company has a 4,500 Ha. land concession that is being used to grow rubber. The SIA reports this as part of a broader push to improve farming methods in the area, but observes that provincial officials have found it difficult to convince farmers to change their traditional farming methods despite continued education about modern, improved agricultural methods.

The role of women are described in a general manner in the SIA. For example, "In the project area, women tend to deal with routine duties, take care of family, and do small-scale work" such as raising children and preparing food (Kunming Engineering Corporation Limited 2015, p. 5-18). Similarly, there is a general overview of medical complaints faced by women and that women in the downstream area have expressed concerns about the impact of the dam on agricultural production. The reported concerns related particularly to river bank areas where floods normally deposit sediment. However, the SIA downplayed this concern with the argument that most people expect the construction of the dam to improve their livelihoods because of things like better infrastructure and improved social services.

The SIA acknowledges that there will be impacts on the amount of productive agricultural land because of inundation in the upstream areas. It describes the people along both banks of the upstream section of the river as primarily being rice and field crop farmers, who also practice a limited amount of upland swidden farming that includes encroachment on forests. Livestock are reported to act as village banks, meaning that cattle and other livestock can be sold when a family has a need for money. For those who lose farmland as a result of the project, the SIA proposes community development funds be used to invest in sustainable agriculture.

7.4.2 *Trade and economics*

The construction of the dam is likely to have a large impact on trade and the general economic situation in the area. For example, the design of the dam includes a ship lock for ships of up to 500 tonnes, allowing for passage of 1.5 million tonnes of shipping annually (this is equivalent to 3,000 ships of 500 tonnes each).

The SIA reported that there is a paved road from Pak Beng to the "Oudomxay civic centre" (Kunming Engineering Corporation Limited 2015, p. 5-16), which presumably means Muang Xay (the capital town of Oudomxay province). The SIA reported that there are limited other roads connecting riparian villages, however, associated with the dam there will be upgrading of road infrastructure by the project. According to the SIA, this will facilitate the movement of people, goods and equipment, thus give local communities better access to market and better communications. The limited roads connecting riparian villages means that, currently, most transport occurs along the Mekong River, primarily with small boats.

According to the SIA, households in the 100km immediately downstream from the dam site, in general rely on agriculture for their livelihoods, and on average have less than 0.25 Ha. of land for growing lowland rice, less than 1 Ha. for each of upland rice and grazing lands, and less than 0.6 Ha. of land for gardens and perennial trees. Nearly 40% of the downstream population surveyed used water from the Mekong or its tributaries for household consumption, with other sources including wells, piped water and gravity fed water systems.

With the expected influx of 3 – 4,000 workers for the dam construction, the SIA reports an expected increase in demand for accommodation, food, transportation on the river, as well as entertainment. This is expected to particularly affect downstream villages/towns including Pak Beng and Pak Ngeui. These places currently do not produce enough food locally to cater to the tourist trade.

In order to enhance the economic opportunities around the dam site, and along the river, the SIA recommends promoting tourism, and developing tourist attractions along the river as well as at the dam itself, including the building of wharfs or jetties.

The SIA acknowledges that some farmers don't have enough land or adequate fisheries, and thus that they are not food secure. It recommends vocational training as well as economic support for development of small businesses. The SIA also observes that employment and income generating opportunities will increase alongside the dam construction.

7.4.3 *Fishing*

Fishing is an important food security buffer for the people in the impact zones. The SIA observes that most fish caught in the area upstream of the dam site are for household consumption, and that for downstream communities, fishing is a "way of life of the people" (Kunming Engineering Corporation Limited 2015, p. 5-17). The SIA downplays the importance of fish in the region's ecology, however, arguing that there are no endemic fish species in the up or downstream stretches of the Mekong River that will be directly affected by the dam. The SIA also argued that the fish population upstream of the dam site is limited, despite many rapids that may be suitable fish breeding sites. According to the SIA, the people in the upstream area fish primarily on a small scale in ponds, rice paddies and tributaries rather than in the Mekong mainstream itself.

The SIA argues that once the dam is complete, the reservoir will provide a rich fishing ground. At different points in the SIA it is suggested that downstream communities will be able to make their way above the dam wall and take advantage of this, and in contrast that exclusive rights to fishing in the reservoir may be granted to resettled upstream communities. There is an acknowledgement in the SIA that there will be a loss of productive fishing during the construction phase of the project. The SIA proposes that loss of fishing can be mitigated by using community development funds to invest in aquaculture schemes.

7.4.4 *Wildlife trade and trafficking*

The only reference to the wildlife trade is that the SIA acknowledges that wildlife trade is one of the biggest threats to biodiversity in Laos.

