THE MEKONG RIVER COMMISSION SECRETARIAT

Strategic Directions for Integrated Flood Risk Management in Focal Areas

The Flood Management and Mitigation Programme, Component 2: Structural Measures & Flood Proofing in the Lower Mekong Basin

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CONTENTS

CHAPTER 1

INTRODUCTION

1 INTRODUCTION

1.1 Guide to the reporting structure of the Flood Management and Mitigation Programme - Component 2, Structural Measures and Flood Proofing

Component 2 on Structural Measures and Flood Proofing of the Mekong River Commission's Flood Management and Mitigation Programme was implemented from September 2007 till January 2010 under a consultancy services contract between MRCS and Royal Haskoning in association with Deltares and Unesco-IHE. The Implementation was in three stages, an Inception Phase, and two Implementation Stages. During each stage a series of outputs was delivered and discussed with the MRC, the National Mekong Committees and line agencies of the four MRC member countries. A part of Component 2 - on 'Roads and Floods' - was implemented by the Delft Cluster under a separate contract with MRC. Component 2 prepared five Demonstration Projects which have been reported separate from the main products.

The consultancy services contract for Component 2 specifies in general terms that, in addition to a Final Report, four main products are to be delivered. Hence, the reports produced at the end of Component 2 are structured as follows:

Volume 1 **Final Report**

Volume 2 **Characteristics of Flooding in the Lower Mekong Basin**
Volume 2A *Hydrological and Flood Hazards in the Lower Mekong Basin;*
Volume 2B *Hydrological and Flood Hazards in Focal Areas;*
Volume 2C *Flood Damages, Benefits and Flood Risk in Focal Areas;*
Volume 2D *Strategic Directions for Integrated Flood Risk Management in Focal Areas.*

Volume 3 **Best Practice Guidelines for Integrated Flood Risk Management**
Volume 3A *Best Practice Guidelines for Flood Risk Assessment;*
Volume 3B *Best Practice Guidelines for Integrated Flood Risk Management Planning and Impact Evaluation;*
Volume 3C *Best Practice Guidelines for Structural Measures and Flood Proofing;*
Volume 3D *Best Practice Guidelines for Integrated Flood Risk Management in Basin Development Planning;*
Volume 3E *Best Practice Guidelines for the Integrated Planning and Design of Economically Sound and Environmentally Friendly Roads in the Mekong Floodplains of Cambodia and Vietnam*[1]*.*

Volume 4 **Project development and Implementation Plan**

Volume 5 **Capacity Building and Training Plan**

Demonstration Projects
Volume 6A *Flood Risk Assessment in the Nam Mae Kok Basin, Thailand;*
Volume 6B *Integrated Flood Risk Management Plan for the Lower Xe Bangfai Basin, Lao PDR;*
Volume 6C *Integrated Flood Risk Management Plan for the West Bassac Area, Cambodia;*
Volume 6D *Flood Protection Criteria for the Mekong Delta, Vietnam;*
Volume 6E *Flood Risk Management in the Border Zone between Cambodia and Vietnam.*

The underlying report is **Volume 3A** of the above series.

[1] Developed by the Delft Cluster

1.2 Strategic directions for integrated flood risk management in focal areas

At the end of the Inception Phase of the FMMP-C2 a number of focal areas were selected for which strategic directions for flood risk management were to be developed during the Stage 1 Implementation Phase.

The focal areas that were selected for this planning exercise are:
1. The lower Nam Kok basin in Thailand;
2. The lower Se Bang Fai basin in the Lao PDR;
3. The Upper Se San basin in Vietnam
4. The transboundary Mekong Delta area on the right bank of the Bassac
5. The transboundary Mekong Delta area on the left bank of the Mekong.

The analysis for the Nam Mae Kok basin was delayed and could only partly be completed in Stage 2 due to issues with the hydraulic model of the basin.

Two other focal areas (Bokeo in Lao PDR and Kratie in Cambodia) refer to areas where bank protection is the main issue, rather than flooding.

For the upper Se San basin it was found that the target area (Kontum) is barely at risk and that flood risk reduction should focus on vulnerability reduction in areas upstream of Kontum rather than on structural measures to reduce the flood hazards at Kontum.

For the formulation of the strategic directions for flood risk management in the above mentioned focal areas the following approach was developed:
1. Assessment of the flood risks for the actual situation;
2. Formulation of flood risk management measures;
3. Estimates of impacts of the flood risk management measures.

For the assessment of the flood risks in these areas reference is made to Volume 2B for the flood hazard part and Volume 2C for the flood damage and risk analysus part.

It is noted that the *acceptability* of the assessed flood risks in the focal areas has not been evaluated. Such evaluation would require an extensive consultation and political decision making process, especially when it comes to the assessment of the acceptability of the risk of loss of live and other intangible consequences of the floods. Such consultation and decision making process cannot be carried out in the framework of the FMMP-C2.

What has been achieved, though, is to illustrate to what extent flood risks can be reduced and whether the measures that are required to achieve the risk reduction can be justified from a socio-economic and environmental point of view.

Structural flood risk reduction measures aiming at flood protection may create benefits that go beyond the reduction of the existing flood risk. Such measures may allow for a more attractive land use than the actual one, generating more potential benefits. It is deemed essential to keep these potential developments in mind when evaluating the socio-economic impacts of flood risk reduction measures.

It is not the intention to asses under the FMMP-C2 the most attractive land use in the flood prone focal areas. For the socio-economic evaluation, though, of the flood risk management measures, assumptions are made regarding potential land use in the areas once protected against floods. These land use scenarios are indicative only and should be re-evaluated in the framework of integrated land and water resources management in the respective areas.

CHAPTER 2

STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE LOWER SE BANG FAI FOCAL AREA

2 STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE LOWER SE BANG FAI FOCAL AREA

2.1 Flood damages and risks

The Se Bang Fai floodplain, downstream of the crossing with Road 13, experiences flooding problems during the rainy season nearly every year.

Four districts in the Khammouane Province, Thakhek, Nongbok, Mahaxay, Se Bang Fai, are prone to flooding, as well as 1 district in Savannakhet Province: Xaybouly. More than 80% of the flooding is caused by overflow from the Se Bang Fai River. A second cause of flooding is improper drainage of the area after heavy rain. Drainage canals and other infrastructure (gates) to discharge the water out of the area into the Se Bang Fai or the Mekong River are absent or in a poor condition. Finally, backwater of the Mekong River occasionally causes indirect flooding in the area. When the water in the Se Bang Fai River exceeds a certain water level, backwater from high discharges in the Mekong River cause a reverse flow and flooding of up to 1.5 meters occurs in the lower areas. Flooding generally starts between the end of July and September, and normally last between 15 and 30 days. Most of the area flooded is used for agricultural purposes. A comprehensive description of the flood hazard is given the Volume 2B.

On the basis of the results of the socio-economic survey carried out in the Nongbok district flood damage and flood risk assessments have been made for this district as presented in the Volume 2C. The risk in this district under the actual land use conditions has been estimated at some USD 3 million per year. Extrapolating the results of the Nongbok district to the flood prone area downstream of the national Road 13, it is estimated that the flood risk in the lower Se Bang Fai area is of the order of USD 6 mln per year. 90% if this risk is related to agricultural damages.

It is noted that this estimated risk refers to the actual land use and does not take into account a more intensive land use that may develop in case the flood hazard in the area is reduced.

2.2 Flood benefits

Apart from the negative impacts of flooding as mentioned above, floods also have positive impacts on the social economy such as natural fishing and soil fertility. Results from focus group discussions held in focal areas[2] showed that benefits from natural fishing for people living flooded areas vary from 150-3,200 US$/household in normal flood years to US$ 290-6,400 for big flood years. The fishing is mainly from river and creeks.

According to the MRC-Technical Paper[3] on fish yields, the data for typical yields of fish in paddy fields in Lao is limited. However, it is reasonable to expect that the fish yield in Lao would be lower than in the Cambodian and Vietnamese flood plains. The lower limits of natural fish in Cambodia and Vietnam were 55-80 kg/ha. The flood plain in Se Bang Fai is under rainy seasonal paddy from June-October, with much shorter flooding duration compared to flood plains in Cambodia and Vietnam. It is estimated that the fish yield would be about 20 kg/ha, resulting in the value of 6 US$/ha. Farmers in the studied area said that there are no flooding benefit to agriculture in terms of sedimentation and soil fertility, acidity leaching and pest control to the land.

[2] See Volume 2C for detailed analysis of the focal group discussions

[3] MRC-Technical Paper, No:16, October 2007:Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin

2.3 Structural flood risk management options

The reduction of the flood risk can be achieved by either the reduction of the flood hazard with the help of structural measures, the reduction of the vulnerability or a combination of both.

The flood risk in the lower Se Bang Fai is mostly due to agricultural damages. Reduction of vulnerability is therefore most effective if the vulnerability of the agricultural production is reduced. This can be done by adapting the cropping pattern to the flood regime and/or the introduction of more flood resistant crops.

It is assumed that the actual cropping pattern is already optimally adjusted to the flood regime (traditional coping mechanism) and that further vulnerability reduction is to be sought in the use and/or development of less vulnerable varieties.

The reduction of the flood hazard in the lower Se Bang Fai area can in principle be achieved by:

1. The creation of flood retention capacity in or upstream of the flood prone area. Such measure allows for the reduction of the Se Bang Fai peak discharges and, consequently of the peak water levels in the river and adjacent floodplains.
2. The creation of additional discharge capacity of the river system. Such measure will reduce the peak water levels. The discharge capacity can be increased by deepening and or widening of the river itself or by creating additional capacity in a diversion and/or by-pass channel.
3. The construction of diking schemes that protect selected areas against high water levels.
4. The construction of gates to prevent or to control flood waters to enter the Se Bang Fai floodplains;
5. The improvement of the drainage system in the flood plains, allowing for a reduction of the duration of the flooding. Further reduction of the duration of flooding can be obtained by the installation of gated structures at the locations where the (natural) drainage system of the flood plains drains into the Se Bang Fai or the Mekong river.
6. The construction of a diiversion or by-pass canal from the Xe bangfai to the Mekong.

Regarding the creation of flood retention capacity upstream of the flood prone area, a project idea was identified concerning the construction of a flood storage reservoir in the Se Bang Fai at the confluence with the Xe Noy, just upstream of the Road 13 crossing, combined with construction of a flood gate in the Se Bang Fai mouth. This option has been discarded for reasons of far-reaching resettlement needs of the implementation of such option.

Under the actual conditions the floodplains have their own natural retention capacity. The creation / reservation of retention capacity in the flood prone area is, therefore, only relevant in combination with the implementation of diking schemes. In that case, part of the flood plain can be protected while another part is reserved for the retention of flood waters.

For the creation of additional discharge capacity, reference is made to previous studies on the flood diversion channel "Xelat" from Banne Sokbo to Banne.

Diking schemes for flood protection can be considered at several levels, from the so-called mini-polders to a full protection of the flood plains on both sides of the river downstream of the NR 13. Mini-polders refer to the protection of isolated areas in the order of 1,000 ha each. For the right bank of the lower Sebanfai (Nongbok) plans have been developed for polders from 3,000 ha to almost 10,000 ha. However, consultation of the stakeholders revealed that they prefer embankments that protect the whole area.

At the Nongbok district level, ideas have developed that focus on drainage improvement rather than on flood protection. A number of 23 schemes have been identified for widening and deepening (natural) drains to be provided with gates at the confluence with Se Bang Fai or Mekong. These schemes try to achieve a reduction of the inundation time of flooded area to 15 days or less. Some of the schemes already exist but need rehabilitation and/or improvement.

From the Demonstartion Project the develop an Integrated Flood Risk Management Plan for the Lower Xe Bangfai area it is concluded that substantial reduction of the existing risk can be achieved by reduction of the duration of flooding. Hence, flooding would not be eliminated completely in order to preserve the important wetland areas and fisheries benefits. Controlled flooding can be used in that approach.

The option of embankments along the river banks and controlled flooding with drainage improvement in combination with gating of the small Xe Bangfai tributaries can be attractive to achieve this goal.

2.4 Impacts of structural flood risk management options

2.4.1 Flood risk reduction

The flood risk in the Nongbok district was estimated with the help of the results of the existing ISIS model, which has a number of shortcomings as explained in Volumes 2A and 2B. The risk assessment was done for the situation in which both sides of the lower Se Bang Fai (Nongbok and Savannakhet) are unprotected.

Despite the shortcomings of the hydraulic ISIS model, an attempt has been made to simulate the impact of the diking and diversion options on the flood hazard in the lower Se Bang Fai. The results are given in appendix 3 to Volume 2B and in Volume 6B, ythe Demonstration Project on the preparation of an Integrated Flood Risk Management Plan for the lower part of the basin. New risk estimates have been made with the help of these simulation results for the diking option only. Four scenarios have been considered:

1. Scenario 1: the base case , i.e. without further embankment construction;
2. Scenario 2: Left bank embankment to protect areas in Savannakhet province;
3. Scenario 3: Embankment on both banks of the Se Bang Fai river.
4. Scenario 4: a diversion canal from the Se bang fai, dowstream of ban Se Bangfai, to the Mekong river.

The Scenario 2 has largely been implemented since 2002 but it is likely that the embankment was designed for a probability of exceedance of 15% only. The flood assessment for this scenario indicates that diking of the Savannakhet bank has given a 0.1-0.2 m extra flooding depth in the Nongbok area. This corresponds with an **increase of the flooding risk** in the order of 0.04 million USD per year.

Under Scenario 3, a **flood risk reduction** of 3 million USD per year has been calculated for Nongbok. However, protection of the Nongbok floodplains would create a loss of natural fish in this area in the order of 0.1 million USD per year. Further investigations in the demonstration project showed that also taking into account the risk at the Savannakhet side and for a probability of exceedance of 1%, total risk reduction would be USD 6 mln per year.

Scenario 4, is very effective from a hydraulic point of view, an optimal canal bottom width of some 125m have been reseached in the framework of the Demonstration Project. In economic terms the diversion channel together with (lower) embankments is some 12% more costly.

2.4.2 Environmental impacts

The seasonally inundated Lower Se Bang Fai floodplain is a sensitive and valuable ecosystem. It consists of a mosaic of fresh water lakes, river ponds, rice paddy and fresh water marshes. Close to the river there are several old river channels with oxbow lakes, that silted up and form fairly large marshes. Although not much is known about the flora and fauna species present in the area, it is to be assumed that these areas are important habitats for fish and water birds. The wetlands are also important as refuges for 'Black fish' in the dry season and as spawning and nursing areas for both 'Black' and 'White fish' in the flood season.

No officially protected areas are located in Se Bang Fai plain, however, BirdLife International on it's website mentions an Important Bird Area (IBA) located in the area. Details are not known at present.

Population in the project area is concentrated along the river and in villages located on the higher old levees in the floodplain, where densities are considerable. The river is an important source of water for domestic use.

Paddy rice is the main crop in the area, while the banks of the Se Bang Fai River are intensively used for the production of fruits, vegetables and cash crops like tobacco. Fisheries is important in the flood season. It is a source of food and additional income for a substantial part of the population.

Potential environmental impacts of structural flood risk management measures are:

1 Destruction of natural habitats, valuable resources

1.1 Provision of full flood protection, keeping out the floods, will have a detrimental effect on the wetland habitats, the more so when combined with improved drainage. A large proportion of the wetlands will dry out and the floral species composition will change drastically. This will have a negative impact on the value of these ecosystems as a habitat for wetland dependent fish and birds, they will decrease greatly in numbers or disappear completely. When not flooded anymore, the function of the floodplain as a dry season refuge for 'Black fish' and a wet season fish spawning and nursing area (for both 'Black' and 'White fish') will be lost.

1.2 Indirect impacts of reduced flooding will also be considerable. Better protection of the area will increase the value of the land for agricultural production and hence will increase the pressure on the presently not-cultivated areas.

1.3 Other important habitats in the project area are pools and slow water stretches in the river. These are not expected to be affected by the project.

2 Loss of biodiversity, rare and endangered species

2.1 Reduced flooding will have a significant negative impact on the biodiversity in the area. Species composition of flora and fauna will change and the diversity and extent of water bodies and swamps in the floodplain will decrease. Sixty-seven fish species have been recorded in the lower Xe Bang Fai. No endemic species were among these. Most of the recorded species are highly migratory. Adults and juveniles spend the dry season in deep refuge pools in the mainstream Mekong. At the onset of the wet season, they migrate upstream until they encounter a tributary, and then swim up the tributary until they reach a floodplain or another suitable spawning/nursing habitat. There are over thirty medium and large size species of cyprinid and pangasiid catfish which exhibit this general migration pattern.

2.2 The first major fish migration of the year commences at the beginning of the wet season. At that time, according to villagers, a large number of fish species begin migrating up the

Se Bang Fai, and its larger tributaries, while other fish species are believed to move from deep-water pools to spawning areas in the Se Bang Fai.

2.3 These two migrating groups include the following taxa: Cyprinids (Labeo chrysophekadion, Labiobarbus sp., Sikukia gudgeri, Hypsibarbus sp., Puntioplites sp.), Catfish (Pangasius larnaudii, P. macronema, P. pleurotaenia, P. bocourti, Wallago attu, W. leeri, Bagarius sp, Hemibagrus wyckioides, H. nemurus, Helicophagus waadersi, Laides sp., Mystus spp.), Mud perch (Pristiolepis fasciata), Glassfish (Parambassis siamensis), River loach (Schistura sp. or Nemacheilus sp.). During overbank flooding events fish migrate laterally to temporally inhabit adjacent flood plains for spawning and feeding.

2.4 In the dry season 'Black fish' species remain in lakes and swamps on the floodplain, where they are able to survive harsh conditions. The open waters and wetlands are vital in maintaining a breeding stock of these species. A decrease in number or area of the floodplain lakes, or even a later arrival of the floodwater, results in drying out of the floodplain lakes and ponds or the development of very poor water quality conditions and ultimately in a loss of species like snakehead, mud perch, spiny eels, climbing perch, walking catfish, and gouramies.

2.5 It will be clear that under Alternatives 1 and 2 the survival rate of 'Black fish' in the floodplain will decrease considerably and that lateral migration to spawning and feeding areas in the floodplain will be impossible for 'White fish'. Under alternative 3, upstream fish migration in the Se Bang Fai will be impossible and will ultimately lead to the disappearance of most of these migratory species.

3 Loss of environmental services

3.1 Flooding and the related sustenance of wetlands is known to have a number of benefits, these benefits may disappear or decrease if flooding is prevented or diminished, as discussed below.

3.2 Higher agricultural production: information gathered during Focal Group discussions in the area showed that paddy yields after a year with a high flood are not different from yields after a year with a normal flood. Also there was no difference in required agro-chemical inputs. Apparently the silt deposition during the flood does not improve the soil fertility and there are no positive impacts of flushing of contaminants or sanitation (killing pests and bugs) of the soil. Reduced flooding will reduce the replenishment of groundwater and surface water bodies with flood water. As already described, this will affect the wetland ecology, but probably also the amount of surface and ground water available in the next season. Of importance is also that not only the available quantity will be affected, but also the quality of the water. Pollutant concentrations increase in the course of the dry season and flooding flushes these pollutants out or reduces the concentrations to harmless levels. Reduced flooding will result in a deterioration of the water quality in the area.

4 Impact on Protected Areas

4.1 Not applicable, there are no officially protected areas located in the area. BirdLife International on it's website states that there is an Important Bird Area (IBA) located in the area. Details are not given.

5 Impact on Fisheries

5.1 After rice, fish is the most important item on the diet for all ethnic groups in the area. Besides, the sale of fish on local markets adds to the income of most households. Fish is caught all year round by men, women and children. The seasonal fish migrations between the Mekong River and the Xe Bang Fai are important periods for fisheries.

5.2 The main Se Bang Fai channel is the most important fishing ground during the dry season (when fish concentrate in refuge habitats), while habitats on the floodplain (flooded forests, swamps, backyard ponds, paddy fields) are important during the wet season.

5.3 As described before reduced flooding of the floodplains will have a significant negative impact on fish stocks, both in the floodplain itself and in the river.

6 Land acquisition and resettlement

6.1 Under Alternative 1 and 2 the dikes along the Se Bang Fai, and partly the Mekong River, will be heightened. Because of their relatively elevated position, these river banks are the areas where population is concentrated. Land acquisition and resettlement are important issues in this case. Of additional concern is the (temporary ?) impact of the dike construction on the riverbank gardening. This is an important activity, providing food and income to a large number of families. Females may be affected more than man, because the river bank gardening is mainly done by women. Construction of a diversion channel, under Alternative 2, will entail additional land acquisition and resettlement, as well as loss of some agricultural area.

6.2 An alternative including the construction of a storage reservoir would require the acquisition of a large area: the impoundment area of the reservoir is estimated at 10,500 ha. This area includes agricultural land of 18 villages. Resettlement would be a too big issue. For this reason such scenario has been discarded.

7 Human health and safety impacts

7.1 Overall the project will have a positive impact on human health and safety. People will be better protected against flooding, floods will last shorter and food (rice) production, and so food security, will increase. This is not the case for the amount of fish available in the flood season, that will greatly reduce. Reduced flushing and dilution of polluted water at the end of the dry season may pose a threat to human health.

7.2 Construction activities are another threat to health and safety for a variety of reasons: emission of dust, fumes, noise and vibration from construction sites and access roads, increased traffic and workers accidents. Inflow of workers from other areas increases the risk of a spread of HIV/AIDS.

Reduced flooding in the Se Bang Fai flood plain will have a number of significant environmental impacts. The area is at present a fairly important wetland area, which sustains a high biodiversity of flora and fauna, mainly water birds and fish. Reduction of the flooding will affect the dry season refuge habitats, small lakes, ponds and marshes, which are important for the survival of floodplain fish. In the flood season, the flooded wetlands, forests and rice paddies are an important spawning and nursing area for both floodplain resident fish and migratory fish. It will be clear that fisheries in the area will reduce greatly. Even more so if the objective of the project is reached by construction of a dam across the Sebanfai. Such a dam would obstruct the fish migration up and down the river.