7.4.5 *Deforestation and forest degradation*

Forest degradation is an important consideration in the SIA because of the reliance that poor and vulnerable communities have on forest areas to ensure they are food secure. Forest degradation is recognised as a problem for sustainable growth in Laos, and according to the SIA, the Lao government has a land and forest allocation program which is designed to both protect the forests of Laos as well as to encourage the replacement of shifting cultivation with cash crop production.

Despite this, the SIA noted that there were no formal surveys of encroachment into forest areas in the dam's impact zones. The SIA noted that the reservoir will inundate 2,964 Ha. of forest lands, which is a comparatively small area of forest for a dam. The limited inundation of forests is closely linked to the steepness of the valley along this section of the Mekong.

The SIA mentions that expansion of agriculture, illegal logging and illegal hunting as well as uncontrolled burning are all degrading forests in Laos. Degradation of forests causes numerous problems, such as negative impacts on various economically important fish that feed on bark, roots, leaves and other forest items, in areas that flood during the wet season.

7.4.6 *Land tenure and titling*

Land tenure and titling is included as an area through which to view the SIA because it is a focus area for the Lao government. For example, the government estimates that nationally there are 2.6 million plots of land that need titling, and that of these 1 million urban and 100,000 rural plots have been surveyed and titled (Derbidge and Sisoulath 2018). In relation to land titling, the SIA discusses legislation relating to Lao citizens, including ethnic minorities. It also acknowledges that land rights in rural areas are primarily based on customary ownership. The SIA does not provide any specific detail with regard to land titling in the dam's impact zones.

7.5 DISCUSSION

The discussion below analyses the content of the SIA provided above. The analysis is divided into three areas: 1) People focused analysis, including health and ethnicity; 2) Economic aspects, including agriculture, trade, fishing as well as forest related aspects; and 3) A general examination of the impact analysis in the SIA, including aspects related to land tenure.

7.5.1 *People*

The SIA focuses exclusively on people and communities who will be directly affected by the dam. For example, while the largest burden will fall on the shoulders of those who will need to re-locate or re-settle, the SIA does not provide any detail on people who live further uphill from the river, and who may be impacted by the building of the dam in different ways. This is problematic, as there are many villages and communities whose lowest houses are located at elevations of around 345 masl (about 5 metres above the design water level of the reservoir). Analysis of satellite imagery indicates that many of these villages/communities use the currently existing land between their villages and the river for riverbank gardens and/or grazing of livestock. These river bank areas will be largely inundated by the reservoir. Thus, while the dam's construction and operation may not directly affect their ability to continue living in the same location, the loss of prime growing land has the potential to cause those living near the poverty line to fall into poverty, as per concerns raised by GoL (2018) and World Bank (2014) about shocks that can cause vulnerable people and communities to fall into poverty. The SIA does discuss the concept of land for land, which could mitigate this impact as long as there is land available near each village. Despite this, the details of how the land for land scheme will be administered, and specifically the provisions to facilitate simple and easy access for poor and vulnerable group to the compensation scheme, are not provided.

The health impact assessment (HIA) section of the SIA provides a detailed view of the health situation in the dam's impact zones, including surveys of up and downstream communities for likely health impacts associated with the dam. Despite this, only upstream communities were considered in terms of access to health services. The SIA does have a generic baseline for ethnic minority groups, referring to ethnic minorities in northern Laos having significantly lower health outcomes than the majority population. However, the surveys conducted for the HIA section have not picked up on this observation to determine whether or not the ethnic minority groups in villages in the impact zones also have lower health outcomes than average. The impact section of the SIA does include detailed tables on potential impacts on health associated with the project, as well as proposed mitigation options. Not all the listed impacts are clear, however. For example, under construction related impacts on women and vulnerable groups, it merely states that in the potentially impacted communities there will be a particularly vulnerable sub-sector of the population including young children, elderly people and poor or disabled people.

Ethnic minority groups are acknowledged as being particularly vulnerable to the negative impacts of development projects. Despite this, while the SIA refers to the World Bank's operational policy on indigenous people (World Bank 2005), the authors of the SIA appear to have viewed the policy as only relating to resettlement of affected populations. The SIA response to the operational manual is merely to say that "an Ethnic Groups People's Plan (which complies with World Bank and Lao PDR guidelines) has been incorporated into the resettlement plan" (Kunming Engineering Corporation Limited 2015, p. 3-15). Additionally, key aspects of the bank's requirements relating to indigenous people do not appear to have been met. For example, the bank requires that an "appropriate gender and intergenerationally inclusive framework" is established to ensure that local communities, civil society organisations and indigenous people's organisations have opportunities for consultation at each stage of the planning and implementation of the project (World Bank 2005, p. 2). The SIA report does not show evidence of the establishment of this type of framework, despite extensive project planning and community level consultation meetings for the SIA focussed research. Some of the weaknesses in the discussion of ethnic minority groups comes from including them within the larger 'vulnerable groups'. Following the definition of 'vulnerable groups', the SIA talks about vulnerable peoples and groups, but does not disaggregate impacts of mitigation options specifically for people belonging to ethnic minority groups. The grouping together of ethnic minorities under the broader vulnerability umbrella may also why the survey data on 18 upstream communities does not provide a breakdown of how many people of each ethnicity live in each community. Additionally, while the SIA includes evidence that some community consultations have taken place in relation to the dam, there is no detail about numbers of people who participated, or about representation from women, children, ethnic minority groups, disabled people and other poor and vulnerable groups.

While the SIA provides a general overview of women's roles in the community, and acknowledges the importance of gender aspects in relation to the dam construction and operation, their impact assessment provides little information about impacts that are gender sensitive. The impacts section notes that with the dam will come improved schooling infrastructure that will benefit girls who currently live too far from schools or are too poor for their families to send them to school. It also argues that women will benefit from reproductive health awareness programs, thus reducing birth rates and increasing the age at which women marry. These impacts are not well considered within the broader socio economic context. For example, the SIA does not address the poverty aspect of whether or not girls are able to go to school, except indirectly by assuming that the dam construction will lead to economic development. However, as per Cada *et al.* (2017), even with support from both the World Bank and the Asian Development Bank, it is unclear whether revenue from the Nam Theun 2 hydropower project has resulted in any reductions in poverty levels. Similarly, a reproductive health awareness program, by itself, is unlikely to have much influence on underlying cultural factors that link to, for example, women marrying young. The SIA notes that there are a variety of ethnic groups in the dam's impact zones, each with its own culture and traditions, but does not link tradition and culture to any of the impacts or the mitigation plans.

7.5.2 *Economic aspects*

There are three economic components that must be considered in order to critique the SIA. First, agriculture is a key component of both the local economy and people's livelihoods. Second, while fishing is not so important economically, it has strong livelihood and food security implications. Finally, trade within the region, both legal and illegal have large implications for the livelihoods of the riparian communities who will be directly and indirectly impacted by the dam and hydropower project.

While the SIA down-played the concerns expressed around loss of sedimentation for riverbank gardens downstream of the dam site, it would be more compelling to consider whether this concern is objectively sound. For example, flows in the Mekong River have already changed as a result of upstream dams, and it seems likely that the Pak Beng dam would flatten the annual flood pulse significantly in the immediate downstream area, negatively impacting the conservation of fisheries and activities such as river bank gardening (see e.g. Baran and Myschowoda 2009).

The observation of a foreign owned rubber plantation in the area matches with reports of government efforts to promote agri-business, as well as statistics regarding rubber plantations in northern Laos (Agricultural Census Office 2012, Bartlett 2012, GoL 2015). Despite these linkages, the SIA fails to consider whether the construction of the dam is likely to have any ramifications relating to expanded areas of plantations, and whether or not this could impact on the people in the area.

The SIA acknowledges that there will be impacts on the amount of productive agricultural land because of inundation in the upstream areas. However it glosses over how this will be dealt with. In one section it places the responsibility on the Lao government to ensure the improved agricultural capacity of the remaining land so that communities can be food secure. In another section it acknowledges a requirement to establish community development funds for dislocated communities, and recommends that some of these funds be used to invest in sustainable agriculture for those who lose farmland as a result of the project. However, the loss of farmland is likely to be more widespread than just resettled communities. Changes in river flows are likely to result in downstream bank erosion over time, as well as loss of fertilisation through sedimentation.

Despite the rhetoric in the SIA about people maintaining their livelihoods from their own perspective, there are a variety of pressures that mean this is unlikely to occur. This can be seen in the SIA mitigation option for loss of farmland: that funds set aside from project profits can be invested in sustainable agriculture. Sustainable agriculture is a worthy ideal, however traditional shifting agriculture practices allowed lands to lie fallow for upwards of seven years, allowing lands to recover their natural productivity, and this was a sustainable form of agriculture (Cairns 2017). Thus, ideas around sustainable agriculture should be explained and elaborated on, including consideration of why local government officials find it difficult to encourage local farmers to shift to different methods of farming.