Other important issues are the river bank gardening and land acquisition/resettlement. River banks are cultivated intensively, mainly by women. The fruits and vegetables grown there are important for the diet, tobacco is important as cash generator. Land acquisition may be considerable, since population is concentrated on the riverbanks.

From an environmental point of view complete flood protection, keeping the floods out, does not seem to be a good idea. A flood protection system that would allow flooding of the area during the main flood period of the Mekong River would sustain the precious wetland ecology and the fisheries potential.

The findings of the initial environmental evaluation are summarised in the "screening table" overleaf.

Screening question	Yes	No	Remark
A. Project siting Is the Project area adjacent to or within any of the following environmentally sensitive areas?			
– in or near sensitive and valuable ecosystems (e.g., protected areas, wetlands, wild lands, coral reefs, and habitats of endangered species)	X		the area is an important wetland area, consisting of a mosaic of fresh water lakes, river ponds and fresh water marshes. No official protected areas are located in Xe Bang Fai plain
– in or near areas with cultural heritage sites (e.g. archaeological, historical sites or existing cultural or sacred sites)		X	-
– densely populated areas where resettlement may be required or pollution impacts and other disturbances may be significant	X		population is concentrated along the river bank and in villages on higher grounds. Alternative 3 of the project may require significant resettlement
– regions subject to heavy development activities or where there are conflicts in natural resource allocation		X	-
– watercourses, aquifer recharge areas, or reservoir catchments used for potable water supply	X		river water is an important source for domestic water for a large proportion of the population in the area
– lands or waters containing valuable resources (e.g. fisheries, minerals, medicinal plants, prime agricultural soils)	X		the area is an important rice producing area. Besides fisheries provides additional food and income to the rural population
B. Potential environmental impacts Is the project likely to lead to:			
– permanent conversion of potentially productive or valuable resources (e.g. fisheries, natural forests, wild lands)	X		the wetlands in the project area are likely to be affected when flooding reduces. Reduced access to, and flooding of, the floodplain reduces fisheries potential greatly
– destruction of natural habitat and loss of biodiversity or environmental services provided by a natural system	X		a reduction of the flooded area will affect the flora and fauna diversity (fish and water birds). Under alternative 3 upstream migration of fish will be hampered
– risk to human health and safety (e.g. from generation, storage, or disposal of hazardous wastes, inappropriate occupational health and safety measures, violation of ambient water or air quality standards)		X	limited, some construction activities related health and safety risks are to be expected. Improved flood protection on the other hand reduces risks and improves food security and thus health
– encroachment on lands or rights of indigenous peoples or other vulnerable minorities		X	-
– displacement of large numbers of people or businesses	X		under Alternative 3 a considerable number of people will have to be resettled
– absence of effective mitigation or compensation measures		X	-

2.5 Strategic directions

2.5.1 Land use scenarios

Rice cropping and vegetables growing are the main agricultural activities in the project area. Agriculture is the area's largest sector of employment, with 92 percent of the inhabitants having rice production as part of their livelihood systems. Vegetables and other crops are grown by residents on the somewhat elevated Se Bang Fai river banks, as well as in the flood plains around natural lakes as water recedes. Lowland wet rice is cultivated in the lower lying areas.

The Se Bang Fai plain is one of the four main rice production areas in central Lao. Success or failure of lowland rice is closely linked to the natural flood cycle and every year part of the crop

is damage by the flood. Yields are highest, 2.0 - 2.8 ton/ha, in areas that are not flooded very long. The total paddy cropped area is 12,381 ha/yr, or 2.13 ha per household.

In the project area there are two main types of rice production: rainfed lowland (wet season) paddy and irrigated lowland (dry season) paddy. In the wet season 8,029 ha are cropped, in the dry season the cropping area is 4,351 ha. Although food security appears not to be an issue in the area, the Government of Lao PDR has embarked on a major program of irrigation development along the Se Bang Fai; most villages along the river now have irrigation pumps, and a network of canals with water control structures has been constructed to deliver water to the fields in the dry season.

The development of a strategic direction for flood risk management in the lower Se Bangfai area is closely related with the envisaged land use scenarios. The risk under the present land use conditions is relatively low, essentially because the actual cropping patterns are fully tuned to the natural flood cycle. Nevertheless, the risk under the actual conditions is still of the order of USD 2 million per year in the Nongbok district alone.

A strategic direction for flood risk management could aim at:
1. risk reduction under the present land use conditions;
2. flood protection measures that aim at a more intensive land use.

2.5.2 Reduction of the actual flood risk

If no substantial development of the agricultural sector in the lower Sebanfai flood plain is envisaged, the reduction of flood risk in this area should focus on the reduction of the actual flood damage in this sector. Based on the risk assessment that was made for the Nongbok district it can be derived that the agricultural flood risk in the lower Se Bang Fai floodplain is of the order of USD 150 per year per hectare. A protection of this area against floods lower than the 1 in 10 year flood would reduce the risk with some USD 100 per year per hectare. This risk reduction does not justify substantial investments in large scale diking schemes.

It is anticipated that substantial reduction of the existing risk can be achieved by reduction of the duration of flooding. The option of drainage improvement in combination with gating of the Se Bang Fai tributaries could be an attractive option to achieve this goal.

The diversion option will reduce the peak levels along the Se Bang Fai downstream of the diversion canal. It will have no impact on the Mekong back waters. Further analysis of this option is required to assess its impacts on the agricultural risk. It is anticipated though that the cost of such measure is prohibitive as compared to the benefits (risk reduction)

A mini-polder might be attractive if it protects an area where the actual land use would justify such investment. Further analysis is required to assess whether such area exist in the lower Se Bang Fai flood plain.

2.5.3 Flood protection for agricultural development.

Flood protection for agricultural development

Khammouane and Savannakhet provinces have expressed desire to develop the agricultural sector in the lower Xe Bangfai floodplains by having a larger irrigated area. However, irrigation schemes are at present used for about 50% of the irrigation scheme areas, these small schemes are located on the river levees and are not seriously affected by flooding. Though there is a potential for new irrigation schemes, the focus should first be on the rehabilitation of the existing schemes so that these can be used to their full extent.

CHAPTER 3

STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE UPPER SE SAN FOCAL AREA

3 STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE UPPER SE SAN FOCAL AREA

3.1 Flood damages and risks

The upper Se San focal area corresponds essentially with the Kon Tum province in Vietnam. Reported flood damages in this province over the period 2001 - 2005 are of the order of 0.9 million USD per year (in 2007 a damage of 1.9 million USD was reported). These damages are direct damages only. About half of the damage is related to irrigation and transport infrastructure, while the other half is related to households and agriculture.

Kontum town does not suffer from inundation, except under extreme flood conditions. Some damage was reported in the year 1996, which was an exceptional year (estimated probability of less than 0.02%). Despite the fact that Kontum is relatively safe for flooding, its location on the bank of the Dak Bla tributary makes bank protection necessary to avoid damages due to erosion. Information on erosion damages is not available.

Most flood related damages in the in the province occur reportedly in the area upstream of Kon Tum town. In the framework of Community Based Disaster Risk Management programme, damage assessments were made in two communes in the Tu Mo Rong District. The results are shown in the tables overleaf. From these tables it appears that most disaster related damage is due to land slides and not the direct impacts of floods. However, fatalities are essentially related to floods.

3.2 Flood risk management options

Flood risk management in the province focuses essentially on the reduction of the vulnerability of the people and infrastructure. Ongoing flood risk management measures include:

1. Soft measures for vulnerability reduction like:
    a. Capacity building at commune level (UNDP)
    b. Early warning
    c. Emergency management, preparedness plans

2. Hard measures for vulnerability reduction:
    a. Flood proofing / upgrading infrastructure (roads, bridges, culverts, irrigation works)
    b. Bank protection Kon Tum (2.6 km)

3. Soft measures for hazard reduction:
    a. Reforestation (5million has)

Structural works to reduce the flood hazards upstream of Kon Tum town are not envisaged.

Hazards impacts during the past 10-15 years in Mang Ry Commune

Year	Hazards	Affected areas	Damages on human, house, property and production	
			Damaged items?	***Reasons?***
1994	Fire	Ng□c La	Burnt whole village (80 houses)	
1996	Fire	Ng□c La	Burnt 7 houses	
	Landslide	Pu Tá	Filled up 2ha production land and 3 storehouses	Located at mountain side close to road. Land was buried by soil and unable to be recovered.
1997	Fire	Pak D□n	Burnt 20 houses	Several households did not extinguish the fire when they left for field; strong wind fanned the rest fire in kitchen and caused house burning.
	Landslide	Long Hy	Killed many cows and buffaloes	Let wander
	Landslide	Chung Tam	Lost 2ha production land of rice, corn and noodle	Close to road, buried by soil and unable to be recovered.
2000	Drought	whole commune	Damaged 0% of Spring crop due to water shortage	
2002	Fire	Long Hy II	Burnt 3 houses	Fire was not extinguished before leaving for field; strong wind fanned the rest fire in kitchen and caused house burning.
	Typhoon	whole commune	Lost 60-70% of crop, unable to be harvested	
	Typhoon	**Long Hy**	**Killed one person Drifted one cow**	**Crossing stream without bridge Wander nearby stream**
	Flood	**Ng□c La**	**Drifted two elders**	**Crossing stream without bridge**
	Landslide	Ng□c La	Filled up 3ha field, lost 100% Winter crop	Hill blow-off caused field bury
2004	Fire	Ng□c La	Burnt 4 houses	Children started fire recklessly causing house burning.
2005	Thunder	Ng□c La	Killed one person and injured 5 people	Working in forest and children came home from school.
2006	Landslide	Long Hy	Filled up 2ha field	Land bury
	Landslide	Pu Tá	Lost 3ha field, unable to produce.	Soil buried channel system leading to no water for production.
	Landslide	Ng□c La	Lost 500m^2 rice field	Soil filled up field close to stream
2007	Landslide	Long Hy II	Lost 200m^2 rice	Stream-nearby field was buried and unable to be produced
	Typhoon	Đăk D□n	Roofed-off 5 houses	Corrugated iron roof were not reinforced
	Landslide	Đăk D□n	Filled up 2ha rice crop	Stream-nearby field was buried and unable to be produced
	Flood	**Ng□c La**	**Killed one person**	**Drifted while crossing stream**
	Whirlwind	Ng□c La	Roofed-off kindergarten and	Iron-roofed houses were not reinforced.

Year	Hazards	Affected areas	Damages on human, house, property and production	
			Damaged items?	***Reasons?***
			primary school.	
	Landslide	Ng□c La	Lost 5ha rice field	Field was close to sloppy mountain side.

Hazards impacts during the past 10-15 years in Tumorong Commune

Year	Hazards	Affected area	Damages on human, house, property and production	
			Damages	***Reason for damage***
1996	Typhoon	Đăk Ka	- Damaged stored sentry-boxes - 3 rods of farm products	Storehouse is temporarily built in field.
	Whirlwind	Tu C□p	- Roofed-off many houses and damaged 8 sentry-boxes for rice storing in field.	- No materials available for house-enforcement; - Bamboo sentry-box placed in exposed mountain.
	Whirlwind	Tu M□ Rông	- Roofed-off - Farm loss	- Bamboo houses & iron-roofed houses are not re-enforced before whirlwind
	Hail	Tu C□p Tu M□ Rông Đăk ka Văng Săng	- 80% of farm lost; - Broke trees and farms	- Heavy hail in large areas buried rice and farm products in their growing period.
1997	Landslide	Văng Săng	- Buried irrigational ditch, transportation road and farm fields	- Field is close to landslide area, buried with rocks and soil.
	Typhoon with heavy rain	Tu C□p Văng Săng	- Roofed-off houses and damaged sentry-boxes in field.	- Houses were not re-enforced; - Temporarily built sentry-boxes.
1998	Flood	Tu M□ Rông	- Damaged irrigational works; - Lost 4ha field of non-production since no water.	- Flood filled up irrigation work causing water shortage for production.
2002	Typhoon	Đăk Neang	- Damaged communal house and roofed-off residential houses; - Totally damaged farm products	- Heavy storm, temporary bamboo houses were not re-enforced before flood season.
2003	Typhoon	Đăk Chum I		
2004	Thunder	Tu C□p	- Damaged electronic appliances (TV, radio...) and television station.	- Located in thunderstruck area in high mountain.
2005	Thunder	Đăk ka	- Damaged 5 televisions and burnt one communal house.	- Located in thunderstruck area in high mountain
2006	Whirlwind	Đăk Chum II	- Roofed-off 3 houses and damaged irrigational channel system and farm products.	- Temporary houses not be enforced yet; - Earthen irrigational channel not concretized yet.

Year	Hazards	Affected area	Damages on human, house, property and production	
			Damages	***Reason for damage***
	Typhoon Whirlwind	Đăk Chum I	- Damaged many residential houses, storehouses, and communal house; - Farm products were hit by typhoon causing no harvest and poultry loss.	- Heavy storm with so strong wind that residents were unready for house re-enforcement. Poultry were let wander without keeping facilities.
2007	Whirlwind	Long Leo	- Damaged farm products and 1.1ha rice.	
	Typhoon	Văn Sang	- Roofed-off many houses collapsed one house and one school.	- Temporary bamboo houses. Wooden school with metal roofing.
Yearly	Drought	Whole commune	- Lack of water for production.	- Clue channel system is blown off by flood and unable to store enough water for production field; - Earthen channel.

3.3 Strategic direction

The Steering Committee for Flood Storm Control of the People's Committee of Kontum Province has stipulated that a long term plan for flood risk management needs to be developed to minimise the losses to replace the existing reactive approach.

In line with this recommendation CBDRM activities are initiated in which the communal Committee for Flood and Storm Control members together with villages' representatives develop plans for "Safer Communities". The objective of these plans is to give supplementary measures for annual flood control and disaster mitigation in the commune in conjunction with long-term prevention measures for 3 years with stable production development plan of the villages of the respective communes. The plan objectives include:

1. Improving community's awareness and capability on hazards' prevention and response in areas frequently-hit by disasters;
2. Providing basic facilities which are not available in community to serve emergency rescue work, especially against landslide and flood;
3. Upgrading infrastructure to ensure safer transportation in flood season;
4. Establishing early warning system, warning boards in high-danger areas as well as information boards on disaster at community.

The relatively low flood related damages (besides the human fatalities) and limited development potentials do not justify substantial investments in sub-basin wide structural measures for flood hazard reduction. Flood proofing of infrastructure, though seems a sound measure that could reduce substantially the existing flood risks in the area, including human fatalities.

In a UNDP/CECI DIPECHO (2007) study looked to what extent disaster risk reduction had been integrated into the implementation of Program 135 in Kontum. The study found that the planning of Program 135 investments in the province did not specifically look at disaster risk reduction as a factor in the planning process. For example, Program 135 funds were being used in the province to distribute livestock and agriculture inputs to villagers that had suffered losses

after disasters. However, the investments in agriculture production and transportation were not analyzed in the context of how trends in disaster impacts in the local area might have an adverse impact on efforts to improve livelihoods. The project recommends that guidelines need to be developed that link the implementation of the Action Plan of the NSDPRM (National Strategy for Natural Disaster Prevention, Response and Mitigation) with major national investments such as Program 135 and the socio-economic development process. The guidelines would need to have legal bearing on local officials and include measures such as disaster proofing of infrastructure works and other assessments prior to implementing poverty reduction activities.

An essential element in such guidelines would be the assessment of flood hazards in the area or locality at stake. The proposed methodology for such assessment in the Upper Sesan basin has been described in Appendix 4 of Volume 2A.

CHAPTER 4

STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE MEKONG DELTA TRANSBOUNDARY AREA

4 STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE MEKONG DELTA TRANSBOUNDARY AREA

4.1 Flood management levels

The focal areas in Mekong Delta cannot be considered in isolation from the entire Delta. For the management of floods and the related risks in the Mekong Delta the following basic options have been looked into:

1. Flood management by structural measures at the Delta level. This option looks into the possibility to make use of the storage capacity of the Tonle Sap to reduce flood risks in the Mekong Delta.
2. Flood management by structural measures at a regional level. In the Delta focal areas the following regions are distinguished:
   a. Floodplains on the right bank of the Bassac River in Cambodia and south of the Phnom Penh Municipality.
   b. Floodplains on the left bank of the Mekong River in Cambodia and south of the National Road No. 1.
   c. Deep flooded plains on right bank of the Bassac River in the Long Xuyen Quadrangle in Vietnam.
   d. Deep flooded plains on the left bank of the Mekong River in the Plain of Reeds in Vietnam.
3. Flood risk management at a sub-regional or local level. This option considers flood risk management at tertiary level and the protection and/or flood proofing of human settlements and infrastructure in the Delta focal areas.

Flood management options at Delta level that aim at the reduction of the flood hazards Delta wide are very limited. Such options would have to consider the reduction of the flood discharges and volumes that enter the Delta or the creation of diversion and/or retention options in the Delta.

The management of flood discharges that enter the Delta by upstream retention would not only require enormous storage capacities in the basin but also an operation of these storages aiming at flood control. Effects of hydropower developments on floods have been investigated by Beecham and Cross (2005) and Adamson (2007). Results of these studies show that the Chinese dams have a high potential to reduce flood peaks in the upper part of the LMB. The effect, however, rapidly reduces further downstream. Together with a high development of hydropower in the LMB reductions of the annual flood peak of 4 to 5 dm can be achieved. In the delta the effect is limited, on average, to 1 to 2 dm, but for the extreme flood of the year 2000 only 5 cm. Though the effect is small on the flood levels and inundated area a significant effect was found on the duration of flooding, which reduced substantially for some 40% of the flooded area. It is noted, however, that these effects required an active storage capacity equal to roughly the annual amount of Mekong flood volume stored temporarily in the Tonle Sap. Hence, upstream retention as a flood mitigating measure for the delta is not considered a realistic option.

The option of Delta wide diversion schemes have been investigated in the Flood Control Planning for Development of the Mekong Delta (Basin-wide,2007). Results of these studies show that different diversion options have regional impacts only and none of them have Delta wide impacts.

The only substantial retention option within the Delta area is related to the use of the storage capacity of the Tonle Sap Great Lake. Preliminary investigations show that an uncontrolled diversion of early flood water (July-August) to the Great Lake has a very limited impact on the

flood hydrograph in the Delta. A controlled diversion of early flood waters could, however, delay the early flooding downstream of Phnom Penh by some three weeks on the average. (See Appendix 11 to Volume 2a). Such diversion, though, provides no risk reduction for infrastructure and housing in the floodplains, since the flood damage to these structures is driven by peak of flood. A diversion scheme for flood risk management can be supplemented with works that regulate the outflow of the Tonle Sap lake and the adjacent floodplains. Such regulation would provide additional benefits since it improves the low flow conditions in the delta. Such comprehensive regulation scheme aiming at an integrated water resources management in the Delta is beyond the scope of this FMMP-C2.

Flood management at regional level is the approach that is being followed in the Vietnamese part of the delta. This approach was suggested in the Mekong Delta Master Plan and is being applied ever since. This approach refers to the different regions in the Delta with different levels of flooding (deep, shallow) and distinct boundary conditions requiring different flood control solutions.

This regional approach is also suggested for the Cambodian part of the Delta. The development of cross boundary strategic directions is not considered appropriate, in view of the great difference between the development level and pace at the two sides of the border. Emphasis is to be given to the potential impacts that the separate regional strategic directions may have on neighbouring regions, rather than to try to come to common strategic directions.

The sub-regional flood risk management refers to:
1. The "flood proofing" of settlements and infrastructure within the regions.
2. Differentiation of flood protection levels within regional protection schemes.
3. The zoning of regional protection schemes.

The flood proofing of settlements and infrastructure is essentially part of the "living with floods" approach in the focal areas.

Regional protection schemes have in principle a regional protection level. It is possible though to differentiate within a region the protection levels without loosening the living with flood principle. In general such differentiation would require different dike levels for different land uses, or more regulation works.

Sub-regional flood risk management could be attractive from a financing and/or implementation point of view. Zoning of regional schemes allows for a phased implementation and also for a differentiation of protection levels.

For the flood risk management in the Delta focal areas also other measures than structural ones can be taken. In the framework of the Integrated Flood Risk Management other relevant measures for flood risk reduction refer to: (i) land use / crop planning, (ii) awareness raising and (iii) early warning. These measures aim at the reduction of the vulnerability. For the focal areas in the Mekong Delta it is assumed that these soft measures are already in place. When land use changes occur as a result of structural flood protection measures, then the need for enhancement of the soft measures should be assessed.

4.2 Regional flood management scenarios.

For the management of floods and the related risks in the Mekong Delta the following basic options have been looked into:

1. Scenario 0: Existing condition of land use and flood control levels in Cambodia (Takeo and Prey Veng) and in Vietnam (Long Xuyen Quadrangle and Plain of Reeds);
2. Scenario 1: Vietnamese areas provided with full flood control, Cambodian areas unchanged;
3. Scenario 2: Cambodian areas provided with early flood control and Vietnamese areas unchanged;
4. Scenario 3: Vietnamese areas provided with full flood control, Cambodian areas provided with early flood control;

CHAPTER 5

STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE WEST OF BASSAC REGION IN CAMBODIA (TAKEO)

5 STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE WEST OF BASSAC REGION IN CAMBODIA (TAKEO)

5.1 Flood damages and risks

The West of Bassac region is located on the provinces of Kandal and Takeo along the west side of the Bassac. This area has an extension of 2,113 km^2. In this area two districts have been surveyed for damage and risk assessment. The following risk have been estimated for these districts (see Volume 2C for the details).