Just as agriculture links closely to people's food security in the region, so does fishing. Because people rely on fish to buffer their diets, the reported difference between the upstream communities and downstream communities indicated in the SIA (that upstream fishing is only done on a small scale, but downstream it is a way of life) do not seem plausible. Another reason to question the SIA's observation in this regard is that the geography in the two regions is similar, with the Mekong flowing down a narrow, rocky incised valley and so the dam site is unlikely to mark a distinct difference in livelihoods of this nature.

The SIA suggests that fishing is only practiced on a small scale in the upstream area, however scientific assessments based on consumption levels indicate that the capture fisheries account for between 40,000 and 60,000 tonnes of fish caught per year in the Mekong mainstream between Chiang Sean and Luang Prabang. While the population density in the dam's impact zones is much less than the population density closer to Chiang Sean, assuming a relatively even per capita consumption of fish along the river suggests that around 15% of the 40 – 60,000 tonnes is caught in the dam's impact zones. This amounts to around 6,000 – 9,000 tonnes of annual fish capture over both the upstream and downstream areas, or 3,500 – 5,000 tonnes in the upstream impact zone alone.

In another example of the SIA glossing over networked activities, the observation in the SIA that most fishing done upstream of the dam happens outside the Mekong mainstream appears valid as a standalone argument, however, there is substantial literature that discusses the importance of the deep pools as habitats for mature fish, while the range of juveniles is much broader. For example, juveniles are often found in flood plains during the wet season. In essence, the SIA does not consider the ecological networks that link tributaries and ponds to the Mekong mainstream. The SIA also indicates that there are no endemic species in the up or downstream sections of the Mekong. However, in contrast, the findings in the fish section of the baseline report of this study found seven endemic species in the Mekong mainstream between Xieng Kok and Xayabury. While this is not problematic of itself, it suggests that the research for the part of the report that makes this claim may be incomplete.

There are a number of elements of the argument presented in the SIA about improved fishing grounds in the reservoir that need to be considered. First, the rich fishing grounds in the reservoir. A number of authors have argued that water reservoirs do increase local fish production. For example, Baran *et al.* (2007) cites Bernacsek's (1997) equation to predict the catch in a reservoir. The equation's variables include the reservoir surface area, the average depth and the inflow. Baran *et al.* (2007) does not take issue with the broad applicability of the equation, but does point out that loss in wild fish production is not taken into account, and also shows that reservoir fish catches would be likely to increase over the first 5 – 10 years, but would then decline. Secondly, the authors of the SIA argued that downstream communities, who live on around US$1 per day, could do their fishing in the reservoir. People living on the poverty line are not likely to be able to bear the expense and effort of travelling up to 100km in order to catch fish for household consumption. On top of this, as pointed out by Baran *et al.* (2007), there are issues around access rights that could make it even more difficult for downstream communities to profit from the presumed upstream bounty. Even the SIA itself suggests consideration of ensuring that communities near the reservoir be granted exclusive access.

The SIA also suggests that aquaculture can be used to replace fish stocks that are lost as a result of dam construction, however using aquaculture as a mitigation option should be modelled rather than just assumed. This is because, for example, aquaculture relies heavily on capture fisheries to supply larvae and fry (Baran *et al.* 2007). With regards to fish there are a number of considerations that need to be addressed so that poor and vulnerable groups, including ethnic minority groups, do not have their food security put at risk.

With regards to changing patterns of trade associated with the dam and linked infrastructure and development works, the SIA outlines the number and size of vessels that the dam's ship lock will be able to accommodate. The SIA does not, however, consider any social impacts that are likely to result from the increased size or number of vessels on the river. Some of the key potential impacts that are not discussed in the SIA include:

8. Wakes from increased large vessel traffic leading to river-bank erosion, and hence a likely loss of riparian farmland.
    8.1. This is likely to impact on food security, especially for ethnic minority and other poor communities who rely on river bank areas for vegetable gardening or subsistence farming.
9. More ships crews and passengers are likely to lead to more organic pollutants (waste water) entering the river.
    9.1. The increased pollutants may result in increasing levels of food- and water-borne illnesses such as acute watery diarrhoea, which is already a chief complaint in the area.
10. Increased large vessel traffic provides a larger capacity for carrying produce from plantations, as well as logs and other timber.
    10.1. This will make it likely that there will be increased pressure on poor and ethnic minority communities to relinquish their customary lands, as outside investors apply for land concessions in the area.
11. Construction of the dam will almost certainly link to road upgrades spreading out from the dam site and Pak Beng dam (The SIA paints the consequences of upgraded road infrastructure in a positive light, but does not consider the more far reaching possibilities that are likely to be associated with improved transport).
    11.1. The road upgrades are very likely to facilitate further expansion of logging and plantation concessions, and wildlife trade, spreading the impact described in 3.1 far beyond the banks of the river.