Cambodia	Koh Andet District	USD 0.7 mln per year
	Koh Thom District	USD 0.7 mln per year

Further analysis is needed to assess the flood damage risk at the level of the focal area. From the flood hazard maps it is preliminary estimated that the flood risk is of the order of some USD 3 million per year. About half of this risk corresponds to agricultural risks.

5.2 Flood benefits

Apart from the negative impacts of flooding as mentioned above, floods also have positive impacts on the social economy such as natural fishing and soil fertility. Results from focus group discussions held in focal areas showed that benefits from natural fishing for people living in deeply flooded area would vary from 80-945 US$/household. According to the MRC-Technical Paper on fish yields, average amount of fish catch from rice field in Mekong Delta Flood Plain (deep water flooded areas) would be 80-119 kg/ha resulting in the value of 30-40 US$/ha. The amount of fish catch from rice field (in Prey Veng province) would be 55-92 kg/ha resulting in the value of 20-30 US$/ha. Farmers also mentioned that floods have significant benefit for crop cultivation. After big a flood, Winter-Spring Paddy (Planting in November and harvesting in March) has a higher yield than normal flood years by 1.5-2.0 ton/ha. It would result in flood benefit for agriculture of about 150-230 US$/ha after a big flood. Assuming big flood frequency of one third, the annual flood benefit for agriculture would be 50-77 US$/ha.

5.3 Structural flood risk management options

Three flood risk management zones were identified based on present flood conditions, existing road and flood embankments, human settlements and land use. Subsequently, the type of structural components required for each area has been preliminarily designed as a result of flood damage and benefits due to the risk reduction.

The three zones and their structural components are described as follow (see **Error! Reference source not found.**):

Zone 1

The zone 1 is located in the Kandal Province and is part of the Bassac flood plain. Road National 21 (RN21)is constructed as a road/flood embankment aligned along the west bank of the Bassac. The RN21 was designed as flood free road. Along the RN 21 there a large number of connections to colmatage canals linking the Bassac with the flood plain in the western side of the Bassac. The flood plain drains in the direction of the Prek Ambel river.

The Prek Ambel is the biggest natural offtake channel of the Bassac with the flood plain and it has the function of a bypass channel during the high flood. Further south, the Prek Ambel drains into the Bassac river through the Maot Chrouk canal. The Prek Ambel oftake will be controlled.

Zone 1 has a total area of 208.6 km^2 and has been sub-divided into five large polders. Zone 1 could be developed as flood free zone. In order to make the zone 1 flood free, the following structural measures are planned:

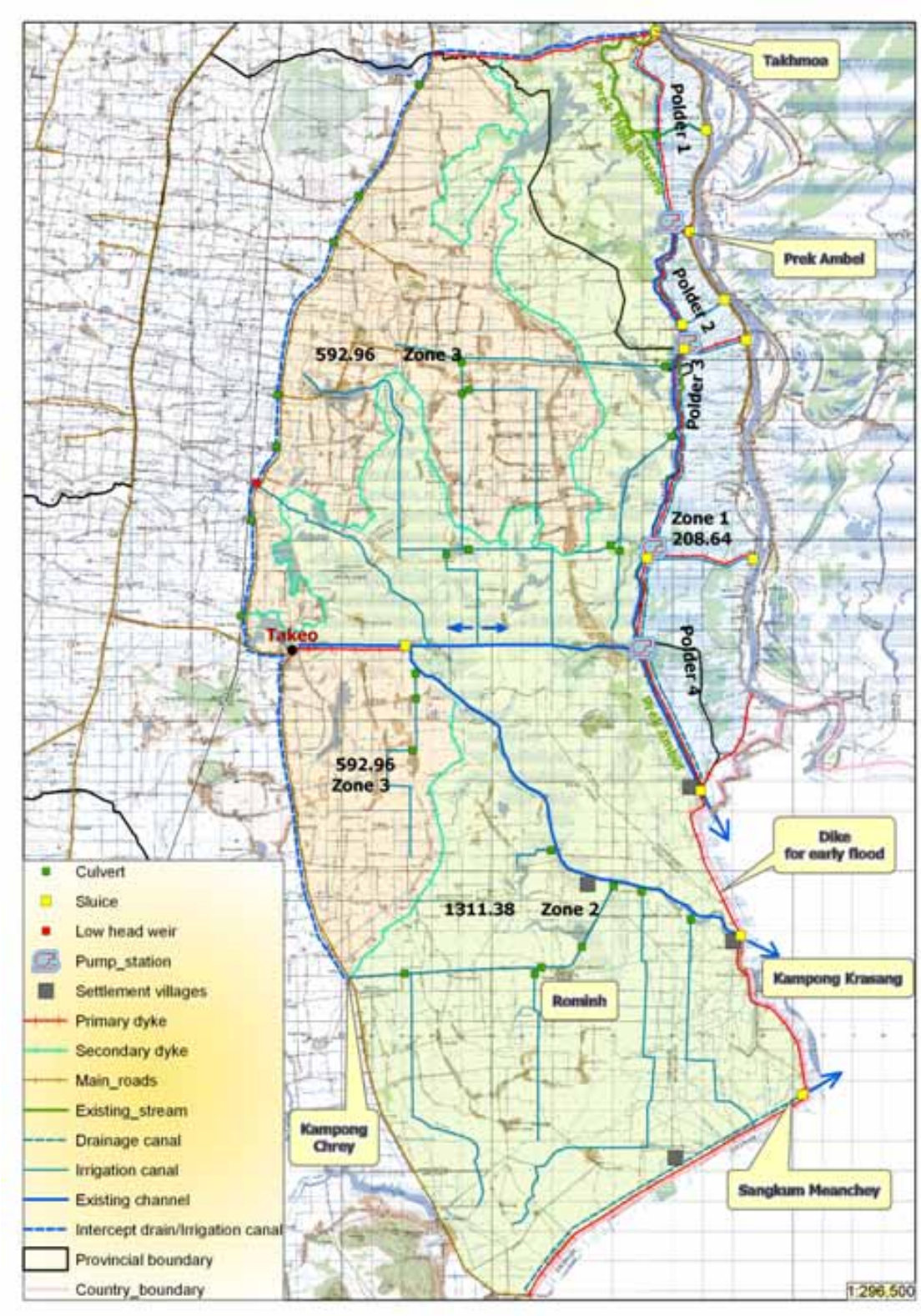
- Closure of all the colmatage canals along RN21 and keeping only four main canals linked to each one of the four large polders proposed. Flow from the Bassac into the polders will be controlled by regulators with gates.
- In order to create the 4 polders a flood protection dike along the left bank of the Prek Ambel has to be constructed.
- A main drainage canal along the dike and control gates for drainage are also required.
- The system of existing colmatage canals inside the polders will be connected to a main drainage canal connected to the Prek Ambel river.
- The Prek Ambel river has two functions: (i) drainage during the receding period and (ii) working as a bypass to divert excess water from the Bassac during the flood period which will prevent increasing water level along the Bassac that would threaten the area East of the Bassac. The required conveyance capacity of the Prek Ambel as bypass will be determined from modelling simulations.
- To control flows at the offtake of the Prek Ambel, a regulator with control gates will be constructed at the offtake.
- At some places in the polders pumping stations or accumulation areas are required to drain the area
- Polder number 4 at the southern side of zone 1 needs a full protection dike from Chrey Thom on RN21 to the Moat Chhrouk canal.

Zone 2

The zone 2 has a total extension of 1,311.4 km^2. The northern east corner of this area is located in the Kandal Province and the rest of the area is located in Takeo province. This area is deep flooded during the high flood season. This zone could be protected against early floods to secure early rice crop (May-July). Because the neighbouring zone 1, at the Bassac west side is envisaged to be made flood free, then flooding in zone 2 of this area can only come from the southern side due to higher water level in the Bassac.

The structural components for this zone are:

- One dike from Moat Chhrouk canal to Kampong Krasaing (at the border, meeting point with the Stung Takeo) for early flood prevention. This dike needs to be constructed flood proof.
- A flood proof dike from Kampong Krasaing to Sangkom Meanchey running along the southern border from Sangkum Mean Chey to Phnom Den (meeting point with the RN2)
- One main drainage canal along the southern border (between Cambodia and Vietnam)
- One regulator with control gates at the Moat Chhrouk canal exit
- One regulator with control gates on the Stung Takeo at the exit
- At the northern border of the zone 2, construction of a dike and a drainage canal is required.
- One water control structure at the junction of Stung Takeo and Takeo canal
- Flood free settlement areas at four locations in deep flooded areas. Each settlement area is planned to accommodate around 500 families. Each flood free area will have an extension of 15,000 m^2 and connection to rural road(s).
- Improvement of rural roads in the southern part (deep flooded area) to connect with flood free settlement areas.



Zone 3

The zone is entirely located in Takeo Province and has a total extension of 593.0 km^2. This zone is a shallow flood area that is not inundated under early flood conditions with probability more than 10%. This area could be given protection against high floods to make more intensive land use possible, provided that irrigation is available.

The components of this area are:

- A low dike along the eastern side of the zone 3.
- A main canal to intercept excess flow from the western catchment area. This canal will also serve the purpose to divert water from the Bassac for irrigation, during the dry season. This canal will be constructed parallel to the RN2 from Ta Khmao to Takeo;
- Regulator with control gates at the right bank of the Bassac at Ta Khmao.
- Interceptor canal from Takeo to Kampong Chhrey

5.4 Impacts of structural flood risk management options

5.4.1 Flood risk reduction

In case early flood protection is provided to the deep flooded areas and year around protection to the shallow flooded areas[4] the risk reduction has been estimated at 0.430 M US$/year in Koh Andet, this corresponds with some 55% of the actual risk. This estimated risk reduction is mainly related to the reduction of the agricultural risk in the shallow flooded area.

The benefits of the protection of the deep flooded areas against the early floods come from a second crop that can be planted once also irrigation water will be available. According to 2006 statistics, the dry season paddy area was 10,800 ha in Koh Andet district, 13,000 ha in Koh Thom district. It is anticipated that the second paddy crop in these focal areas would be the same as dry season crop. Assuming that the net benefits from paddy is 500 US$/ha, it would result in 5.4 M US$/year in Koh Andet district, 6.5 M US$/year in Koh Thom district.

5.4.2 Transboundary impacts

The flood risk management options that consider protection of agricultural areas go automatically together with the reduction of the storage of flood waters in these areas until the design level of protection works have been reached. This reduction of floodplain storage results in the increase of the river discharges at and downstream of the protected area and, consequently in the increase of the river water levels.

Runs with the ISIS model have been made to simulate the impact of the previously described protection works on the water levels in the downstream area in Vietnam. The results of these simulations are shown and described in the Appendix 6 of Volume 2B. It has to be taken into account that the model allows for a relative assessment of these impacts only. That is to say that the presented absolute values are to be given due care. More accurate modelling is required to assess the absolute values of these impacts and the eventual impacts on the flood risks in Vietnam.

From the modelling results it is learned that the protection works in Cambodia have a marginal (<0.1m) impact on the early flood levels in Long Xuyen Quadrangle. The impact on the maximum flood levels in the LXQ is negligible. However, due to the embankments in Cambodia, the maximum water level in focal areas of Vietnam being lower than the actual ones. It would result in reduction of risk for Vietnam at 0.1 million US$/year in Chau Phu district.

In the Bassac river, though, the maximum flood levels may increase 1-3 decimetres at Chau Doc and about 1 decimetre under early flood conditions.

[4] protection levels are set at 10%, that is to say that protection is given for 9 out 10 years on the average

5.4.3 Environmental impacts

Sensitive and valuable ecosystems that are encountered in the Cambodian Delta are seasonally-inundated riparian forests; seasonal wetlands, including marshes, small pools and pools; and seasonally inundated grasslands. These ecosystems are important as a habitat of a variety of fish and waterbirds and for the sustenance of the inland fisheries.
No officially protected areas are located in the project area, however, BirdLife International has declared Boeung Prek Lapouv in the south eastern part of the West Bassac Focal Area an Important Bird Area (IBA). The area south of Angkor Borei is an area with archeological value. Remains of pre-Ankoran canals crossing the floodplain, have been found here.

Population density in the project area is fairly low. Locally, densities in the more protected, higher areas along river banks and dikes, are fairly high. There are no regions subject to heavy development where conflicts over resource use are to be expected. Water courses in the area, rivers and canals, but also ponds and lakes are used as a source for drinking water by the majority of the rural population.

As far as resources are concerned, the area is primarily an agricultural, rice producing area. Of importance as a source for food and income for the rural population is also the inland fisheries.

The following potential environmental impacts have been identified:

1. Destruction of natural habitats, valuable resources
   1.1. The sensitive and valuable ecosystems encountered in the Cambodian Delta are all dependent on the seasonal flood. Protection against early flooding will mean an average delay of the onset of the flooding with about one month. Area and depth of flooding during the main flood are not expected to change. Direct impacts on the riparian forests, seasonal wetlands and seasonally inundated grasslands are probably limited, although species composition may change: some species will simply not be able to survive the prolonged drought (see 2.2). When also provisions for quicker drainage after the flood are made, the total period of flooding may become so short that wetlands dry out or change so much in species composition that they loose their ecological value.
   1.2. The indirect impact of the project on the natural areas may be significant as well. Increased protection against the early flood will encourage people to extent their agricultural activities to areas that are presently not used for rice growing. Encroachment into forest/scrublands, wetlands and natural grasslands will be the result.

2. Loss of biodiversity, rare and endangered species
   2.1. As stated above prolonged drought may have an impact on the biodiversity in the area. Species composition of aquatic flora may change and the diversity and extent of marshes may reduce. In the dry season 'Black fish' species remain in lakes and swamps on the floodplain, where they are able to tolerate acidic and low oxygen conditions. The wetlands are vital in maintaining breeding stock. Prolonged drought en more floodplain lakes and ponds drying out completely could result in a decrease in numbers of for example climbing perch (Anabas testudineus), clarias catfishes (e.g. Clarias batrachus) and striped snakehead (Channa striata).
   2.2. Eighty-five to 95% of the freshwater fish populations in the Mekong basin have an inundation spawning pattern and undertake lateral migrations from the mainstream and tributaries into the inundation zones to spawn and rear young between July and September. Representatives of this group are some of the cyprinids, such as Cyclocheilichthys enoplos (Soldier river barb or Chhkok) and Cirrhinus microlepis

(Small mud carp or Prul/Kralang). Late access to the floodplain or blockage of migration routes will have an impact on the standing stocks of these migrating species.

2.3. Apart from fish, the wetland areas support a high diversity of other aquatic animals including vertebrates - reptiles, birds, mammals and amphibians, and invertebrates, such as insects, crustaceans and mollusks, all of which depend upon maintenance of aquatic ecosystems and could be affected if the total area of the wetlands reduces or when wetlands dry out completely during part of the year.

2.4. Desiccation could also lead to loss of seasonally-inundated riparian forest along the banks of lakes and rivers and the loss of some of the over 200 species of plants that are known to occur in these forests. The woody species of this forest are bearing fruits and seeds at the time of inundation, providing food for the 34 species of fruit-eating fish of the Lower Mekong Basin. Delay of the flooding could imply that the fruit is already fallen and decomposed before the fish arrive.

2.5. Loss of wetland areas could also affect the number and diversity of waterbirds, particularly cormorants, Oriental Darter, Spot-billed Pelican, Greater and Lesser Adjutants, Milky Stork, Woolly-necked Stork Ciconia episcopus, Black-necked Stork Ephippiorhynchus asiaticus, Painted Stork, The Globally Endangered White-shouldered Ibis Plegadis davisoni, Glossy Ibis P. falcinellus, Black-headed Ibis Threskiornis melanocephalus, White-winged Duck, Pallas's Fish Eagle Haliaeetus leucoryphus, Grey-headed Fish Eagle, the Globally Vulnerable Masked Finfoot Heliopais personata, and the Globally Near-threatened Sarus Crane Grus antigone.

2.6. Late inundation of the seasonally inundated grasslands might reduce the feeding areas of a number of birds, including the Sarus Crane, White-shouldered Ibis and Greater and Lesser Adjutants. They are also of crucial importance for the Globally Endangered Bengal Florican Houbaropsis bengalensis.

3. Loss of environmental services.

3.1. Flooding and the related sustenance of wetlands are known to have a number of benefits, some of these benefits will be affected by later and shorter flooding as discussed below.

3.2. The importance of deposition of fertilizing sediment is illustrated by the results of the Focal Group discussions. It turned out that after a year with a good flood rice yields are about 1 ton/ha higher than in years after a year with a bad flood. In some areas an increase of 1.5 ton/ha was mentioned. Production costs were estimated to be the same in years after a year with a good flood as compared to years after a year with a normal flood. Overall benefit of the flood for agricultural production is estimated at 620,000 to 920,000 Riel/ha. Not only the fertilizing of the soil with sediments is important, also the flushing of toxic materials and pollutants by the floodwaters, the sanitation of the soil (killing of pests and bugs) and possibly the god replenishment of ground and surface waters. Impacts of delaying the flood on this benefit are not thought to be very significant, the highest sediment concentrations are observed during the main flood. The delayed replenishment of groundwater and surface water bodies will not affect the quantities of water available in the next season. However, shortages for human and ecosystem use (flora and fauna) will increase, since the dry season is prolonged. Water quality at the end of the dry season will deteriorate with delayed flooding. Not only the available quantity may be affected, but also the quality of the water. Pollutant concentrations become higher and the flushing/diluting effect of the flood is delayed. Finally the flow regulation effect of the flooding will be less, meaning that early flood levels downstream will increase.

4. Impact on Protected Areas
   4.1. The Boeung Prek Lapouv IBA (Important Bird Area) forms one of the largest areas of adjoining natural habitats remaining in the Mekong Delta. Although not (yet) officially a protected area, the area has a high conservation value. Changing flood patterns or canal/dike construction could have a negative impact on the area and reduce the number of aquatic vegetation species and the area's importance in providing critical wetland habitat to 25% of the world's population of endangered, non-breeding Eastern Sarus Cranes (Grus antigone sharpii). In total 58 bird species including 34 water bird have been observed in the area, 6 species are globally threatened: Sarus Crane (Grus antigone), Bengal Florican (Houbaropsis bengalensis), Spot-billed Pelican (Pelecanus philippensis), Painted Stork (Mycteria leucocephala), Darter (Anhinga elanogaster) and Black-headed Ibis (Threskiornis melanocephalus).

5. Impact on Fisheries
   5.1. People in rural areas rely heavily on fisheries for their subsistence. With an average of 76 kg of fish is consumed per person/year, fish provide from 40 - 60% of animal protein intake. The productivity of the Lower Mekong Floodplains ranges between 139 and 230 fish kg/ha/year, which is very high compared with other river systems in the world. Fish productivity depends amongst others on accessibility of the floodplain for fish, the availability of food and the length of the period that the fish stay on the floodplain to grow. All these three factors could be influenced negatively by the project. Dispersal of 'White fish' fry over the floodplain with the flood water will be delayed. At the time of flooding the amount of fry in the floodwater may have diminished somewhat resulting in lesser stocks. At the same time the survival rate of 'Black fish' in the floodplain habitats will be reduced.
   5.2. Deterioration of the floodplain vegetation results in a lower food availability and the growth period of the fish during their stay on the floodplain is reduced with one month. These impact may have an effect on an area larger than the project area, downstream river fisheries might be effected as well.

6. Land acquisition and resettlement
   6.1. Project implementation will entail quite a length of canals and dikes to be constructed. Partly these canals and dikes will follow existing alignments. In other words, a fairly large percentage of the works will be carried out at places where the population is concentrated and land acquisition and resettlement may be unavoidable.

7. Human health and safety impacts
   7.1. Overall the project will have a positive impact on human health and safety. People will be better protected against flooding, floods will last shorter and food (rice) production, and so food security, will increase. This is not necessarily the case for the amount of fish available in the flood season. Reduced water availability and poor water quality at the end of the (prolonged) flood free period may pose a threat to human health.
   7.2. Construction activities are another threat to health and safety for a variety of reasons: emission of dust, fumes, noise and vibration from construction sites and access roads, increased traffic and workers accidents. Inflow of workers from other areas increases the risk of a spread of HIV/AIDS.

8. Impact on cultural, historic and archaeological sites
   8.1. Large scale construction of canals and dikes will partly destroy the remains of the pre-Angkorian canals that have been found in the area around Angkor Borei.

Protection against the early flood, which means delaying of the flood and shortening of the flood period, may have a number of environmental impacts. Most significant are probably the impacts on the inland fisheries and the wetland vegetation and associated fauna.

Prolongation of the dry period may result in lower survival rates of 'Black fish' and so a reduced restocking during the flood season. Also 'White fish' migration into the floodplain might be effected, because the timing of the flooding may not coincide anymore with the presence of fish fry and larvae in the flood water. A deterioration of floodplain ecosystems like riparian forests and flooded grasslands could result in reduced food availability for the fish.