The information provided in the SIA with regard to livelihood resources for the upstream affected population is limited to half a page, and is quite generic and vague. For example, the SIA observed that fishing can be done in the Mekong and its tributaries, in ponds and in paddy fields, but does not link this to peoples’ livelihoods, or discuss how reliant the population in the impact zone is on fish.

The SIA only considers riparian communities. While the report does not define what is meant by riparian, the number of villages discussed suggests that they are referring to communities living on the actual river banks, and that those villages and communities inland from the river are not considered. Additionally, there is no consideration of villages and communities who live along the transport corridors that link Pak Beng dam site to other parts of Laos and into neighbouring countries. For example, it is very likely that there will be much heavier traffic on the road between Pak Beng town and Muang Xay during the dam construction, which will mean a higher risk of traffic accidents and pedestrians being injured and killed. The heavier traffic could also provide economic opportunities for villages along the corridor (e.g. establishing restaurants and roadside markets), and the improved road is likely to attract investors seeking land concessions.

There are a number of significant differences reported between the communities up and downstream from the dam site, include average incomes. These are reported as being US$0.49/person/day for upstream communities, and in a range between US$0.82 and US$1.09/person/day for downstream communities. While the numbers of people in the surveys are small, and so the differences in income are not necessarily unreasonable, an explanation of why the downstream population have a higher income may provide some insights into how the different communities will be able to cope with changes wrought by the dam’s construction.

In another example of lack of consideration of flow-on impacts, while the SIA expects that there will be increased demand for accommodation, food and entertainment in the vicinity of the dam site, it does not consider what this means in terms of the towns where this will be provided. For example, the need for towns with a small population to accommodate hundreds or thousands of workers means that new buildings, new sanitation facilities, and probably new roads will need to be built. This will mean more workers coming in, construction noise and dust in the towns and increased traffic on the roads. If town expansion is not planned ahead of time, slums are likely to develop with poor sanitation services that will lead to higher rates of water- and food- borne diseases. Lack of waste disposal mechanisms in slums would also be likely to result in increased vector-borne disease rates. Slums and under-employment are also frequently associated with increased alcohol consumption, gambling and violence (see e.g. Bass *et al.* 2018).

Another important aspect of the economy in the region is forested areas particularly because subsistence farmers rely on non-timber forest products to help ensure their food security. Forests face a variety of threats such as logging, plantations and swidden agriculture. It is however, difficult to measure what is happening to forests in the region because of a lack of formal surveys of encroachments into forests, meaning there is no robust baseline data. Without accurate baseline data monitoring changes to the forests, and understanding their causes, becomes very challenging. Without this knowledge, it becomes much more challenging to plan support for ethnic minorities, subsistence farmers and other poor groups of people to adapt and adjust to the forest-related impacts associated with the dam and hydropower project.

With regard to forests, the SIA only discusses the immediate impacts of the dam, such as that the reservoir will inundate 2,964 Ha. of forest lands. It does mention that agricultural expansion and illegal logging are degrading forests, but it does not make any connection to likely or possible deforestation or forest degradation that may result from the dam or other infrastructure that is put in place or upgraded as a result of the dam's construction. For example, there are likely to be road upgrades to places including Muang Xay, Muang Ngeun and Pak Tha. Improved roads to these locations will increase the attractiveness of the area, to investors, for logging and agricultural plantations, particularly along the road corridors. It is worth noting that examination of satellite imagery shows large cleared areas of land on the Lao-Thai border at Muang Ngeun, which are probably either mining or logging areas. In the face of added incentives for companies to seek land concessions, it is very likely that communities in those areas will face pressure to relinquish their customary lands. Local authorities are very likely to add their support to this pressure, because growth in agri-business is a national policy, even though it is recognised as being linked to undermining the food security of poor people including ethnic minorities (e.g. MAF 2010). In addition to development along the road corridors, there is very likely to be expansion of the towns near the dam site, with more shops, more hotels, and a likely growth in the number of residents as people come looking for work and other opportunities.