Screening question	Yes	No	Remark
A. Project siting Is the Project area adjacent to or within any of the following environmentally sensitive areas?			
– in or near sensitive and valuable ecosystems (e.g., protected areas, wetlands, wild lands, coral reefs, and habitats of endangered species)	X		the area consists for a large proportion of wetlands harboring a number of protected species and of vital importance for maintaining the Lower Mekong fisheries. Boeung Prek Lapouv has been identified as an Important Bird Area (IBA) by BirdLife International.
– in or near areas with cultural heritage sites (e.g. archaeological, historical sites or existing cultural or sacred sites)	X		in the area pre Angkorian canals have been identified
– densely populated areas where resettlement may be required or pollution impacts and other disturbances may be significant		X	population is concentrated along canals and dikes, works will concentrate on these areas
– regions subject to heavy development activities or where there are conflicts in natural resource allocation		X	development in the region is limited
– watercourses, aquifer recharge areas, or reservoir catchments used for potable water supply	X		canal and river water is used as a source for domestic water by the majority of the population in the area.
– lands or waters containing valuable resources (e.g. fisheries, minerals, medicinal plants, prime agricultural soils)	X		the area is an important fisheries area, both for 'black fish' (floodplain residents) and 'white fish' (migratory) species, and as such has more than regional importance
B. Potential environmental impacts Is the project likely to lead to:			
– permanent conversion of potentially productive or valuable resources (e.g. fisheries, natural forests, wild lands)	X		the yearly flooded grasslands, paddy fields and natural areas are important fish spawning and rearing areas
– destruction of natural habitat and loss of biodiversity or environmental services provided by a natural system	X		a reduction of the flooded area might affect the flora and fauna diversity (fish and water birds) and could have a negative impact on the fisheries resource
– risk to human health and safety (e.g. from generation, storage, or disposal of hazardous wastes, inappropriate occupational health and safety measures, violation of ambient water or air quality standards)		X	limited, some construction activities related health and safety risks are to be expected
– encroachment on lands or rights of indigenous peoples or other vulnerable minorities		X	-
– displacement of large numbers of people or businesses		X	-
– absence of effective mitigation or compensation measures		X	-

Natural vegetation could deteriorate because delayed flooding will lead to a further desiccation of the floodplain at the end of the dry season. Important ecosystems/habitats like riparian forests, seasonally flooded grasslands and marshes may be effected, resulting in a change in

species composition. As a result they may lose their importance as a habitat for a large number of (rare and endangered) species of fish and water birds. Of special conservation importance is the Boeung Prek Lapouv wetland. It is important that measures are designed that this wetland will be provided with sufficient water year round, and further drainage of the area should not be allowed.

The findings of the initial environmental evaluation are summarised in the "screening table" above.

5.5 Strategic directions

5.5.1 Land use scenarios

In the Cambodian West of Bassac region "living with flood" is the leading concept. Land use is merely restricted to single rice cropping in the absence of adequate structural measures for flood management and irrigation. The formulation of a strategic direction for flood risk management in the deep flooded areas is based on the living with flood concept in combination with the following land use scenarios:

1. single cropping in the deep flooded area (actual land use)
2. double cropping in the deep flooded area
3. double or triple cropping in the shallow flooded areas

The direct relation between the different land use scenarios and flood risk management strategies is as follows:

- Single cropping can be done without protection of the agricultural land. Structural measures can be restricted to protection and/or flood proofing of human settlements and public infrastructure.

- Double cropping in the deep flooded areas requires flood management to secure that sufficient flood free time is available between two floods. In practice, this comes down to early flood protection of the agricultural land and/or adequate drainage of flooded areas after the flood. Additional protection and/or flood proofing will be required for infrastructure and human settlements.

- Double or triple cropping in the shallow flooded areas requires a full protection of these areas. A differentiation of the protection levels in these areas is to be considered, in which human settlements and essential infrastructure is provided with a higher level of protection then the agricultural areas.

5.5.2 Flood management strategic directions

The existing flood risks in the West of Bassac area do not justify substantial investments in flood protection works to reduce agriculture related risks. In case no further agricultural development in this area is envisaged, flood risk management measures should focus on the reduction of flood risks related to business, housing and infrastructure. These risks can be reduced by:

- early warning
- relocation of houses and businesses
- flood proofing and/or protection of residential areas and infrastructure.

An early warning system for the inhabitants of the flood prone areas is already in place. Relocation of houses and or business may be considered if the related costs are less than flood

proofing and/or protection. This is not likely to be the case. For that reason it is suggested to focus on flood proofing and protection of the objects that are at risk in the flood prone areas.

Agricultural development can be strived at in the shallow flooded areas (zones 1 and 3), the deep flooded area (zone 2) or in both. A socio-economic evaluation is required to determine the most attractive approach and/or phasing for such development.

Flood risks in the shallow flooded areas are related to the peak flood levels rather than to early floods. Risk reduction measures in these areas should therefore aim at protection against the main flood. The level of protection of the agricultural lands is to be derived from a socio-economic evaluation. It is anticipated that a 10% protection level will be adequate (this means that flooding is accepted once in the ten years on the average). For the residential and business areas and the infrastructure within these protected zones a higher level of protection may be more appropriate, for instance 4 or 5%.

(It is noted that living in a protected zone may bring additional risks. Flooding of a protected zone may be caused by a dike breach. A dike breach creates more hazardous conditions than normal flooding. Early warning is often not possible and high flow velocities may locally occur.)

Agricultural development in the deep flooded area requires protection against early floods in order to have sufficient time available for the safe harvesting of a second crop. This protection can be provided in different ways:

- by providing protection to the early flood level only (once this level is exceeded the protection works will be overflown and the protected area will inundate automatically;
- by providing controllable protection works that allow the flooding to take place when suitable (This type of protection is practiced in the deep flooded areas in Vietnam)

It is suggested to follow the first (less costly) approach. In a later stage of development of the area it can than be considered to upgrade the protection works to "flood management" works.

Protection of the deep flooded areas against early floods is supposed to go together with protection and/or flood proofing of residential and business areas and essential infrastructure for not only the early but also the main flood.

5.5.3 Mitigation of transboundary effects

The preliminary results show that the early flood protection in the West of Bassac area in Cambodia may have marginal impacts, if any, on the flood risk in Vietnam. More detailed modelling is required to make a more accurate assessment. In case the increase, if any, of the flood risks in Vietnam is not considered acceptable, mitigating measures are to be found that compensate for the loss of storage during the early floods. It is suggested to investigate the possibility to compensate for this loss by providing additional discharge capacity of flood waters in the border area towards the Gulf of Thailand (West China Sea).

CHAPTER 6

STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE EAST OF MEKONG AREA IN CAMBODIA (PREY VENG)

6 STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE EAST OF MEKONG AREA IN CAMBODIA (PREY VENG)

6.1 Flood damages and risks

The flood risk in this region has been estimated for the Kampong Trabek District only (see Volume 2C). This risk has been estimated at 0.7 million USD per year. Flood hazards in this district are less severe than those in the districts Preah Sdach and Peam Chor that are located between Kampong Trabek and the Mekong. Further analysis is needed to assess the flood damage risk at the level of the focal area. From the flood hazard map it is preliminary estimated that the flood risk in this region is of the order of some USD 2 mln per year. Over 60 % of this risk is related to agricultural damage.

Flood damage to agriculture is mainly for the wet season paddy in the surveyed district.. In the absence of August-flood protection as practised in Vietnam, the flood damages to agriculture (mainly paddy cultivation) depends more on the maximum annual level of the flood than on its timing. Therefore, also for Agriculture the maximum annual flood level has been used to analyse the flood damages.

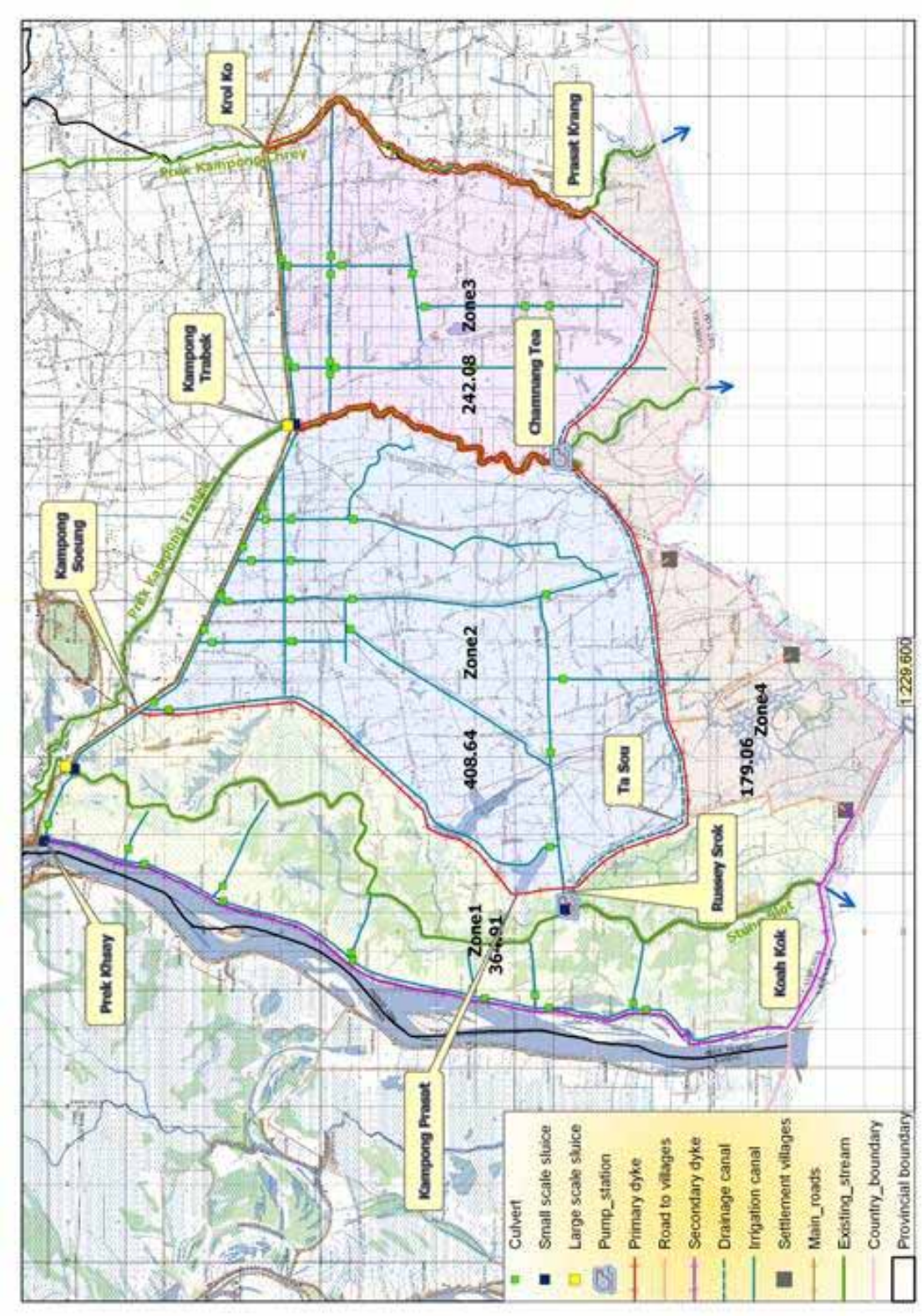
6.2 Flood benefits

Results from focus group discussions held in focal areas showed that benefits from natural fishing for people living in deeply flooded area would vary from 80-945 US$/household. According to the above mentioned MRC-Technical Paper, average amount of fish catch from rice field in Mekong Delta Flood Plain (deep water flooded areas) would be 80-119 kg/ha resulting in the value of 30-40 US$/ha. The amount of fish catch from rice field in Prey Veng province would be 55-92 kg/ha resulting in the value of 20-30 US$/ha. Farmers also mentioned that floods have significant benefit for crop cultivation. After big a flood, Winter-Spring Paddy (Planting in November and harvesting in March) has a higher yield than normal flood years by 1.5-2.0 ton/ha. It would result in flood benefit for agriculture of about 150-230 US$/ha after a big flood. Assuming big flood frequency of one third, the annual flood benefit for agriculture would be 50-77 US$/ha.

6.3 Structural flood risk management options

To the south of the RN1, the flood plain is drained by the two major rivers the Stung Slot and the Prek Kampong Trabek. Flood water expands to both sides of these two rivers in their respective flood plains, Low lying area (elevation 3-4m amsl) extends from the flood plain of the two rivers further south leaving the middle part with higher elevation (above 5.0m amsl) where is concentrating settlement of subsistence rice farmers communities. Towards the Cambodian/Viet Nam border, low lying areas practically joint together to form a vast deep flooded area.

The focal area has a total extension of 1,194.7 km^2 (119,469 ha). The total area has been sub-divided into four flood protected zones, see **Error! Reference source not found.**


Krol Ko
Prek Kampong Chhey
Prasat Krang
Kampong Trabek
Zone3
242.08
Chamnang Tea
Kampong Soeung
Prek Kampong Trabek
Zone2
408.64
Ta Sou
179.06
Zone4
1:229,600
Russey Srok
Stung Slor
Zone1
364.91
Prek Khsay
Kampong Prasat
Koah Kok
Culvert
Small scale sluice
Large scale sluice
Pump_station
Primary dyke
Road to villages
Secondary dyke
Drainage canal
Irrigation canal
Settlement villages
Main_roads
Existing_stream
Country_boundary
Provincial boundary

- Zone 1 between the Mekong and the Stung Slot river (deep flooded zone 364.91 km^2). The zone 1 has an extension of 364.91 km^2 and belongs to the deep flooded area with longest flood duration as compared to other areas. People live only along the Mekong river bank and sparsely along the Stung Slot river bank in the northern part. Most of them depend on fisheries, dry season cash crop and dry season rice crop from May to July (generally one crop per year due to lack of water management). The beginning of the crop season depends on the speeds of the flood recession, generally (December-January).

- Zone 2 between the Stung Slot and the Prek Kampong Trabek river (408.64 km^2). This zone is dominated by subsistence rain fed wet season rice. The zone is located in between the Stung Slot and Prek Kampong Trabek rivers. Most of the area located in the Stung Slot and Prek Kampong Trabek rivers is subject to frequent floods, while other parts of the zone, at higher ground elevations suffers from drought.

- Zone 3 between the Prek Kampong Trabek and the Prek Kampong Chhrey river (242.08 km^2). The western part of this zone is considered as deep to shallow flooded areas, whereas the southern part slopes down to the zone 4 deep flooded area.

- Zone 4 is located within the deep flooded area in the southern part of the three other zones (179.06 km^2). In this zone only dry season recession rice crops are possible due to high flood depth and duration. This zone could be subdivided into two parts i) between the Stung Slot and the Prek Kampong Trabek, ii) between the Prek Kampong Trabek and the Stung Kampong Chhrey. This zone is not easily accessible by roads during the flood season. Currently two dry season crops are possible, when water is taken from the Soha Caico canal at the border and sufficient time is available between two floods.

Structural flood risk management options have been outlined that would aim at securing and stabilizing rice production of at least two crops per year as follows:

The zone 1 would be protected against early flood, zones 2 and 3 would have a protection against the 1:10 years flood and zone 4 zones would have no protection.

Zone 1:

This deep flooded area would be protected against early floods until the 1st of August. After end of July the area would be left flooded until November-December. The flood recession crop will start from November until April depending on the ground elevation and speed of the flood recession. A limited early crop season starts from May and it is harvested in July. Water supply for May-July crop season would be supplied by low head pumping.

The zone would be protected by the following components:

1. One dike along the left bank of the Mekong to protect against early flood spill until end of July. This dike starts at Prek Khsay and it is connected to the RN1 and extends to the south, along the Mekong bank, up to the border with Vietnam near Koh Kok.
2. Rehabilitation of seven controlled colmatage canals that would remain connected to the dike along the left bank of the Mekong and the Stung Slot River. The canals have the function of drainage and water supply in this zone;
3. A flood proof dike/road embankment from Russey Srok to the border with Vietnam at Koh Sampouv. This dike/road embankment is designed with crest level to protect against early flood only.
4. Until end of July the discharge capacity of the opening under the RN1 bridge would be controlled to protect against early flood caused by the Stung Slot river flow.

Zone 2:

This zone has an extension of 408.64 km^2 and is considered as shallow flooded area and would be protected against the 1:10 years high flood. This zone could allow for three crops per year. The following structural measures are proposed:

1. One flood protection dike bordering the left floodplain of the Stung Slot river. The crest level of this dike is designed to protect against the high flood with return period 1:10 years. This dike starts around Kampong Soeung and ends at Russey Srok south at Kampong Prasat. This dike is the west boundary of zone 2.
2. One dike along the right bank of the Stung Kampong Trabek river starting from Kampong Trabek to Chemnang Tea. This dike would be designed with crest level required to protect against 1:10 years flood.
3. One discharge control structure at Kampong Trabek bridge on RN1.
4. An irrigation canal parallel to RN1 from Kampong Seung to Kampong Trabek.
5. A pumping station and drainage canal running from Ka Sou to Chemnang Tea.
6. Inside this zone 2 there is also proposed an irrigation and drainage canal network.
7. A flood proof dike/road in the southern part (between zone 4 and zone 2) Ka Sou to Chemnang Tea. The crest level of this dike/road would be designed to protect against 1:10 years flood.

Zone 3:

This zone could be also considered for double rice cropping (wet season and recession crops) by pumping from the Prek kampong Trabek. To secure two full crops per year, the following measures are envisaged:

1. Flood protection dike along the left bank of the Prek Kampong Trabek river, from Kampong Trabek to Chemnang Tea. The dike is designed for protection against the 1:10 years flood.
2. Flood protection dike along both sides of the Stung Kampong Chhrey river. The crest level of this dike is also designed to protect against flood with 1:10 years return period. The dike starts at Krol Ko to Prasat Kraing.
3. Irrigation/drainage canals for irrigation and water supply inside zone 3;
4. Lateral drainage canal at the border with the zone 4 with pumping station at Chemnang Tea to drain out excess flood water caused by local rainfall.
5. A flood proof dike/road embankment in the southern part (between zone 3 and zone 4) from Chemnang Tea to Prasat Kraing. The crest level of this dike/road would be designed to protect against 1:10 years flood.

Zone 4:

To address the problem of flood and people living far away from their lands, the following structural measure is proposed:

1. Construction of flood proof settlement areas along the border with Vietnam, including connection to road embankments. Each settlement area would allow accommodating 200 families. The total area each settlement is 60,000 m^2.

6.4 Impacts of structural flood risk management options

6.4.1 Flood risk reduction

In case early flood protection is provided to the deep flooded areas and year around protection to the shallow flooded areas[5] the risk reduction has been estimated at 0.5 million US$/year in Kampong Trabaek, or about two third of the actual risk. This estimated risk reduction is mainly related to the reduction of the agricultural risk in the shallow flooded area.

The benefits of the protection of the deep flooded areas against the early floods come from a second crop that can be planted once also irrigation water will be available. According to 2006 statistics, the dry season paddy area was 6,900 ha in Kampong Trabaek district. It is expected that the second paddy crop in these focal areas would be the same as dry season crop. Assuming that the net benefits from paddy is 500 US$/ha, it would result in 3.45 M US$/year in Kampong Trabaek district.

6.4.2 Transboundary impacts

The flood risk management options that consider protection of agricultural areas go automatically together with the reduction of the storage of flood waters in these areas until the design level of protection works have been reached. This reduction of floodplain storage results in the increase of the river discharges at and downstream of the protected area and, consequently in the increase of the river water levels.

The results of these simulations are shown and described in the Appendix 6 of Volume 2B. It has to be taken into account that the model allows for a relative assessment of these impacts only. That is to say that the presented absolute values are to be given due care. More accurate modelling is required to assess the absolute values of these impacts and the eventual impacts on the flood risks in Vietnam.

From the modelling results it is learned that the protection works in the Prey Veng area south of National Road no 1 in Cambodia tend to have a positive impact on the flood risks in the Plain of Reeds in Vietnam. This is due to the fact that the protection works in Cambodia block, partially, the actual floodplain flow on the left bank flood plains of the Mekong. This holds for both the early flood and the peak flood. This would result in reduction of risk for Vietnam of 1.4 million US$/year in Tan Hong district, and 0.5 million US$/year in Tam Nong district.

In the Bassac river, though, the maximum flood levels may increase 1-3 decimetres at Chau Doc and about 1 decimetre under early flood conditions.

6.4.3 Environmental impacts

Sensitive and valuable ecosystems that are encountered in this region, such as seasonally-inundated riparian forests; seasonal wetlands, including marshes, small pools and pools; and seasonally inundated grasslands are essentially the same as those for the West of Bassac area described in Chapter 5..No officially protected areas are located in the project area.

The potential environmental impacts of flood risk management in this area correspond, therefore, with those described in the previous chapter.

[5] protection levels are set at 10%, that is to say that protection is given for 9 out 10 years on the average

6.5 Strategic directions

6.5.1 Land use scenarios

Also in the Cambodian East of Mekong region "living with flood" is the leading concept. Land use is merely restricted to single rice cropping in the absence of adequate structural measures for flood management and irrigation. The formulation of a strategic direction for flood risk management in the deep flooded areas is based on the living with flood concept in combination with the following land use scenarios:

1. single cropping in the deep flooded areas (actual land use)
2. double cropping in the deep flooded area
3. double or triple cropping in the shallow flooded areas

The direct relation between the different land use scenarios and flood risk management strategies is as follows is as described in the previous chapter.

- Single cropping can be done without protection of the agricultural land. Structural measures can be restricted to protection and/or flood proofing of human settlements and public infrastructure.

- Double cropping in the deep flooded areas requires flood management to secure that sufficient flood free time is available between two floods. In practice, this comes down to early flood protection of the agricultural land and/or adequate drainage of flooded areas after the flood. Additional protection and/or flood proofing will be required for infrastructure and human settlements.

- Double or triple cropping in the shallow flooded areas requires a full protection of these areas. A differentiation of the protection levels in these areas is to be considered, in which human settlements and essential infrastructure is provided with a higher level of protection then the agricultural areas.

6.5.2 Flood management strategic directions

For the flood management in East of Mekong area the same strategic direction is proposed as for the West of Bassac area described in section 5.5.2. An essential difference, though, would be to keep a substantial zone unprotected near the Vietnamese border. Flood protection in this area is closely related to the operation of the flood management infrastructure in Vietnam and flood management, if any, in this area is to be done jointly with Vietnam.

6.5.3 Mitigation of transboundary effects

The preliminary results show that the flood protection in the East of Mekong area in Cambodia would have positive impacts on the flood risk in the Plain of Reeds in Vietnam. More detailed modelling is required to make a more accurate assessment.

A slight increase in the flood water levels in the Mekong is anticipated though. This increase could be compensated for by creating additional discharge capacity in the border zone, either towards the Vam Co river, the Gulf of Thailand or both.

CHAPTER 7

STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE WEST OF BASSAC AREA IN VIETNAM (LXQ)

7 STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE WEST OF BASSAC AREA IN VIETNAM (LXQ)

7.1 Flood damages and risks

For the estimate of the flood risks in the LXQ reference is made to the Volume 2C. The average annual damage in the An Giang Province alone has been estimated at some 23 million USD per year. The flood risk in the surveyed Chau Phu District has been assessed at 1.9 million USD per year. It is noted that a substantial part of the risk in the An Giang province is related to bank erosion. This phenomenon is not reflected in the flood risk of the Chau Phu district.

Further analysis is needed to assess the flood damage risk at the level of the focal area. From the flood hazard maps it is preliminary estimated that the flood risk in the Vietnamese part of the focal area (Long Xuyen Quadrangle) could be two times the flood risk of An Giang Province only.

It is noted that under the present land use and flood protection conditions the risk related to agriculture is relatively low as compared to the total risk. The share of agricultural risk is only 1% of the total risk. By far most of the risk (about 85%) is related to infrastructure and relief.

It is moreover noted that under average flood conditions hardly any damage occurs and that most risk is related to extreme flood conditions. Apparently, adequate protection is already in place for the lower floods.

7.2 Flood benefits

Apart from the negative impacts of flooding as mentioned above, floods also have positive impacts on the social economy such as natural fishing and soil fertility. Results from focus group discussions held in the Vietnamese focal areas showed that:benefits from natural fishing for people living in deeply flooded area vary from 100-300 US$/household in normal flood years and from 120-750 US$/household in big flood years.

According to the MRC-Technical Paper No 16 on fish yields, the average amount of fish catch from rice fields in the Mekong Delta Flood Plain (deep flooded areas) are 80-119 kg/ha, resulting in a value of 30-40 US$/ha. Farmers also mentioned that floods have significant benefit for crop cultivation. After big a flood, application of fertilizers and pesticides to Winter-Spring Paddy (Planting in November and harvesting in March) is less than in a normal flood year, and the yield is higher by 0.5-1.0 ton/ha. It would result in flood benefit for agriculture of about 200-300 US$/ha after a big flood. Assuming big flood frequency of one third, the annual flood benefit for agriculture would be 60-100 US$/ha.

7.3 Structural flood risk management options

7.3.1 Options

The transboundary focal areas correspond with the so-called deep inundation areas. The Vietnamese long term planning for these areas is essentially based on the "living with floods" concept and management of floods to allow for a safe production of double rice Winter-Spring and Summer-Autumn crops.

The following objectives have been formulated by Vietnam for the flood management in the deep inundation areas:

1. Agriculture: Double rice cultivation of winter-spring and summer-autumn has to be produced reliably and stably ; it is recommended not to encourage to produce the third crop season; fruit trees are to be reasonably developed in favourable areas; creating favourable condition for changing crop seasons; develop agriculture mechanization.
2. Transportation:
    a. National roads, inter-provincial roads and provincial roads: roads are reliable and safely constructed over flood level of 1961 for transportation during the whole flood season.
    b. District roads: constructed according to probability of road scales of non-inundated with low and medium floods and inundated with high foods
    c. Rural roads: will be constructed over water levels of low, medium and high floods of the early and late season. These roads might be inundated by large floods. Although having favourable condition, construction of higher roads should not be done because of blocking flood ways causing increases of water levels and longer inundation.
3. Navigation lines:
    a. Inter-province lines: It should be operating fully in the flood season hence it has to have ship-transfer facilities in case of flood control works block free passage of the waterway;
    b. Inner-region: Full transport only in inner-region is needed hence vessell transfer facilities are not needed.
4. Residential areas:
    a. Towns and inhabitant centres , schools, infirmaries have to be ensured of no inundation in the flood season, including high floods
    b. Inhabited lines along large roads and big canals have to be ensured not to be inundated in the flood season
    c. Scattered inhabitant areas need to be protected in the flood season

For the Long Xuyen Quadrangle these objectives are specified as follows:

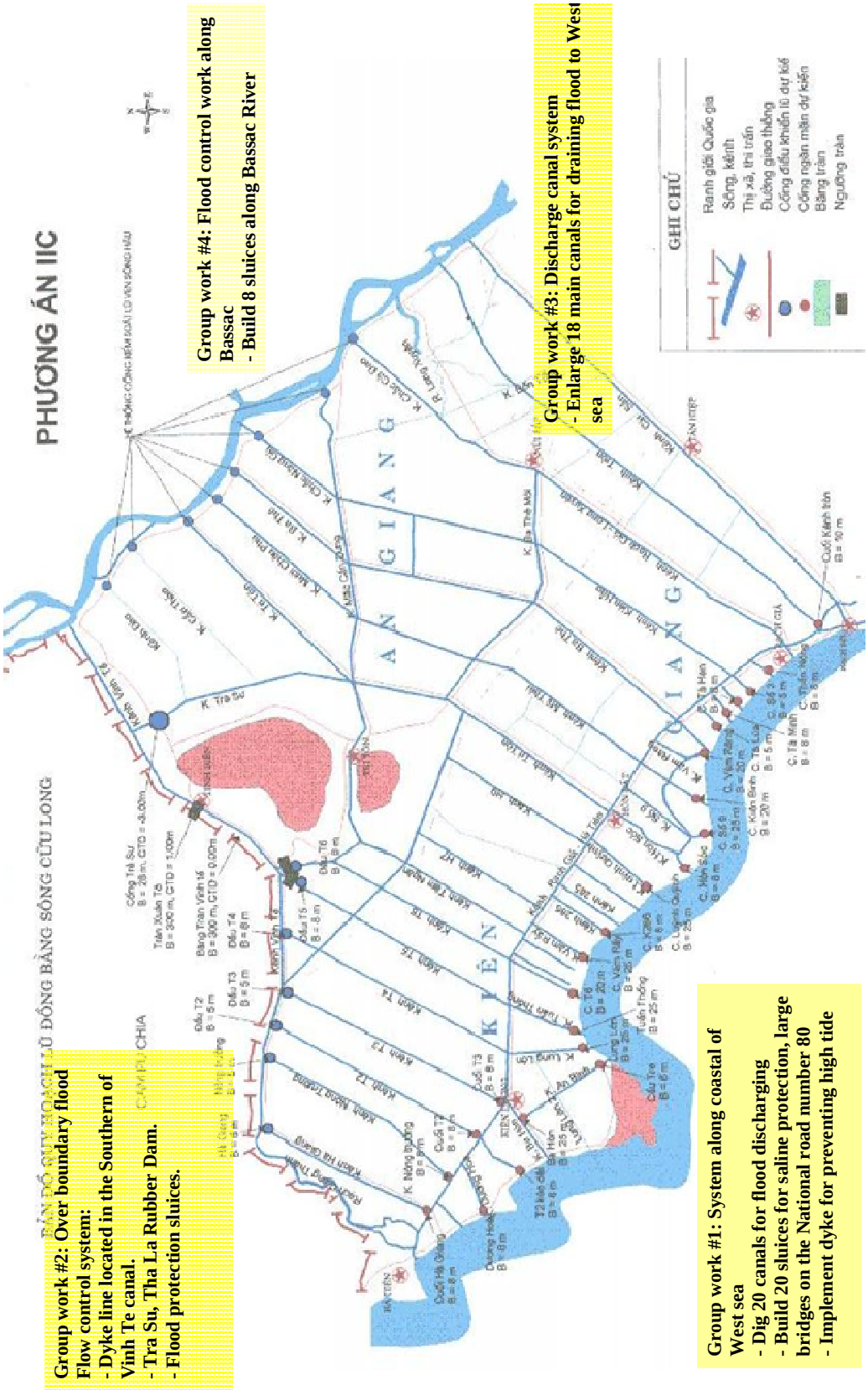
1. Safely protect all inhabited and urban areas;
2. Full transportation in the whole year for National Road 80, National Road 91, National Road N1, National Road N2 and the provincial Road Long Xuyen – Hue Duc, Long Xuyen - Tri Ton;
3. Reduce water levels for early and end-of-season in order to safely produce double rice : Winter-Spring and Summer-Autumn;
4. Reduce level of flood-peaks for main-flood-season in the eastern sub-area and areas along the National Road 80;
5. Reclaim land of the Ha Tien Quadrant in order to put into agricultural production;
6. Combine with other hydraulic works in order to complete water resources system for development of socio-economy. Simultaneously, combine with transportation construction and inhabited areas in order to develop rural areas in a trend of civilization and modernization.

7.3.2 Structural measures

The structural measures that have been identified to realize above mentioned objectives are shown in the **Error! Reference source not found.** overleaf and refer to:

1. Control floods from the border to the Long Xuyen Quadrant and drain floods to the Gulf of Thailand
2. Build up flood drainage construction to the Gulf of Thailand
3. Build up salinity prevention construction, and keep fresh water in the coastal areas of the Gulf of Thailand
4. Build up flood control construction from the Bassac river to the Long Xuyen Quadrant.

These structural measures allow in principle not only for a protection against early floods but also for full control of floods that are lower than the design flood of the works.



7.4 Impacts of structural flood risk management options

7.4.1 Flood risk reduction.

If the flood risk management works as described above would be operated to provide full protection to the LXQ, then most of the flood risks, apart from the bank erosion, would be eliminated. This would give a risk reduction of some USD 1.9 million/year for the Chau Phu District only.

If these works, however, would be operated to protect the LXQ against the early floods only (until half of August) then only the very minor agricultural risk would be eliminated.

Full protection would enable a third paddy crop. Currently, there are 1,913 ha in Chau Phu district covered by the third crop during the flood season. These areas are bounded by national roads and embankments developed by local authorities. The existing third paddy crop occupies about 5% paddy land in Chau Phu district. Since the third crop grows during the rainy season with high flood water in river and canal, drainage of excess water on the field by pumping would be critical. It is assumed that additional 70% of paddy land could be used for a third crop, considering the existing third paddy and that depression areas may not economically for this crop. Net benefit of additional paddy would be at the rate of 900 US$/ha, resulting in expected additional benefit from cultivation of third paddy as USD 24 million in the Chau Phu district.

Full flood protection in LXQ would reduce natural fish on paddy field at the rate of of 30-40 US$/ha. Taken into account the remaining flooded paddy area, the fish loss would be some USD 1.3 million/year in Chau Phu district.

Flooding brings sedimentation to the delta, leaches acid sulphate substances and toxicity from the soil, and controls pests. This benefit was evaluated as 60-100 US$/ha for W-S paddy. Full flood protection would create the loss of these benefits to an estimated amount of some USD 2.6 million/year for Chau Phu district.

7.4.2 Transboundary impacts

The flood risk management options that are described in the previous section allow for the management of not only the early floods, but also the floods arriving after August. Operation of the flood management infrastructure beyond the early flood (or half of August) will create increased water levels in the rivers both downstream and upstream of the protected area. In principle the flood management infrastructure could be kept closed until after the passage of the flood peak. In that case, the peak levels upstream of the protected area will increase and affect directly the flood risk in Cambodia.

Runs with the ISIS model have been made to simulate the impact of the scenario which implies that for the Vietnamese Focal Areas flood water will enter neither Long Xuyen Quadrangle nor the Plain of Reeds unless the management decides for controlled inlet. The conditions in the Cambodian Focal Areas are as in the present conditions.

The results of these simulations are shown and described in the Appendix 6 of Volume 2B. It has to be taken into account that the model allows for a relative assessment of these impacts only. That is to say that the presented absolute values are to be given due care. More accurate modelling is required to assess the absolute values of these impacts and the eventual impacts on the flood risks in Vietnam.

The results of these runs indicate that full flood control for the Focal Areas Long Xuyen Quadrangle and Plain of Reeds would aggravate the flooding conditions in Cambodia: from 1.5

to 1.7 m in Prey Veng to 0.5 to 0.8 m in Takeo. Corresponding increment of risk have been calculated at some USD 1 million US$/year in Koh Andet district and USD 0.3 MU US$/year in Koh Thom district. It is repeated again that these calculations are based on ISIS simulation results, and should be considered with due care.

7.4.3 Environmental impacts

Sensitive and valuable ecosystems that are encountered in the Vietnamese Mekong Delta are Melaleuca swamp forests and seasonally-inundated grasslands. These remaining natural areas are important as a habitat for a large number of bird species. Seasonally inundated grasslands, together with inundated paddy fields are important fish spawning and rearing areas.

No officially protected areas are located in Long Xuyen Quadrangle, however, Bird Life International identified 10 priority wetland areas for conservation at the national or provincial level.

Population in the project area is concentrated along the river and canal banks, where densities are considerable. There is a shortage of agricultural land and pressure on the resource is high. Water courses in the area, rivers and canals, are used as a source for drinking water by a large proportion of the rural population.

The area is intensively cultivated, with rice as the main crop. Fisheries is important in the flood season. It is a source of food and income for a substantial part of the population.

The potential environmental impacts of implementation of 'full protection' of the Long Xuyen Quadrangle are described briefly in the following. It has to be remarked that full protection only means that floods can be kept out of the area completely, but that this will probably not be the case. Controlled flooding of certain areas during certain parts of the year will be allowed, possibly in a rotational scheme.

1. Destruction of natural habitats, valuable resources
   1.1. Natural and semi-natural vegetation communities in the area are limited in extent and are under heavy pressure. Both the Melaleuca swamp forests and the seasonally flooded grasslands are dependent on regular, annual flooding. Keeping the floods completely out will result in a deterioration of these ecosystems and have a very negative impact on the species diversity of the flora and fauna. Especially waterfowl (73 species) and wetland dependent birds (another 27 species) will reduce in numbers or disappear completely. However, keeping out the floods completely is not likely to happen and measures to provide the remaining natural swamp and grassland areas with sufficient water could be designed.
   1.2. Indirect impacts on the remaining natural areas are probably as important as reduced flooding. Better protection of the area will increase the value of the land for agricultural production and hence will increase the pressure on the presently not-cultivated areas. Already now there is a shortage of land and encroachment in natural areas.

2. Loss of biodiversity, rare and endangered species
   2.1. Reduced flooding will have an impact on the biodiversity in the area. Species composition of flora and fauna will change and the diversity and extent of swamps and grasslands will reduce.
   2.2. Disappearance of the swamp forest would mean loss of plant species like Melaleuca leucodendron, Syzgium sp., Elaeocarpus hygrophilus, Ficus microcarpa and Cassia grandis, as well as a number of fish, amphibians, reptiles and birds. The forests are of prime important for breeding colonies of large water birds.

2.3. Loss of the seasonally inundated grasslands would mean the loss of plant species like Eleocharis dulcis, Oryza rufipogon, Phragmites vallatoria, Eleocharis ochrostachys, Ischaemum rugosum, Lepironia articulata, Eragrostis atrovirens, Setaria viridis, Mnesithea laevis and Panicum repens. Globally threatened birds like the Bengal Florican Houbaropsis bengalensis and White-shouldered Ibis Pseudibis davisoni, would lose an important habitat, as would the Sarus Crane Grus antigone.

2.4. A total of 194 birds species have been identified in a 1999 survey, fourteen of which are globally threatened or near-threatened. Of these, three are classed as endangered, two as vulnerable and nine as near-threatened.

2.5. The Mekong Delta provides habitat for a significant proportion of the regional or global population of several bird species. Most notably, the Glossy Ibis legadis falcinellus, Little Egret Egretta garzetta and Cattle Egret Bubulcus ibis, Indian Cormorant Phalacrocorax fuscicollis and Purple Heron Ardea purpurea.

2.6. Bird species richness is highest in seasonally inundated grassland and swamps (100 species), while anthropogenic habitats (including paddy fields, aquacultural ponds and villages) have the lowest richness (83 species). Melaleuca forest also holds a large number of species (97).

2.7. Of the 14 globally threatened or near-threatened species recorded in the area, nine were recorded in seasonally inundated grasslands and swamps, and only three were recorded in anthropogenic habitats (Greyheaded Lapwing, Spot-billed Pelican and Painted Stork).

2.8. There are 260 species of fish known to occur in the area, 200 of these contribute to the commercial fishery. A large proportion of these has an inundation spawning pattern and undertakes lateral migrations from the mainstream and tributaries into the inundation zones to spawn and rear young between July and September. Late or no access to the floodplain or blockage of migration routes will have an impact on the standing stocks of these migrating species and may ultimately lead to the disappearance of certain species.

3. Loss of environmental services

3.1. Flooding and the related sustenance of wetlands is known to have a number of benefits, these benefits may disappear or decrease if flooding is prevented or diminished, as discussed below.

3.2. Higher agricultural production: information gathered during Focal Group discussions in the area showed that paddy yields after a year with a high flood are substantially higher than in a year after a year with a normal flood. After a high flood the yield is 0.3 to 1.5 ton/ha (4 to 20%, on average 0.7 ton/ha) higher. Not only the yields are higher, but also the related production costs are lower (15 to 20%), resulting in a net benefit of the flooding for agriculture of between 2.35 and 5.50 million VND/ha. The difference can be attributed to a number of positive effects of the flooding: the floods bring fertile sediments, acidity, toxic materials and salts are flushed from the land and harmful insects and pests get killed. In flood free areas the replenishment of groundwater and surface water bodies with flood water will not take place. This will affect the quantities of water available in the next season. This is probably not a big problem, because water can be brought to the area via the canal system. Of more importance is that not only the available quantity will be affected, but also the quality of the water. Pollutant concentrations increase in the course of the dry season and flooding flushes these pollutants out or reduces the concentrations to harmless levels. Reduced flooding will result in a deterioration of the water quality in the area. The Melaleuca forests provide a number of valuable products to local people. The timber is valued for construction of housing, and is also used as fuel wood. The production of honey is practiced in Melaleuca forest, and honey harvested from wild bees is particularly highly valued. Other forest products are taken to provide a source of income. These include aquatic fauna for food, Melaleuca oil (a valuable medicine),

'chaoi' Stenochlaena palustris (a plant used for making rope and fish nets), 'mop' Alstonia spathulata (a woody plant used for making fishing floats) and Melaleuca bark (used for thermal insulation).

4. Impact on Protected Areas
   4.1. In the Long Xuyen Quadrangle Focal Area, 10 priority wetland sites for conservation have been identified. Highest priority is given to the seasonally inundated grasslands of the Ha Tien plain and the Tinh Doi and Tra Su wetland areas.
   4.2. The Ha Tien plain contains significant populations of several globally threatened and near-threatened birds (Sarus Cranes and the endangered White-shouldered Ibis). The area also has a high diversity in flora, including unique gradients from brackish to freshwater and from acid to alluvial vegetation communities.

5. Impact on Fisheries
   5.1. Fisheries is important for the rural population in the area. A much as 200 different fish species contribute to the fisheries in the area, in addition shellfish, mainly Mollusca and Crustacea, are collected. Some 70% of the households in the area is involved in fishing. All fishing households use part of the fish catch for consumption. Most families sell part of the catch to increase family income. In total some 50% of the capture fish production is sold to markets.
   5.2. The main habitats used for fishing, in order of importance, are flooded irrigated rice lands and riverine floodplains, perennial rivers, perennial canals and rainfed rice paddies. Flooded rice fields are the main fishing ground during the flood season.
   5.3. The importance of the flooding for fisheries is illustrated by the results of the Focal Group discussions held in the area. It appeared that during a high flood catches are 50 to 100% higher than in years with a normal flood. Average value of the catch per household during a normal flood was reported to be 3.6 million VND, in a high flood year this is 6.2 million VND, or an increase with about 75%.
   5.4. Making the area completely flood free, will basically destroy the inland fisheries. Fish will not be able to migrate to the flooded wetlands and rice field and the area of feeding and spawning grounds will reduce, as will the area where fish can be caught. As a rule of thumb it is estimated that for every ha that does not flood, fish production lowers with about 100 to 200 kg.

6. Land acquisition and resettlement
   6.1. Project implementation will entail canal and dike construction or enlarged. These canals and dikes will mainly follow existing alignments. In other words, a fairly large percentage of the works will be carried out at places where the population is concentrated and land acquisition and resettlement may be unavoidable.

7. Human health and safety impacts
   7.1. Overall the project will have a positive impact on human health and safety. People will be better protected against flooding, floods will last shorter and food (rice) production, and so food security, will increase. This is not necessarily the case for the amount of fish available in the flood season. Reduced flushing and dilution of polluted water at the end of the dry season may pose a threat to human health.
   7.2. Construction activities are another threat to health and safety for a variety of reasons: emission of dust, fumes, noise and vibration from construction sites and access roads, increased traffic and workers accidents. Inflow of workers from other areas increases the risk of a spread of HIV/AIDS.

Reduced flooding in the Vietnamese Delta will have a number of significant environmental impacts. Probably most important is the negative impact on inland fisheries. Reduction of access to the floodplain for migratory fish and reduction of the area where the fish can spawn and feed, will reduce the possibilities of rural people to be engaged in fisheries as a means to improve household nutritional conditions and household income.

Also important is the very likely further decline of the few remaining natural areas (seasonally flooded grasslands and Melaleuca swamps). These areas are important habitats for a large variety of flora and fauna species, among which a number of rare and endangered species.

Finally, a number of environmental benefits of flooding will be lost. Important are the decreased supply of fertilizing sediments, the reduced flushing of acid and toxic materials from the soil and the reduced sanitation of the area (pest control). Also the reduced flushing and diluting of polluted water at the end of the dry season will result in deteriorating water quality conditions.

It is recommended not to make (parts of) the area completely flood free. A system of controlled flooding should be designed, which reduces the damages, but at the same time conserves the benefits of the flooding as much as possible. Special attention should be given to the remaining natural area's, they are not only threatened by changes in the flooding regime, but also, and probably even more so, by encroachment of local people.

The potential environmental impacts of implementation of 'full protection' of the Long Xuyen Quadrangle are summarized in the following screening table.