7.5.3 *Impacts Analysis*

As has already been noted, the impact analysis in the SIA focuses exclusively on direct impacts, and ignores many indirect impacts that have a high likelihood of exacerbating income gaps and further disadvantaging poor and vulnerable communities, including ethnic minority groups. In addition, the impacts described are not well linked to the baseline reporting, are generally poorly explained and little attempt has been made to quantify, or in some cases even to describe, the impacts. For example, in relation to the construction phase of the project one of the projected impacts relates to in-migration. The point just says, "In-migration – the in-migration of job seekers/construction workers can cause a great deal of change. Overall this is a negative impact and is expected to be of medium Significance" (Kunming Engineering Corporation Limited 2015, p. 7-8). While the report indicates that there will be 3,000 – 4,000 workers for the construction, the details of job seekers are not detailed. Some of the questions this raises are: 1) Is it likely that there will be more job seekers than jobs? 2) If so, have the potential impacts of an influx of unemployed (predominantly) young men been considered? 3) Will unemployed job seekers remain in the project area hoping for work, or will they return to their places of origin? 4) Is it likely that an influx of unemployed youth could lead to additional crime in the area? 5) Are gangs likely to form?

While the report acknowledges that customary land rights predominate in rural areas, there is no discussion in the report of the implications of lack of legal title to land, or possibilities for poor people (including ethnic minorities) to be pressured to give up their customary rights to land within the scope of government encouragement for those currently practicing shifting cultivation to modernize. In 2003 the Lao government ratified amendments in the Land Law which allow for individuals and other entities to have "permanent land use rights" in the country (GoL 2003, Article 49). Titling land for the poorest and most vulnerable people will provide them with added protection and rights in the case that investors pressure them to make livelihood changes such as giving up their traditional attachment to the land and becoming waged labourers on plantations.

The SIA does allude to a grievance procedure at several points but does not provide any detail on who is responsible for the process or how it is supposed to work. Relatedly, Cada *et al.* (2017) noted that while the resettlement action plan recommends that a formal grievance procedure be established, that evidence from other similar projects highlights that vulnerable groups are reluctant to make use of formal, government processes to lodge complaints about experiences such as unfair treatment.

The impacts that the SIA does not consider, or only considers very superficially are detailed below, divided into three causal areas: 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. The impacts described below assume that no attempt has been made to mitigate negative impacts or to enhance positive impacts. The impacts are divided into the three causal areas:

Increased number and size of boats on the river

The construction of Pak Beng dam is planned to be accompanied by the implementation of the LMDP, as can be seen by the size of the ship lock that has been included in the dam design. The lock will be capable of facilitating transport of boats of 500 tons, up to a total of 1.5 million tons of shipping each year. This volume and size of boat traffic will have a number of implications:

1. The Pak Beng dam is **likely** to be associated with the LMDP navigation upgrades:
    - 1.1. Increased large vessel traffic has the **potential** to result in more boat accidents, particularly as those living in the area currently rely on small boats for transport.
    - 1.2. Wakes from increased large vessel traffic **will** lead to river-bank erosion, and hence a likely loss of riparian farmland:
        - 1.2.1. This is **likely** to impact on food security, especially for ethnic minority and other poor communities who rely on river bank areas for vegetable gardening or subsistence farming.
2. More ships crews and passengers are **likely** to lead to more organic pollutants (waste water) entering the river:
    - 2.1. The increased pollutants have the **potential** to result in increasing levels of food- and water-borne illnesses such as acute watery diarrhoea, which is already a chief complaint in the area:
        - 2.1.1. Increases in food- and water-borne diseases are **likely** to disproportionately affect poor and vulnerable people:
            - 2.1.1.1. There is the **potential** for poor and vulnerable households to be driven into poverty because of a need to pay for medical care as well as degraded ability to work.
3. Increased large vessel traffic provides a larger capacity for carrying produce from plantations, as well as logs and other timber:

3.1. This makes it **likely** that there will be increased pressure on poor and ethnic minority communities to relinquish their customary lands, as outside investors apply for land concessions in the area:

3.1.1.1. There is **potential** for loss of traditional life-style practices.

3.1.1.2. There is **potential** for loss of food security as households become dependent on mono-crops and the fluctuations of world price markets.

3.1.1.3. There is **potential** for communities to improve their lives because they have a more consistent income and can enhance their engagement with the market economy (but this is more likely if they are not pressured to give up their lands).

Associated infrastructure upgrades

A project the size of Pak Beng dam will almost certainly be associated with improved infrastructure such as roads that link the site to other areas. This will facilitate transport of construction materials and personnel for the dam itself, as well as supporting likely growth in nearby towns such as Pak Beng and Pak Ngeui. For example, it is very likely that existing roads to towns including Muang Xay, Muang Ngeun and Pak Tha will be upgraded. This is particularly the case because the Lao government is promoting modern industrialised agriculture as part of the country's national development planning (MAF 2010), and road upgrades will support moves away from traditional shifting agriculture, by providing farmers with access to agricultural inputs and markets, thus facilitating the integration of remote rural populations into modern market-oriented ways of living.