7.5 Strategic directions

7.5.1 Flood management strategic directions

Strategic directions for flood risk management in the LXQ are clearly defined in the long term flood control planning 1998, as approved by the Vietnamese Government in 1999. Objectives and guiding principles for the flood management in the Long Xuyen Quadrangle have been mentioned above under section 7.3.1.

7.5.2 Mitigation of transboundary impacts

From the model simulations as described in Volume 2B it is clear that any flood management that goes beyond the early flood (half of August) protection, will have impact on the flood hazard and eventually the flood risk in Cambodia.

Retention options to compensate for lost storage capacity are hardly available in the Vietnamese part of the Mekong Delta. It is therefore suggested that compensating measures are sought in the diversion of floodwaters just upstream of the protected LXQ area towards the South China Sea (Gulf of Thailand).

Screening question	Yes	No	Remark
A. Project siting Is the Project area adjacent to or within any of the following environmentally sensitive areas?			
– in or near sensitive and valuable ecosystems (e.g., protected areas, wetlands, wild lands, coral reefs, and habitats of endangered species)	X		remaining areas of Malaleuca forest and seasonally inundated grasslands are important bird habitats. No official protected areas are located in the Long Xuyen Quadrangle, but 10 priority sites have been identified for conservation. In the Plain of Reeds Focal Area there are two protected areas. Tram Chim National Park and the Lang Sen Wetland Reserve.
– in or near areas with cultural heritage sites (e.g. archaeological, historical sites or existing cultural or sacred sites)		X	
– densely populated areas where resettlement may be required or pollution impacts and other disturbances may be significant		X	population is concentrated along canals and dikes, works will concentrate on these areas
– regions subject to heavy development activities or where there are conflicts in natural resource allocation	X		in the project area agricultural land is in demand, putting pressure on the land as a resource
– watercourses, aquifer recharge areas, or reservoir catchments used for potable water supply	X		canal and river water is used as a source for domestic water by a large proportion of the population in the area.
– lands or waters containing valuable resources (e.g. fisheries, minerals, medicinal plants, prime agricultural soils)	X		the area is a very important rice producing area. Besides fisheries provides additional food and income to the rural population
B. Potential environmental impacts Is the project likely to lead to:			
– permanent conversion of potentially productive or valuable resources (e.g. fisheries, natural forests, wild lands)	X		the seasonally flooded grasslands and Melaleuca forests have high conservation value, flooded paddy fields are important as fish rearing areas.
– destruction of natural habitat and loss of biodiversity or environmental services provided by a natural system	X		a reduction of the flooded area will affect the flora and fauna diversity (fish and water birds) and will have a negative impact on the fisheries resource.
– risk to human health and safety (e.g. from generation, storage, or disposal of hazardous wastes, inappropriate occupational health and safety measures, violation of ambient water or air quality standards)		X	limited, some construction activities related health and safety risks are to be expected. Improved flood protection on the other hand reduces risks and improves food security and thus health
– encroachment on lands or rights of indigenous peoples or other vulnerable minorities		X	-
– displacement of large numbers of people or businesses		X	-
– absence of effective mitigation or compensation measures		X	-

CHAPTER 8

STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE EAST OF MEKONG AREA IN VIETNAM (POR)

8 STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT IN THE EAST OF MEKONG AREA IN VIETNAM (POR)

8.1 Flood damages and risks

For the estimate of the flood risks in the POR reference is made to the Volume 2C. The average annual damage in the Dong Thap Province alone has been estimated at some USD 44 million per year. Further analysis is needed to assess the flood damage risk at the level of the focal area.

The share of agricultural risk is some 10% of the total risk. Most of the risk (about 55%) is related to infrastructure and relief, and one third is related to housing. It is clear that Dong Thap is more at risk than the An Giang. Also under moderate flood conditions the damage can be substantial (some USD 20 million during the average flood up to some USD 90 million under the once in 5 year flood)

The flood risk in the surveyed Tan Hong and Tam Nong districts has been assessed at respectively USD 2.2 million and USD 2.5 million per year. It is noted that a substantial part of the risk in the Dong Thap province is related to bank erosion. This phenomenon is not reflected in the flood risk of the surveyed districts.

8.2 Flood benefits

Results from focus group discussions held in three districts in the deep flooded areas showed that benefits from natural fishing vary from 100-300 US$/household in normal flood years and from 120-750 US$/household in big flood years.

According to the MRC-Technical Paper No 16 on fish yields, the average amount of fish catch from rice fields in the Mekong Delta Flood Plain (deep flooded areas) are 80-119 kg/ha, resulting in a value of 30-40 US$/ha. Farmers also mentioned that floods have significant benefit for crop cultivation. After big a flood, application of fertilizers and pesticides to Winter-Spring Paddy (Planting in November and harvesting in March) is less than in a normal flood year, and the yield is higher by 0.5-1.0 ton/ha. It would result in flood benefit for agriculture of about 200-300 US$/ha after a big flood. Assuming big flood frequency of one third, the annual flood benefit for agriculture would be 60-100 US$/ha.

8.3 Flood risk management East of Mekong Region Vietnam (POR)

8.3.1 Options

Similar to the approach for the LXQ, the strategy proposed to achieve the flood control objectives for the POR relies on isolating areas from flood waters using dikes, and utilizing embankment systems at different scales and levels to control the transport of flood waters. The corresponding technical options aim at:

1. Influence and control flooding using the principle of “living with floods”; and distributing flood flow in the most efficient way.
2. Reduce flood pressure to the POR central area by improving flood drainage capacity at Tu Thuong and at low parts of Mekong and Vam Co rivers.
3. Control early flood, for harvesting Summer – Autumn crop and accelerate drainage for Winter - Spring crop; concurrently increase horizontal flow to improve sediment accretion from Mekong river.
4. Improve drainage canal system for reducing depth, duration of inundation; increasing dry season discharge for irrigation and impeding salinity intrusion.

5. Use advantages and disadvantages of tidal excursion to enhance effectiveness of drainage and irrigation measures.
6. Control flooding and redistribute flood flow by reasonable operation regime of flood-control works.
7. Raise crest levels for residential areas and road networks
8. Dig new canals and enlarge existing canal system to help reduce depth and duration of inundation, particularly to accelerate flood drainage for early seeding Winter – Spring crop.

8.3.2 Structural measures

The structural measures that have been identified to realize above mentioned objectives are shown in the **Error! Reference source not found.** overleaf and refer to:

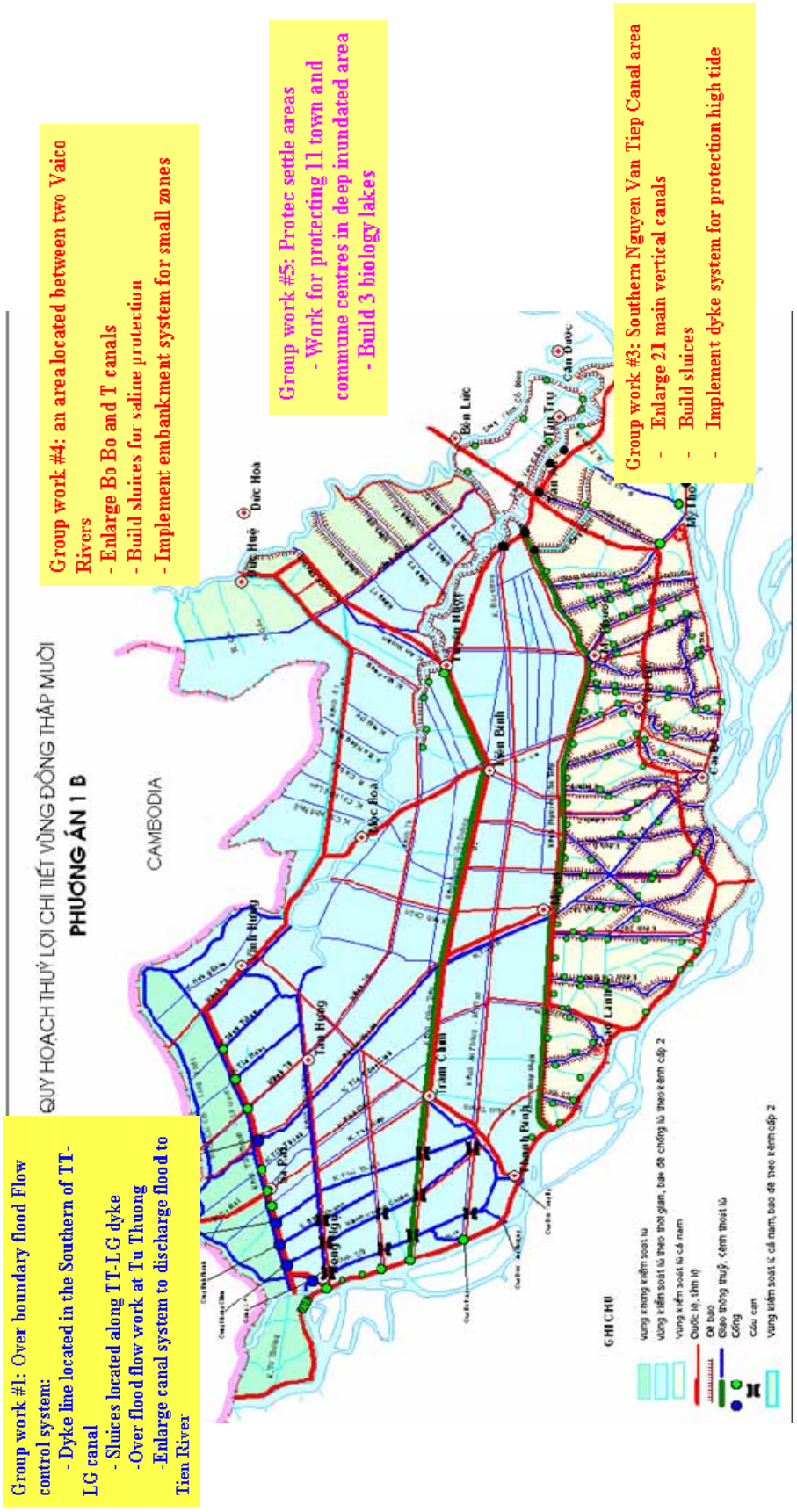
1. Definite frame of canal systems (main, primary, secondary) to ensure they meet the needs of integrated use.
2. Tan Thanh - Lo Gach flood control line includes; dyke, sluices, overflows. This system has function of controlling over flow from inundated area of Cambodia and diverting flood discharge to Mekong and Vam Co rivers. It is operated primarily to protect against flooding in August.
3. Flood drainage work group at Tu Thuong including road-overflow. Its function is to reduce flood pressure for POR central area.
4. Sluices located along upstream reaches of the Mekong River within Vietnames territory (from Hong Ngu to An Phong – My Hoa canal). These sluices have the function of reducing early flooding from Mekong and increasing discharge to remote area of the POR during the dry season.
5. Sluices located along downstream reaches of the Mekong River (from My Tho to Cai Be). These sluices are operated by tidal energy and can improve not only drainage but irrigation capacities also.
6. Sluice + navigation lock Vam Co, built at the confluence of two Vam Co rivers with automatic operation controlled by the energy of tide.

8.4 Impacts of structural flood risk management options

8.4.1 Flood risk reduction

If the flood risk management works as described above would be operated to provide full protection to the POR, then most of the flood risks, apart from the bank erosion, would be eliminated. This would give a risk reduction of some USD 2.2 and USD 2.5 million/year for respectively the Tan Hong and Tam Nong districts.

If these works, however, would be operated to protect the POR against the early floods only (until half of August) then only the agricultural risk would be largely eliminated in the surveyed districts. These risk reductions are estimated at USD 0.2 million for Tan Hong and USD 0.4 million for Tam Nong


Group work #1: Over boundary flood Flow control system:
- Dyke line located in the Southern of TT-LG canal
- Sluices located along TT-LG dyke
-Over flood flow work at Tu Thuong
-Enlarge canal system to discharge flood to Tien River
Group work #4: an area located between two Vaico Rivers
- Enlarge Bo Bo and T canals
- Build sluices for saline protection
- Implement embankment system for small zones
Group work #5: Protec settle areas
- Work for protecting 11 town and commune centres in deep inundated area
- Build 3 biology lakes
Group work #3: Southern Nguyen Van Tiep Canal area
- Enlarge 21 main vertical canals
- Build sluices
- Implement dyke system for protection high tide
QUY HOẠCH THỦY LỢI CHI TIẾT VÙNG ĐỒNG THÁP MƯỜI
PHƯƠNG ÁN 1 B
CAMBODIA
Duc Hoa
Ben Luc
Tan Hung
Tram Chim
Kien Binh
GHI CHÚ

Full protection would enable a third paddy crop. Currently, there are 2,088 ha in Tan Hong district covered by the third crop during the flood season. These areas are bounded by national roads and embankments developed by local authorities. The existing third paddy crop occupies about 8% paddy land in Tan Hong district. Since the third crop grows during the rainy season with high flood water in river and canal, drainage of excess water on the field by pumping would be critical. It is assumed that additional 70% of paddy land could be used for a third crop, considering the existing third paddy and that depression areas may not economically for this crop. Net benefit of additional paddy would be at the rate of 900 US$/ha, resulting in expected additional benefit from cultivation of third paddy as USD 16 million in the Tan Hong and USD 21 million in Tam Nong district.

Full flood protection in LXQ would reduce natural fish on paddy field at the rate of of 30-40 US$/ha. Taken into account the remaining flooded paddy area, the fish loss would be some USD 0.8 million/year in Tan Hong and USD 1.1 million in Tam Nong district.

Flooding brings sedimentation to the delta, leaches acid sulphate substances and toxicity from the soil, and controls pests. This benefit was evaluated as 60-100 US$/ha for W-S paddy. Full flood protection would create the loss of these benefits to an estimated amount of some USD 1.6 million/year for Tan Hong and USD 2.3 million for Tam Nong district.

8.4.2 Transboundary impacts

As is the case for the regional LXQ flood protection scheme, also the POR scheme allows for the management of not only the early floods, but also the floods arriving after August. Operation of the flood management infrastructure beyond the early flood (or half of August) will create increased water levels in the rivers both downstream and upstream of the protected area. Moreover, the blockage of the floodplain flow will affect directly the floodplain flood levels upstream of this blockage.

In principle the flood management infrastructure could be kept closed until after the passage of the flood peak. In that case, the peak levels upstream of the protected area will increase and affect directly the flood risk in Cambodia.

Runs with the ISIS model have been made to simulate the impact of the scenario in which flood water will enter neither Long Xuyen Quadrangle nor the Plain of Reeds unless the management decides for controlled inlet.

The results of these simulations are shown and described in the Appendix 6 of Volume 2B. It has to be taken into account that the model allows for a relative assessment of these impacts only. That is to say that the presented absolute values are to be given due care. More accurate modelling is required to assess the absolute values of these impacts and the eventual impacts on the flood risks in Vietnam.

The results of these runs indicate that full flood control for the Focal Areas Long Xuyen Quadrangle and Plain of Reeds would aggravate the flooding conditions in Cambodia: from 1.5 to 1.7 m in Prey Veng. These results do not take into account though the mitigating impact of the planned Tu Thuong flood release works.

Corresponding increment of risk have been calculated at some USD 1.4 million US$/year in Kampong Trabek district. It is repeated again that these calculations are based on ISIS simulation results, and should be considered with due care.

8.4.3 Environmental impacts

The potential environmental impacts of implementation of 'full protection' of the Plain of Reeds are very similar to those described in the previous sections regarding the Long Xuyen Quadrangle. It has to be remarked that full protection only means that floods can be kept out of the area completely, but that this will probably not be the case. Controlled flooding of certain areas during certain parts of the year will be allowed, possibly in a rotational scheme.

In the Plain of Reeds Focal Area there are two protected areas. Tram Chim National Park and the Lang Sen Wetland Reserve. Tram Chim is a low-lying wetland with seasonally inundated grasslands and natural Melaleuca forests, an abundance of freshwater fish, and consequently many birds.

BirdLife International ranked Tram Chim National Park as one of the most important sites for conservation in the Mekong Delta. The park receives international recognition as seasonal habitat for the globally endangered Sarus Crane. It is also an important breeding site for water birds.

Lang Sen is another remnant of the original wetland landscape of the Plain of Reeds. The Lang Sen Wetland Reserve covers an area of some 5,030 ha, among which 1,500 ha is swampland providing habitats for a variety of wetland fauna and fish. Substantial areas of natural lotus swamp are preserved at Lang Sen. This vegetation type is characteristic of the Plain of Reeds but is now seldom found anywhere to any great extent. It is one of the few remaining sites where semi-natural Melaleuca forest occurs along a natural river channel, and, as such, is of notable biodiversity value. The site is listed as an Important Bird Area (IBA) because a significant number of large water birds, including the Eastern Sarus Crane and the Painted Stork, use Lang Sen as a stop-over area en route between their breeding areas in Cambodia and their non-breeding areas in the Mekong Delta of Viet Nam.

Biodiversity is very high, 156 plant species and 149 vertebrate species (of which 13 species are listed in the Viet Nam Red Book of endangered species) are found. The important and unique vegetation types/habitats are all flood dependent: riparian forests along rivers and canals, seasonally flooded grasslands, swamps and Melaleuca forests.

The above described protected areas are depending on regular flooding for their survival. Reduced or no flooding will reduce their ecological importance significantly.

Also here it is strongly recommended not to make (parts of) the area completely flood free. A system of controlled flooding should be designed, which reduces the damages, but at the same time conserves the benefits of the flooding as much as possible. Special attention should be given to the remaining natural area's, they are not only threatened by changes in the flooding regime, but also, and probably even more so, by encroachment of local people.

8.5 Strategic directions

8.5.1 Flood management strategic directions

Strategic directions for flood risk management in the POR are clearly defined in the long term flood control planning 1998, as approved by the Vietnamese Government in 1999 (Dcision No 144/1999/QD-TTg) and the Master Plan Study on water Works of the Mekong Delta as approved by the Vietnamese Government in 2006 (Dcision No 84/2006/QD-TTg. Objectives and guiding principles for the flood management in the Long Xuyen Quadrangle have been mentioned above under section 8.3.1.

8.5.2 Mitigation of transboundary impacts

From the model simulations as described in Volume 2B, it is clear that any flood management that goes beyond the early flood (half of August) protection, will have impact on the flood hazard and eventually the flood risk in Cambodia. Especially the protection of the Vietnamese POR has substantial impact on the flood hazards in the East of Mekong flood plains in Cambodia.

Retention options to compensate for lost storage capacity are hardly available in the Vietnamese part of the Mekong Delta. Consequently, additional discharge capacity is to be provided at and downstream of the border area to mitigate the cross-boundary impacts. Such additional capacity could be provided in the direction of the Mekong River (KOICA alternative), towards the Vai Co River or towards the Gulf of Thailand.

Transboundary impacts do not only refer to the impact of risk reduction in Vietnam on the flood risks in Cambodia, but also the other way around, as described in the previous chapters related to the flood risk management in Cambodia. It is therefore recommended to investigate the options of diversion in the border zone between Cambodia and Vietnam.

CHAPTER 9

STRATEGIC DIRECTIONS FOR MEKONG RIVER EROSION RISK MANAGEMENT IN BOKEO PROVINCE, LAO PDR, AND KRATIE, CAMBODIA

9 STRATEGIC DIRECTIONS FOR MEKONG RIVER EROSION RISK MANAGEMENT IN BOKEO PROVINCE, LAO PDR, AND KRATIE, CAMBODIA

9.1 Introduction

The Terms of Reference of the FMMP C2 call for the preparation of a FMM Project Development and Implementation Plan (ProDIP) based on a limited number of Flood Management and Mitigation (FMM) projects nominated by the four riparian countries In the Stage 1 Implementation Phase the list of projects has been prepared and endorsed by the countries. During the Stage 2 Implementation Phase the list will be prioritised and the PIN's prepared.

The consultant developed in consultation with the relevant line agencies, Project Ideas in the framework of the IFRM studies in the focal areas.

The Terms of Reference also call for 4-6 demonstration projects to be selected from the list of projects that eventually will make up the ProDIP. The most important criterion in selecting these demonstration projects is their contribution to achieving the principal objectives of the FMMP-C2, that is to say, to the establishment of sustainable flood risk management capacity in the MRC, MRCS, NMC's and national line agencies.

During the second stage of the Implementation phase these demonstration projects will be further developed in preparation of an application by the respective member countries for funding of the implementation of these projects.

This document on strategic directions outlines a strategy for developing a joint project that makes brings the erosion risk management vision in the sub-areas 2T and 1L, shown in **Error! Reference source not found.** , to reality. It will help bringing together the most critical areas of joint work for improving the knowledge on development of the river channel (international border between Laos and Thailand) and sustainable options for reducing erosion risk and minimizing transboundary impacts.

It shall provide a framework for planning, implementing and evaluating erosion control measures, efficient, and effective interventions, whose impacts can be managed in joint coordination. The major components are:

- Rationale, the needs that require an integrated and comprehensive study on river bank erosion mechanisms to improve stabilization of the international border and to reduce damage to infrastructure and agricultural land ensuring sustainable development.
- Guiding principles to guide this joint project.
- Future directions for major areas of river bank erosion work to share and extend river engineering and river training techniques for achieving cost-effective as well as environmentally friendly river bank protections.
- Implementation of the strategic directions with Member Countries and partners. The strategy shall also provide a road map for the joint opportunities to control and formidable challenges ahead

9.2 Background

The most critical impact along the Mekong River on the right bank in Lao-PDR is riverbank erosion that takes place along several areas between Ton Pheung district and Houayxay district. Because river bank erosion is considered as a critical problem in Bokeo, the Government of Lao-PDR allocates annual budget for river bank protection at some critical locations; however, the budget is not sufficient to undertake works to stop the extend of the erosion along the Province and therefore partial protections consisting of temporary works are only possible every year.