4. Construction of the dam will be **very likely** lead to road upgrades spreading out from the dam site:

4.1. It is **likely** that there will be large numbers of inexperienced users of the roads, particularly when they are first upgraded/constructed:

4.1.1. There is a **potential** for higher rates of traffic accidents resulting in injuries and fatalities.

4.2. With improved roads, as well as the improved port facilities and improved navigation of the river, the study area **will** become significantly more attractive to foreign investors, for agricultural, logging and other types of land concessions:

4.2.1. Thus, there it is **very likely** that there will be further expansion of logging and plantation concessions, as well as wildlife trade:

4.2.2. Along the river as well as the upgraded roads leading away from the Pak Beng dam site, it is **likely** that poor and ethnic minority communities will face increasing pressure to relinquish their customary lands, as outside investors apply for land concessions in the area:

4.2.2.1. There is **potential** for loss of traditional life-style practices.

4.2.2.2. There is **potential** for loss of food security as households become dependent on mono-crops and the fluctuations of world price markets.

4.2.2.3. There is **potential** for communities to improve their lives through access to more consistent income, and can enhance their engagement with the market economy (but this is more likely if they are not pressured to give up their lands).

4.3. Improved roads are **likely** to benefit farmers who sell part of all of their produce, through better access to inputs as well as to markets.

4.4. Improved roads has the **potential** to improve communications between riparian villages, and thus strengthening social networks.

Social dynamics creating follow-on impacts

The influx of 3,000 – 4,000 workers, as well as other job seekers will have major impacts on the nearby towns including Pak Beng and Pak Ngeui.

5. The large number of paid workers **will** attract entrepreneurs as well as criminals, thus the population growth **very likely** to be significantly higher just those attracted directly by dam-related employment opportunities:
   5.1. There is **likely to** be more gambling, and more alcohol/substance abuse.
   5.2. It is **likely** that levels of violence/civil disturbances will increase.
   5.3. It is **likely** that gangs will form.
   5.4. It is **likely** that there will be a growth in prostitution.
   5.5. It is **likely** that there will be increased rates of sexually transmitted diseases.
6. New accommodation, restaurants/eateries and shops **will** be constructed to house and feed both those directly employed by the project, as well as entrepreneurs who have come to take advantage of the money making opportunities:
   6.1. There are l**ikely** to be employment opportunities in construction and services sectors.
7. 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)

7.6 RECCOMMENDATIONS FOR IMPROVING THE SIA

Following the critique of the SIA, a number of recommendations are provided below on the need for more information to fill existing gaps in the report, where additional considerations should be explored, as well options for supporting local authorities to prepare for socio economic changes. In particular, the baseline data provided in the SIA is insufficient for an analysis of the impacts on the local communities. Linked to this, the SIA needs to supply much more detail on the expected impacts and how each impact ratings was derived or calculated. The SIA also relies on lessons from previous hydropower projects in Lao to guide its analysis, however as observed by Cada *et al.* (2017), it is now widely acknowledged that the Nam Theun 2 dam livelihoods restoration schemes have largely failed affected communities.

Information related recommendations

- More detail needs to be provided about the community development funds that the SIA says will be established. Details should include:
  - Where the money for these funds will come from, including the algorithms that will be used to calculate deposits.
  - Whether community development funds will be established for each village separately or for all the affected communities together or some other division.
  - How the community development funds will be managed, including any auditing requirements.
  - How the money will be used, including any required approval processes to withdraw/spend money from the funds.
- A need for better 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. See http://www.thepovertyline.net/laos/). The results of these surveys should be used to structure the interventions that will help communities maintain their livelihoods.
    - These surveys must do more than just detail the numbers of women, children and the number of people from each ethnic group. Rather, information needs to be collected on the roles of women and children within households and society, disaggregated by ethnicity. For example, the questioning should be designed to elicit information on areas including:
        - The primary factors (including cultural factors) that preclude girls from going to school within each village.
        - household level income levels as well as food security options and alternatives.
        - Current individual household level land use for farming, livestock grazing and collection of non timber forest products.
    - The survey data collected should inform targeted interventions that support communities to pursue their desired lifestyle and to offer them changes at a rate that is suitable for them.
    - There should be explicit provisions included in the SIA to ensure that local communities are able to maintain their livelihoods from their own perspective. For example, local communities should be offered opportunities related to transitioning away from rice-fed rain to other crops, rather than just being informed what will happen.
- Collecting population data and livelihoods information at the household level, disaggregated by ethnicity for the 25 upstream villages.