These ongoing erosion processes along the left bank of the Mekong River in Bokeo Province (sub-area 2L), Houay Xay and Ton Pheung Districts and the right bank in Thailand has prompted the need to undertake a joint technical evaluation of the present situation and the forecast of potential scenarios of development in the coming flood seasons.

During the monsoon 2007, additional areas of agricultural land were washed away by the river and the potential scenario of eroding Ton Pheung, B Khouan, B Simouangngam and B Don Savan is of great concern for the Lao-PDR Government. The present critical situation, the lack of enough funds to construct permanent river training works and the need to develop a plan for the protection of critical areas requires of urgent support from MRC and donors.

Apart from geo-morphological characteristics of the river the general view of the people in the province is that erosion has increased over the last years due to the impact of river bank protection works implemented along the right bank of the Mekong in Thailand.

This joint project has been nominated in the frame of the ProDIP and deals with related to bank protection along the Mekong Mainstream. This category of projects is considered as "erosion risk management" measures and refers to erosion risk management as well.

Besides the different project categories, a distinction has been made between projects that aim at the preparation of flood risk management plans and projects that aim at the implementation of flood / erosion risk management measures. This joint river bank protection study is classified as a project for preparation of erosion management plans.

9.3 The Rationale

Like many other rivers, the Mekong erodes its banks in many points. Erosion at the Mekong has not reached alarming proportions but the considerations on: (i) international border, (ii) sustained socio-economic development of the region, (iii) flood and protection of existing infrastructure and cultural heritage could require prompt attention at critical locations along the waterfront.

Along the sub-areas 2T and 1L (Figure 9.1) requiring action, the Mekong River has a variable width and it is geologically controlled almost along the whole length and local geology and related rock outcrops are very important. In the Upper Mekong reach the floodplain is only marginally developed, and often the river reaches the flood plain levels only during extreme floods.

There are several provinces and districts along the Mekong River and, urban and infra-structural development will become much more important than in the past, adding significantly to the investment value of property and services needing protection from floods and shifting of the river bank due to erosion.

Contrary to Flood risk management, which, that has received a boost from the execution of the FMMP, erosion risk management up till now has not got the attention it should have. River erosion creates poverty by making people homeless overnight. The poor are affected most.

Figure 9.1 Alignment of the Mekong river in Bokeo Province, controlled by geology, from the Golden Triangle to Chiang Khong Province in Thailand

The problems, which, until now, have prevented a systematic and strategic approach to erosion management in particular in Laos are of a morphological, economic and technical nature:
The increase in population, the investment in infrastructure in towns and rural areas (irrigation and drainage projects), the river training works already carried out in the recent past for various as well as cost-effective improved techniques (JMREMP) in arresting bank erosion, are all reasons for a formulating a project with a broader view into the technical, economic and socio-economic feasibility of protection works against bank erosion.

The strategic directions shall be aimed to jointly study and formulate of an overall erosion management strategy for these sub-areas. It is felt that such a joint study is a first step towards a future control of erosion of the banks of this major international river.

Therefore, the MRC FMMP Component 2 shall promote and provide a strategic directions for studying the river bank erosion problems and alternative solutions and strategies for the river bank protection works along the right and left bank of the Mekong River in Thailand and Lao-PDR. Focus will be placed on those river stretches were river bank erosion poses a higher threat to infrastructure, roads, agricultural land and urban centres.

Areas that require attention
With this component of the FMMP, MRC will provide a framework for a range of investigations into the technical, environmental and social issues to be faced in formulating demonstration projects including structural measures and river bank protection works along the Mekong River.
Furthermore it will increase knowledge of Line Agencies on river morphological changes, erosion risk areas and low cost (adaptive methods) river bank erosion works. Although over the last decade there has been progress in surveying, data collection and developing of design tools it is still required to look into advanced techniques needed to pursue a multi-disciplinary approach in which a multi-criteria analysis can be used for evaluating alternative demonstration projects to alleviate river bank erosion problems caused in the Mekong River.

For the purpose of estimating river bank erosion in these sub-areas and designing river bank protection works as well as for the planning of future programmes of erosion risk reduction measures is necessary to be aware of the geomorphology of the river, as it may have influence on the plans for river bank stabilization. Therefore an important consideration in predicting future developments and river behaviour and response is *"the sensitivity of the channel. This means how close is it to undergoing a change without an external influence".*

Knowledge on the geology and geomorphology of the river also allows the identification of the major and secondary geological controls along the river. These controls will have to be analyzed regarding their correlation with the alignment of the river and future developments due to river bank erosion or major geological events (i.e, shifting in west direction).

The potential for using satellite images to monitor and document recent and contemporary river morphology has been demonstrated through recent studies in other major rivers. Methods for predicting morphological changes of the Mekong River on a short-term (annual) basis can also be developed using dry season satellite images.

Furthermore additional field investigations shall be planned and carried out and their outputs integrated with the geo-morphological study. Additionally, the characterization of the river stretches needs to be prepared for preparing the design of sustainable river bank protection works for site-specific river stretches.

The differences between river stretches along the Mekong are reflected in their channel patterns and these are controlled by the stability of the banks and the river slope.

Between Lao-PDR and Thailand, river Bank Protection (RBP) demonstration projects along the Mekong River main objectives are twofold: (i) to prevent the erosion along the international border between Lao-PDR and Thailand and (ii) to prevent bank erosion that affects urban and semi-urban areas, transport and flood infrastructure from damage during floods that will also likely may increase regional flooding.

9.4 Objective

The main objective is the formulation of an overall joint integrated erosion management strategy project for Laos and Thailand in the Mekong River aiming at a future control of the erosion of the banks of this major river. The strategy should be aimed at sustainable long-term planning of river training (including bank protection at vulnerable reaches) to stabilize the width of the river and thus safeguard valuable land and infrastructure as well as to reduce the risk of conflicts resulting from transboundary cross cutting issues.

Technically and economically feasible river bank management, short-term protection works and river training works on a sustainable scale for a major river like Mekong cannot, in general, be successfully developed unless they are incorporated within an integrated overall strategic programme.

Accordingly, when designing river bank erosion protection measures it is agreed that they should fit into a coherent plan (river training) to harness in optimum way the river system with the possibility of new concepts being applied in recent projects or innovative different concepts in combination with temporary protection works at key locations.

The overall objective of the joint project is to provide a framework in which the technical, economic, social, environmental and other effects of various alternatives for river training works of the Mekong river along sub-areas 1L and 2T, can be assessed and evaluated at different levels of detail. The joint project will moreover, provide a systematic approach of the river training works in regard of their various aspects as design criteria, construction, sequence of implementation, monitoring and maintenance, and the institutional and organizational management requirements related to these aspects.

The respective Line Agencies in both countries will involve hydrologic, hydraulic, hydraulic engineering studies, geotechnical, morphological and geo-morphological studies. It will also

require mathematical and physical modelling studies to support the preparation of the design of river training works and implementation plan. Agro-socio-economic and environmental effects of the proposed schemes are to be included. The Joint project should be consistent with the Line Agencies policies.

9.5 Guiding principles

Four principles guide form the basis for the implementation of the strategic directions outlined for this joint project:

1. Jointly addressing erosion risk management and implementing a joint strategic plan for river bank erosion control, developing effective plans for protection of the priority areas.
2. Taking into account the social and environmental benefits obtained by reduction of risk erosion in the sub-areas 1L & 2T by focusing on priority areas.
3. Mitigation of potential transboundary issues.
4. Application of best practice guidelines and training and capacity building which will lead to prepare cost-effective interventions to protect infrastructure, urban and agricultural areas.

Starting points for developing the guiding principles can be listed as:

Starting points:

- Based on existing knowledge and experience (Thailand, Laos, and other studies carried out within the frame of MRC or bilateral partners)
- Additional data on geotechnical, socio-economic and environmental conditions to be collected,
- Experience from elsewhere (i.e, Europe, China, USA) to be used
- Together with MRC select the most suitable mathematical models to be used. Similarly select most suitable agencies for collecting and processing satellite images.
- Continuous interaction with MRC and Line Agencies and other relevant agencies
- Extensive use of satellite images for development of river bank erosion hazard maps
- Ultimately “learning by doing”, so a flexible plan for implementation

The

9.6 Main components of the joint project:

In order to strategically address the erosion problems and formulate cost effective bank protection projects, in sub-areas 1L & 2T requires answering the following questions: Where, When and What to protect and How.

- WHERE is related to threat in short-time by currents or waves,
- WHEN is a matter of morphological predictions of river channels, making good use of low river stages and the urgency to stop the threat,
- WHAT, is a matter of economics and strategic considerations,
- HOW to protect which is first a technical problem to be solved

The approach of the joint bank protection study focuses on the engineering analysis of all reasonable options and strategies for protecting the river banks against erosion, with special emphasis on floods, environmental, social and political considerations. The main components of the joint project can be summarized as follows:

(1) River training component. Consisting of:
- Division of main river system into different stretches
- Review of earlier studies
- Selection of most stable river planform for each of the different river stretches.
- Interaction with other projects (navigation) and effect of developments upstream,
- identify the influences of bank materials and changes in the planform on the rate of bank erosion,
- Develop bank erosion prediction methods using satellite images. The potential of such prediction methods for erosion monitoring and vulnerability assessment has been recognized,
- Preparing erosion hazard maps,
- Development of short-term (up to 5 years) and medium term strategy (5-15 years), for river bank protection, based also on socio-economic and environmental impacts and economic analysis,
- Review of recent bank erosion protection experiences in Thailand and Laos
- Study of failures and successes with river bank protection works in Thailand and Laos and elsewhere and recommendations on best practice related to type of protection works
- Development of strategy for implementing river bank erosion works and how to reach most stable river planform
- Recommendations for “learning by doing”

(2) Environmental impact component. Consisting of:
- Study of base-line conditions along the river in sub-areas 1L and 2T
- Morphological impact study of proposed strategies on the alignment of the river banks
- Environmental impact study of proposed strategy and alternative approaches (when needed)

(3) Economic analysis component, consisting of:
- C/B analysis of proposed river bank erosion strategy(ies)
- Economic analysis to help formulating short-term and medium-term strategy(ies)

(4) Institutional component, consisting of:
- Advise on present setting of river bank erosion management units in Laos and Thailand,
- Advice on future institutional needs in relevant agencies,
- Training of professional staff responsible for river bank erosion works in the countries’ Line Agencies, and
- Advice on monitoring and maintenance (how, who?)

9.7 Future directions

The future directions lie in continuing and expanding those components of the joint project and learning from the implementation of interventions with proven effectiveness, and in monitoring prediction of erosion where evidence has demonstrated that the need is for river bank protection is greatest. What needs to be done in each of the priority areas for action can be approached in a systematic manner going through the main components and activities listed above. Government Line Agencies and concerned parties will continue to identify priorities for joint implementation of erosion control measures based on erosion risk the socio-economic benefits and other factors relevant to specific contexts.

One important future output of the joint project activities will be definition of hazard areas and preparation of erosion hazard maps by means of modelling results and by means of historical records (rates of average erosion m/year), which will allow to delineate hazard areas on and establish setback requirements. Consequently, it will be also possible to prioritize river erosion

problems. It shall be a systematic process that leads to ranking of river stretches based on the significance of bank erosion and affected infrastructure and structures.

9.8 Implementation

The greatest challenge to promote this strategic directions and development of joint erosion protection plans in the future will be transforming knowledge into action.

As an example, in order to develop a cost-effective plan and secure funds in time for demonstration projects in Bokeo Province, it is urgently needed to review the morphological processes and the present and potentially future planform changes in the Mekong River along the Province. This has to be accompanied by a technical estimate of present bank stability. The understanding of the aforementioned morphological processes will allow determining which areas need to be protected first and what type of measures to control the ongoing erosion are required.

Within the range of potential areas for action, Member Countries will identify priorities bearing in mind the national context, and taking into account inter alia the cost of the measures and impacts on socio-economic development of their Provinces. This joint project will provide guidance to Member Countries and partners to identify priorities and develop strategic operational responses.

Working with MRC, partners and in Joint Initiatives will be very important in view of the importance of investing in sustainable erosion risk reduction measures.

CHAPTER 10

STRATEGIC DIRECTIONS FOR MEKONG RIVER EROSION RISK MANAGEMENT IN KRATIE, CAMBODIA

10 STRATEGIC DIRECTIONS FOR MEKONG RIVER EROSION RISK MANAGEMENT IN KRATIE PROVINCE, CAMBODIA

10.1 Introduction

The Terms of Reference of the FMMP C2 call for the preparation of a FMM Project Development and Implementation Plan (ProDIP) based on a limited number of Flood Management and Mitigation (FMM) projects nominated by the four riparian countries In the Stage 1 Implementation Phase the list of projects has been prepared and endorsed by the countries. During the Stage 2 Implementation Phase the list will be prioritised and the PIN's prepared.

The consultant developed in consultation with the relevant line agencies, Project Ideas in the framework of the IFRM studies in the focal areas.

The Terms of Reference also call for 4-6 demonstration projects to be selected from the list of projects that eventually will make up the ProDIP. The most important criterion in selecting these demonstration projects is their contribution to achieving the principal objectives of the FMMP-C2, that is to say, to the establishment of sustainable flood risk management capacity in the MRC, MRCS, NMC's and national line agencies.

During the second stage of the Implementation phase these demonstration projects will be further developed in preparation of an application by the respective member countries for funding of the implementation of these projects.

The strategic directions shall provide a framework for planning, implementing and evaluating erosion control measures, efficient, and effective interventions, whose impacts can be managed in joint coordination. The major components of the strategic directions are:

- Rationale, the needs that require an integrated and comprehensive study on river bank erosion mechanisms to improve stabilization of the left bank and reducing damage to infrastructure and urban land ensuring sustainable development.
- Guiding principles to guide this project.
- Future directions for other priority location of river bank erosion and extending river engineering and river training techniques for achieving cost-effective as well as environmentally friendly river bank protections.
- Implementation of the strategic directions with Line Agencies and partners. The strategy shall also provide a road map for the opportunities to control and formidable challenges ahead

This document on strategic directions outlines a strategy for developing an erosion risk management plan and measures that brings the erosion risk management approach to reality in sub-area 8C, Kratie Province.

10.2 Background

The Province of Kratie is located within sub-area 8C and it was selected as one of the focal areas for the preparation of demonstration projects in Cambodia. The main objective in this focal area is to carry out a risk assessment of bank erosion and formulate plans and measures for mitigating the erosion risk.

Kratie Province is located in the northeast part of Cambodia. The Province shares the frontier with Mondulkiri province in the east, Kampong Cham province and Vietnam in the south, Kampong Thom province in the west, and Stung Treng province in the north.

Kratie province consists of five districts, 46 communes and 250 villages. The population of Kratie is approximately 290,000 and the population density is 26 people per sq.km. Roughly 70% of the people live along the river, whereas 30% live in the mountains areas.

Kratie Province covers an area of 11,094 square kilometers which is categorized into several areas such as 83% forest, agricultural land 8% and red land 0.5% in Snoul district.

The Mekong River, the natural water resource, flows over about 140 km long across Kratie province. The erosion of the left bank occurs over 6 km from Sambok at km 572 to Ph Thmar Krae Kraon and Ph Russei Cha (km 566) and over 15 km from Kratie (km 572) to Prek Te (km 557).

10.3 The Rationale

A Major river like the Mekong is characterised by having large variation in water levels, shifting river channels with large sand bars and creating deep scour holes along outer bends during the flood season. The left bank of the Mekong along Kratie Province consists of steep slopes of brown silt rising about 14 to 20 m above the low water level. The top of the river bank shows a natural levee and the ground surface gets lower in the first hundred meters away from the river bank.

The left river bank can be under severe attack in a given year and or be not affected by currents in the next year or even for a number of years.

The general geology characteristics of the Mekong River along the District of Kratie as described in the OTCA Report [6], consist of two geological formations in the area of Sambok:

- The Tmor Moykbyk bed on right bank and,
- The Sambok group on the left bank

The bed rock in the river consists of sandstone and it is covered with deposits of several meters thick. The surface deposits are compacted and mainly consist of silty clay and clay and the underlying material is more cohesive and strong bonded to completely weathered rock.

The river valley in general is wide and slightly undulating which extends some 5 to 10 km from each bank. It is also observed that natural vegetation growths at elevation corresponding to the maximum elevation of yearly floods.

River bank erosion rate has not reached alarming proportions but it requires attention at some locations in view of infrastructure, urban areas and economic growth of the District.

As shown in Figure 9.2, the total length of the river threaten by erosion is 21 km in Kratie Province and they are all located along the Kratie District that has approx 40m of waterfront along the Mekong. Consequently it can be concluded that around 50% of the District boundary is affected by river bank erosion.

Most of the areas where erosion occurs are located along the Kratie District in Kratie District Town and upstream of Kratie Town at km 560, Ph Thmar Krae Kram and at km 566 Ph Russei Cha. The road/flood embankment (old alignment of road N7) is parallel to the river bank and at some locations the old road has been eroded already.

[6] Sambor Project Report, Lower Mekong River Basin, Volume VII Basic Data. Overseas Technical Cooperation Agency (OTCA), Japan

The total priority length affected by erosion at Kratie District Town is estimated to be 5 km. Most of the erosion prone area is located between km 557 starting at Prek Te and km 563 Prek Andang Pring, which includes the Kratie town area and port area. At present a total length of 370m of bank has been protected and the works were implemented in two phases, the first one of 130m and the second one 240m. The lower level of the protection works is located at + 17.3m. The top level of the protection is +23.3m which 0.05m higher than the level of the existing road along Kratie Town waterfront.

There is not a long experience in Cambodia of design and implementation of river bank protection works based on morphological analysis or erosion risk management plans. Those attempts to stop locally bank erosion have been carried out at short river reaches near infrastructure (roads and river ports). Failure of the river bank is due to physical factors like high currents, ship waves, scouring and geotechnical instability of the banks, but also it can be due to poor design, construction and maintenance. In other cases the structures applied does not appear to fulfil some functional requirements and they might not yet been exposed to the full environmental design loads.

Figure 9.2. Layout of bank erosion and bank protection sites on Mekong – Kratie District

10.4 Areas that require attention

With this component of the FMMP, MRC will provide a framework for a range of investigations into the technical, environmental and social issues to be faced in formulating demonstration projects including erosion risk management plans and river bank protection measures along the Kratie District.

Furthermore it will increase knowledge of Line Agencies on river morphological changes, erosion risk areas and design of cost-effective (adaptive methods) river bank erosion measures.

For the purpose of estimating river bank erosion in this sub-area and designing river bank protection works as well as for the planning of future programmes of erosion risk reduction measures is necessary to be aware of the geomorphology and morphological changes of the river.

Knowledge on the geology and morphology of the river also allows the identification of the major and secondary geological controls along the river. These controls will have to be analyzed regarding their correlation with the alignment of the left bank of the river and future developments due to river bank erosion and sand bar formation.

The potential for using satellite images to monitor and document recent and contemporary river morphology has been demonstrated through recent studies in other major rivers. Methods for predicting morphological changes of the Mekong River on a short-term (annual) basis can also be developed using dry season satellite images.

Furthermore additional field investigations shall be planned and carried out and their outputs integrated with the geo-morphological study. Additionally, the characterization of the river stretches needs to be prepared for preparing the design of sustainable river bank protection works for site-specific river stretches.

Along the sub-area 8C, river Bank Protection (RBP) demonstration projects main objective is to prevent the erosion along the Kratie District town preventing bank erosion that affects urban and semi-urban areas, transport infrastructure from damage during floods that will also likely may increase regional flooding.

10.5 Objective

The main objective of the strategic directions is the formulation of an erosion risk management plan and erosion control measures in Sub-area 8C aims at a future control of the erosion of the left bank of this major river along Kratie District town. The strategy should be aimed at sustainable long-term planning of river training (including bank protection at priority locations) and thus safeguard valuable land and infrastructure.

Throughout the design process, it is important to understand and evaluate the many types and levels of risk associated with a bank protection project. A risk assessment should consider both the risk of continued bank erosion and the risk associated with the bank protection project with respect to property, habitat, and public safety. All bank protection projects contain some level of risk

The strategic directions will also provide for preparing a riverbank erosion damage assessment considering damages to contents and structures. This means that the riverbank erosion vulnerability values can be determined and combined with the total cost of the elements at risk. A criteria shall be determined for the riverbank erosion vulnerability assessment and damage to infrastructure, buildings etc. Finally, a damage map of the sub-area 8C will be prepared. Proposed parameters can be:

- No damage
- Low damage
- Moderate damage
- High damage

Considering hazards alone may lead to a skewed set of priorities for action. It is equally important to consider the severity of possible impacts from the hazard as well as the frequency or likelihood of a hazard event occurring. The combination of severity/damage and likelihood is termed the level of risk.

A risk assessment for riverbank erosion is not possible at this stage in sub-area 8C, due to lack of information on probability for this type of event.

Accordingly, when designing river bank erosion protection measures it is agreed that those measures should fit into a coherent risk erosion management plan.

The overall objective of the project is to provide a framework in which the technical, economic, social, environmental and other effects of various alternatives for river training works of the Mekong river along sub-area 8C, can be assessed and evaluated at different levels of detail. The project will moreover, provide a systematic approach of the river training works in regard of their various aspects as design criteria, construction, sequence of implementation, monitoring and maintenance, and the institutional and organizational management requirements related to these aspects.

The respective Line Agencies[7] will be involved in hydrologic, hydraulic, hydraulic engineering studies, geotechnical, morphological and geo-morphological studies. It will also require mathematical and physical modelling studies to support the preparation of the design of river training works and implementation plan. Socio-economic and environmental effects of the proposed schemes are to be included.

10.6 Main components of the joint project:

In order to strategically address the erosion problem, prepare an erosion risk management plan and formulate cost effective bank protection projects, in sub-areas 8C requires answering the following questions: Where, When and What to protect and How.