  Survey data should be used to prioritise support for those at risk of productive land loss due to flooding, bank erosion (for example, during the construction stage when the river is constricted at the dam site) or loss of sedimentation. Factors used to prioritise support should be level of vulnerability (based on both household income and level of reliance on subsistence farming), and likelihood of exposure to loss of productive land.

- 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.

  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.

- 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.
- The impacts listed in the impacts analysis section of this critique should be considered in conjunction with those in the SIA, in order to develop a comprehensive mitigation action plan that will safeguard the livelihoods and well-being of the directly and indirectly affected communities.
- Review of the grievance procedures, which are alluded to, but for which no details are provided, in the SIA. Ensure that grievance process systems are developed in detail and that they are suitable and appropriate for use by the local communities (i.e. that people who feel they have been wronged will be comfortable making use of the established grievance procedures).
- Baseline data should be gathered on existing forests and forest encroachments, as this will assist with mapping socio economic changes in the area as well as for monitoring and controlling legal and illegal logging and plantations that are likely to develop as a result of improved infrastructure.

Consideration related recommendations

- Better consideration of the impacts on downstream communities, 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 socio economic 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).
    - Official, permanent titling of land should be conducted in the area prior to the project commencing, as per clause 49 in the amended Land Law (GoL 2003). Poor and rural communities should be prioritised in land titling, as this will support them to maintain their livelihoods from their own perspective (e.g. They can choose to lease or sell the land to which they hold the title to a company seeking land concessions, but they are also in a stronger position to resist pressure to relinquish their title).

Town planning related recommendations

- 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 these towns currently have the planning capacity to map out a desirable future incorporating a thousand or more additional residents.
- 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 or tourism services or eateries.

7.7 CONCLUSION

The SIA conducted for the Pak Beng dam includes several positive elements, and also has a number of key weaknesses. The strengths of the SIA include the village level surveys that were conducted in 18 riparian communities, and which describe the ethnicities that live in those villages, a brief history (for example, how the village came to be located in that situation). Another positive aspect is that the SIA seeks to cover all the relevant topics related to the planning, construction and operation of a hydropower dam on the Mekong mainstream at Pak Beng.

Despite this, the SIA report is somewhat top-heavy. The first 87 pages of the document includes a lot of information on government and other policies (such as the World Bank's operational manual for indigenous people), but does not link these to the treatment and analysis of communities and their circumstances either the upstream or downstream of the dam site. The provincial and district socio-economic condition description does not begin until the 88th page of the 192 page document. Possibly as a result of being top-heavy in this way, the impact assessment and analysis appear quite superficial and only cover the immediate socio-economic impacts, without considering likely and possible subsequent follow-up impacts. Examples of the superficiality can be seen in section 5.1.6 of the report, on livelihood resources for the upstream communities. This section is just 150 words long, providing single sentence overviews of rice growing, the workforce, fishing, non-timber forest products and encroachments on forest areas. The lack of consideration of the multiple layers of socio-economic impacts can be seen in the impact analysis for the construction phase of the dam. The SIA mentions possible prostitution and alcohol related impacts that may result from having 3,000-4,000 temporary workers living and working at the dam site, but does not consider the extended impacts in nearby towns, as merchants move in to supply groceries and alcohol, building new shops and residences, and whether or not the local governments have the capacities and resources to adequately manage and plan for the expansion of the towns in their jurisdictions, such as Pak Beng and Pak Ngeui.

Viewing satellite imagery of the upstream area between the dam site and Pak Tha suggests that at least 24 village communities are located in the upstream area. However, while the SIA lists 25 upstream villages, only the eight communities that will be directly affected by the reservoir (ie. that will need to be resettled or relocated within the same village area) are discussed in any detail. The SIA report also glosses over many important challenges such as how loss of productive agricultural river bank land will be replaced, or how the conclusion was reached that there were limited fish in the Mekong River upstream from the dam site. Finally, the SIA relies on what it describes as lessons learnt from other hydropower projects despite a broad acknowledgement, for example, that the livelihoods of affected communities near Nam Theun 2 hydropower dam have not been effectively safeguarded.

As it stands, there are too many vagaries which undermine the mitigation suggestions for affected communities, a reliance on previous hydropower project experiences (that have failed local communities), as well as a reliance on untested assumptions. Factoring in the items included in the list of recommendations above, will help ameliorate the consequences of the dam. However, realistically, a new SIA should be conducted, taking into account more recent information as well as the indirect effects of the dam that will range far beyond the geographical bounds of the existing SIA.

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