- WHERE is related to threat/erosion risk in short-time by currents or waves,
- WHEN is a matter of morphological predictions of river channels, making good use of low river stages and the urgency to stop the threat,
- WHAT, is a matter of economics and strategic considerations,
- HOW to protect which is first a technical problem to be solved

One of the most difficult but important aspects of the design process is moving from the site and reach assessments to the selection of an appropriate and cost-effective solution.

In order to bridge objectives with selection of techniques, it is important that design criteria are established. These criteria, considering risk and cost, and stratified according to relative priority, outline the objectives of the project and provide the foundation for making design decisions about the specific sizes and components of bank protection alternatives.

The approach of study focuses on the engineering analysis of all reasonable options and strategies for protecting the river banks against erosion, with special emphasis on floods, erosion risk, and environmental, social and political considerations. The main components of the joint project can be summarized as follows:

[7] Provincial Department of Water Resources and Meteorology

Starting points for developing the strategic directions can be listed as in the textbox

Starting points:

- Based on existing knowledge and experience (Cambodia and other studies carried out within the frame of MRC or bilateral partners)
- Additional data on geotechnical, socio-economic and environmental conditions to be collected,
- Experience from elsewhere (i.e, Europe, China, USA) to be used
- Together with MRC select the most suitable mathematical models to be used. Similarly select most suitable agencies for collecting and processing satellite images.
- Continuous interaction with MRC and Line Agencies and other relevant agencies
- Extensive use of satellite images and aerial photographs for development of river bank erosion hazard maps and risk assessment.
- Ultimately "learning by doing", so a flexible plan for implementation

10.7 Additional Information

It is envisaged to collect some additional information (secondary data and from surveys), for the formulation of this project. The information required is as follow:

- Aerial photographs of 1992 (available with LNMC)
- Aerial photos of 2005 (new ones). It may be required to buy them from the relevant organization in Phnom Penh.
- Collect Reports prepared for the Sombak hydro-project (feasibility study)
- Collect existing best practice guidelines for river bank erosion control works
- Information on geology of the area (cross-sections)
- Hydrographic Atlas (bathymetric maps)
- Collecting specific data on river bank protection and urban planning for Kratie in future (short and medium term)
- Socio-economic assessment for preparing erosion risk management plan

10.8 Activities to formulate bank erosion risk management plans and measures

As per the strategic directions it is intended to prepare erosion risk management plans and river bank erosion projects. Therefore, the activities proposed are:

- Analysis of banklines and historical maps, aerial photos,
- Analysis of satellite images and field investigation,
- Determine recent planform development,
- Determine planform characteristics,
- Development of past bank erosion rates and erosion prediction (short-term and medium term prediction),
- Erosion hazard map,
- Channel declining,

- Impact of migration of bifurcation at Kratie,
- Impact of migration of the curved channel without rock controls, downstream and upstream of Kratie Town,
- Bank stabilization design considerations,
- Analysis of most suitable Bank Erosion protection works (cost/effective), including new low cost protection techniques.

10.9 Future directions

The future directions lie in continuing and expanding those components of the project and learning from the implementation of interventions with proven effectiveness, and in monitoring prediction of erosion where evidence has demonstrated that the need is for river bank protection is greatest. What needs to be done in each of the priority locations for action can be approached in a systematic manner going through the main components and activities listed above.

Government Line Agencies and concerned parties will continue to identify priorities for implementation of erosion control measures based on erosion risk the socio-economic benefits and other factors relevant to specific contexts.

One important future output of the project activities will be definition of hazard areas and preparation of erosion hazard maps by means of modelling results and by means of historical records (rates of average erosion m/year), which will allow to delineate hazard areas on and establish setback requirements. Consequently, it will be also possible to prioritize river erosion problems. It shall be a systematic process that leads to ranking of river stretches based on the significance of bank erosion and affected infrastructure and structures.

10.10 Implementation

The greatest challenge to promote this strategic directions and development of national erosion protection plans in the future will be transforming knowledge into action.

As an example, in order to develop a cost-effective plan and secure funds in time for demonstration projects in Kratie Province, it is urgently needed to review the morphological processes and the present and potentially future planform changes in the Mekong River along the Kratie District. This has to be accompanied by a technical estimate of present bank stability. The understanding of the aforementioned morphological processes will allow determining which areas need to be protected first and what type of measures to control the ongoing erosion are required.

Within the range of potential areas for action, Cambodian Line Agencies and Provincial Authorities will identify priorities bearing in mind the national context, and taking into account inter alia the cost of the measures and impacts on socio-economic development. This project will provide guidance to National Line Agencies and partners to identify priorities and develop strategic operational responses.

CHAPTER 11

APPENDICES

11 APPENDIX: ENVIRONMENTAL BASELINES FOCAL AREAS

11.1 Environmental baseline Nam Mae Kok Focal Area

1 General Characteristics

The Nam Mae Kok Basin covers an area of 10,730 km2, 3,336 km2 or 31 % of which are located in Myanmar. The first mayor tributary in Thailand, the Nam Mae Fang, drains an area of 1,732 km2, whereas downstream of Chiang Rai the Nam Mae Lao, with a drainage area of 2,932 km2 joins the main river. The length of the river from source to mouth is 360 km. It crosses the Thai border after 160 km. The river empties into the Mekong at Sop Kok, just downstream of Chiang Saen at an elevation of 355 masl. The Focal Area covers the Lower Nam Mae Kok Basin, downstream of Chiang Rai.

The basin is mountainous with elevations up to 2,000 m, the valleys of the Fang, the Lao and the Kok rivers downstream of Chiang Rai are flat and flood prone. Upper slopes in the basin are steep and densely forested, the flatter, lower, slopes are used for intensive agriculture.

Six different soil types can be distinguished in the project area. Directly along the river Cambisols have developed in the natural levees. These soils have a good structure and favorable chemical properties. They have a high fertility, and are only moderately sensitive to yield decline. Further from the river, in the floodplain, Acrisols are found, acidic, strongly leached tropical soils with a low fertility which are prone to degradation. On the floodplain around Chiang Mai Luvisols and Gleysols are found. Luvisols are the tropical soil most used by small farmers because of their ease of cultivation. Nutrients are concentrated in the topsoil and they have low levels of organic matter. The Gleysols are encountered in waterlogged areas with poor drainage. They may support rice cultivation, but are not suitable for other crops. On the hill and mountain slopes the so called Slope Complex is encountered with small spots of Lixisols.

The natural regime of the rivers in the project area has been modified by irrigation water use and water storage for hydropower production. According to the Basin Development Pan (2006) about 150,000 ha land was irrigated in the wet season and some 15,000 ha in the dry season in 1998 in the basins of the Nam Mae Kok and adjacent Nam Mae Ing together. Chiang Rai is located at the confluence of the Nam Mae Kok and Nam Mae Lao. The city is flood prone when the rivers convey large discharges. The last mayor flood of 2006 came from the Nam Mae Lao and a small creek named Nam Mae Korn.

The water quality and, consequently the aquatic ecosystem in the lower basin, is under pressure for two reasons. Firstly reduced streamflow in the dry season, caused by the increased use of water for irrigated agriculture and domestic/industrial use, reduces the dilution of waste water discharged into the river. Secondly, pollution loads are increasing, due to population growth, changed lifestyles, intensified tourism, and intensified agricultural and industrial production.

In 2000 there were no sewerage systems and treatment plants operational in the project area. Sewage stabilization ponds were under construction for treatment of the waste water of Chiang Rai Town. These will be operational by now. Industries are mostly processing plants for fruits and vegetables, or noodle factories. They produce mainly organic sewage. Most industries are located around Chiang Rai, and in the Fang and Upper Lao sub-basins.

According to the River Basin study of 2000, the assimilative capacities of the rivers in terms of BOD, nutrients or bacteria are big enough to deal with the pollutant inflow and keep the water quality and the diversity of fishes, vegetation, plankton and invertebrates at acceptable levels. However, pressure on the system certainly has increased in the last decade and the situation may have deteriorated since 2000.

According to a recent MRC report (MRC, 2007) the water quality of both the Mekong at Chiang Saen and the Nam Mae Kok in Chiang Rai is good to very good.

Groundwater is extracted for domestic and industrial supplies. Hand pump wells for domestic supplies in rural areas have been established in many places. Groundwater yields are generally characterized as 'high', and no shortages have been reported. Groundwater quality is threatened by pollution with agrochemicals (pesticides and fertilizers) and the uncontrolled disposal of solid waste, what may result in contamination by infiltration.

The following land cover types are found in the area: paddy fields on the floodplain and on low terraces along the rivers; upland crops, cultivated on middle and high terraces and in the hilly areas; fruit trees, grown both on low and high lands; wetlands: low-lying areas that are flooded part of the year or year-round; and forests, disturbed forests and forest plantations. Seventy percent of the area of the Lower Kok Basin is in use for agriculture. Nearly half of this, 34 %, is irrigated paddy. The rainfed areas produce one crop per year, while the irrigated areas can produce one or two crops per year. Typical crop intensities on irrigated lands are 110 - 130 percent only. This is because many farmers seek employment elsewhere in the dry season.

2 Riverine and terrestrial habitats

For the Mekong River system and it's tributaries a number of important habitats for conservation have been identified, they are:

- river channels;
- small islands and riverine sand-bars;
- marshes, small pools and seasonally-inundated floodplain wetlands;
- seasonally-inundated riparian forest; and
- inundated grasslands.

Little information is available on the presence of these habitats in the Lower and Upper Nam Mae Kok.

3 Fauna

According to the Kok River Basin study of 2000, surveys indicate the presence of 115 fish species in the Basin, belonging to 22 families. One family of freshwater prawn was registered. They include several economic species, like for example barb, catfish, and snakehead fish. There are also several exotic species, like loach and carp. Some species migrate between the Mekong and the Kok River Basin, where they breed. Rare or endangered species were not reported. The standing stock is estimated at 20 - 25 kg/ha, which is well below the nearly 100 kg/ha found in productive rivers and reservoirs elsewhere in Thailand.

IUCN information on red list species, reports that the Nam Mae Kok is probably a spawning site for the nearly extinct Giant Catfish (Pangasianodon gigas), one of the world's largest freshwater fish, measuring up to three meters in length and weighing in excess of 300 kilograms. The Thai Department of Fisheries collaborates with local fishermen in the Nong Bong Kai Non-Hunting Area (see Section on Protected Areas below) in obtaining eggs and sperm from the Giant Catfish in order to rear fry for release. The fish was bred in captivity for the first time in 2001. Individuals artificially spawned from wild-caught parents have been released into the Mekong since 1985.

The total number of aquatic bird species documented along the upper Mekong stretch includes about 100 species, comprising rare and endangered species. Nearly 40 per cent of the aquatic birds documented from the region are annual migrants, whereas some 30% of the species is associated with wetland ecosystems. Specific information for the Nam Mae Kok basin is limited.

That information that is available pertains to the Nong Bong Khai Non-Hunting Area and will be presented in the section on protected areas and rare and endangered species below.

4 Protected areas and rare and endangered species

According to ICEM, 2003 (Thailand National Report on Protected Areas and Development. Review of Protected Areas and Development in the Lower Mekong River Region) no protected areas are located in the project area.

In the Inventory of Wetlands of International and National Importance in Thailand of the Office of Natural Resources and Environmental Policy and Planning (ONEPP) of the Thai Ministry of Natural Resources and Environment (2002), the Kok River is listed as a wetland of national importance in Thailand. The river is considered a valuable water resource both for transportation and tourism. Rafting is popular with tourists and there are many resorts, hotels and restaurants along the banks. Gravel mining is a source of income for local people.

In the report 8 fish species are reported to be found in the river: Climbing perch (Anabas testudineus), Nile tilapia (Oreochromis niloticus), Thee-spot gourami (Trichogaster trichopterus), Striped croaking gourami (Trichopsis vittatus), Striped snakehead (Channa striata), Yellow mystus (Mystus nomunus) and Walking catfish (Charias batrachus).

The Nong Bong Kai Non-Hunting Area in the Lower Kok Basin, close to the confluence with the Mekong River, was designated a Ramsar Site in 2001. ONEPP prepared the Nong Bong Kai Strategic Wetland Management Plan in 2004. The information given below is mainly taken from this description and from the Wetlands International website. The flora and fauna encountered in the area is probably representative for other wetland areas in the Lower Nam Mae Kok Basin.

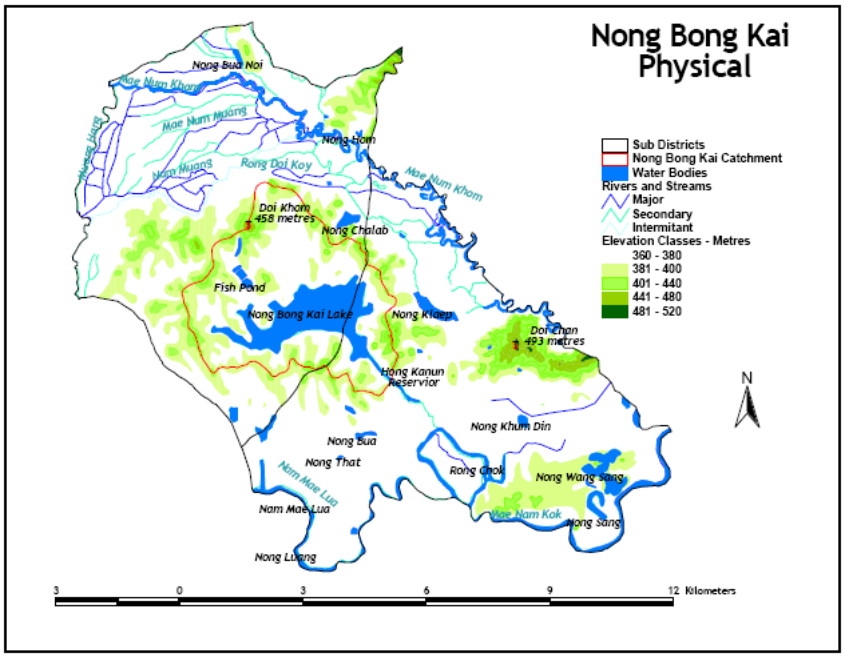
The Strategic Nong Bong Kai Wetland Management Plan covers 100 km2, this area used to be an intermittent floodplain surrounded by low mountains and hills. Villagers constructed an earthen dam on the Lua River to store water for agricultural uses and a 40 ha big lake was created: Chiang Saen Lake locally called Nong Bong Kai Lake. Nong Bong Kai Non-Hunting Area was formally declared on the 4 th of April 1985.

Nong Bong Kai is a natural depression surrounded by low hills, 360-500 m high. Eighty percent of the area is flat to undulating, 360-380 m high, and has slopes not over 2 percent. The Lake is 0 - 4.5 meters deep with an average depth of 2 meters. Maximum water storage is 4.9 million m3. The water level lowers with 1-1.5 m during the dry season. The lake drains to the Lua River a small tributary of the Lower Nam Mae Kok. Figure below shows the location of the area in the Lower Kok Basin.

Flora

Most of plant species that are found in the open water area are floating plants, Water hyacinth (Eichhornia crassipes) and Water fern (Azolla pinnata). These often clot together to form floating mats. Another typical aquatic plant is Cogon grass (Imperata cylindrica). In the submerged zone there are only a few species: Common hornwort (Ceratophyllum demersum), Hydrilla (Hydrilla verticillata), Duckweed (Lemna perpusilla), and Blyxa japonica (Blyxa japonica). Plants in the emergent zone include Water primrose (Jussiaea repens), and Lotus (Nelumbo nucifera).

On the shores 3 zones are distinguished, a herb sub-zone, where species such as Giant reed (Arundo donax), Common reed (Phragmites karka), Cogon grass (Imperata cylindrica), Swamp Millet (Isachne globosa), and Lindernia anagallis (Lindernia anagallis), a shrub sub-zone with species like the Giant mimosa (Mimosa pigra), Pagoda flower (Clerodendrum buchanani), and Bitter bush (Chromolaena odorata) occur and a third sub-zone consisting of Bamboo (Bambusa sp.), shrub and trees.



Location of the Nong Bong Kai site in the Lower Kok Basin

Fish

At least 46 species of fish from 17 families, with 17 species having economic value, are found in the wetland. The most abundant species is the Banded shark. There are 9 exotic species that have been introduced including the Hybrid walking catfish, Indian barb, Mekong giant catfish (Pangasianodon gigas), Iridescent catfish (Mystus reghna), and Giant snakehead (Channa micropeltes). Five threatened species are important for conservation: Big-head walking catfish (Clarias macrocephalus), Walking catfish (Charias batrachus), Siamese fighting fish (Betta splendens), Barb, and Badis (Badis badis).

There are 15 species that migrate in the rainy season between Nong Bong Kai, Lau River and Nam Mae Kok River, for example the Banded shark, Black striped barb and Tawes from the Khong River and Thai minnow and Walking catfish from the Lua River.

Mammals and birds

Wildlife habitats in Nong Bong Kai and nearby areas have been mostly destroyed. This has caused a decrease in the number of wildlife species and now only small animals that can adapt to the changed habitats remain. However, water resources in Nong Bong Kai Lake and adjacent wetlands are an appropriate habitat for migratory birds arriving here to avoid cold and drought in southern China and Siberia. From November to February every year, large numbers of water birds stay and breed in the catchment area and often find food in the paddy fields.

From literature reviews and a bird surveys at Nong Bong Kai Lake and adjacent areas it was found that there are at least 225 bird species. These divide into 79 migratory species such as

Garganey (Anas querquedula), 23 resident breeder species such as Chinese franolin (Francolinus pintadeanus) and 23 migratory/resident breeder species such as the Common Moorhen (Gallinula chloropus).

The status of 219 of these species (97%) is protected and 19 species are threatened. Five species are recognized to be of international importance: White eyed pouchard (Aythya nyroca), Baer's pochard (Aythya baeri), Grey headed lapwing (Vanellus cinereus), Schrenck's bittern (Ixobrychus eurhythmus) - and Painted stork (Mycteria leucocephala).

BirdLife International, on their website, considers the Nong Bong Kai lake an Important Bird Area (IBA), on the basis of the occurrence of Baer's pochard (Aythya baeri), Spotted redshank (Tringa Erythropus) and Small pratincole (Glareola Lactea).

5 Fisheries

In terms of occupation, fisheries plays a minor role only. In the Kok Basin, only 0.8 percent of the households indicate fisheries as their main source of income. However, it is believed that this figures underestimates the significance of the fisheries. From an economic point of view, many people engage in fishing as a side occupation, whereas experience from elsewhere in the Mekong Basin indicates that fisheries for own consumption contributes a large part of the protein to the diet.

Although fishing is mainly practiced for own consumption, there is some commercial capture fishery, which is typically done as a side occupation. Fishing gears are simple, like cast nets, pole and line, and, in the wet season, bamboo traps. Some illegal methods have been reported, like electrofishing, poison, and nets with small mesh sizes. A typical commercial catch is 2 - 6 kg/day in the dry season and 10 - 15 kg/day in the wet season.

In addition to the capture fisheries, there are widespread small-scale hatcheries and fish ponds, for example in connection with integrated farming.

6 Tourism

The provinces of Chiang Mai and Chiang Rai offer a large variety of tourist attractions. They cover both cultural sites, adventures (boating and trekking), natural attractions, shopping, and museums. There are numerous temples, landscapes and natural attractions, as well as activities like cultural shows and festivals. There is a large and steadily growing number of visitors to the provinces and tourism contributes considerably to the economy, both in terms of national and foreign currency. Already, tourists include a small proportion of bird-watchers.

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11.2 Environmental baseline Bokeo Focal Area

1 General characteristics

The Mekong River channel upstream of the Bokeo Focal Area is characterized by a series of massive rocky outcrops, both above water and submerged, forming rapids. Water flows in this stretch are fast and turbulent. Many rapids have associated deep pools and sand banks. The width of the river channel varies between less than 50 m to over 150 m. Because of the rocky substrate of this section, bank erosion is not considered much of a problem, except in the wider areas, such as at Ban Don Moon. Here the banks consist of deposited sand, on which the villagers cultivate crops such as soy beans and ground nuts.

From the Golden Triangle to Ban Nam Keung Mai, the project area, the river is wider, up to 500 m in places. The river is slower moving, with wide meanders. Rocky areas and rapids are absent and the water flow in this area is not turbulent. The riverbanks consist of steep, eroded mud/silt (4 - 10 m high) interspersed with extensive wide sand and pebble beaches. Islands are present in a few sections. The river has been heavily modified through embankments along a significant portion of this stretch of river which is heavily urbanized, especially on the Thailand side. The floodplain is wide and the adjacent countryside is relatively flat. Natural forest is almost absent and has been replaced by cultivation on both banks. A narrow strip of reeds is often present on both sides of the river. There is an extensive area of reeds at the junction between the Nam Mae Kok river and the Mekong on the Thailand side below Chiang Saen. Many tributaries and streams flow into the Mekong River in this area, including the Nam Ruak, Nam Kam, Nam Kok, and Nam Yon.

Downstream of the project area the Mekong flows again through a narrow channel and over the Khon Pi Luang rapids just upstream of Ban Houay Xay. This system of rapids consists of rock outcrops (not as massive as further upstream), mudflats and sand bars created by sedimentation, low lying islands (often with shrubs flooded during high flows) and long deep pools and whirlpools. The deep pools may be several hundred meters long and vary in depth up to 100 m, but are more usually, 30 - 60 m deep.

The surrounding area consists of steep hills and forest cover is present in patches on the Lao side. The Thailand side of the river is largely cleared and cultivated. There are few villages in this stretch.

The banks of the Mekong River in the Bokeo Province comprise of residual soil of weathered rocks (mainly shale and sandstone) and old and recent alluvial deposits, ranging in texture from clayey silt and silty clay, to silty fine sand of both recent and old levee deposits, to gravel.

Water quality in the vicinity of the project area is reported to be good to very good, but may deteriorate in future (MRC, 2007). Two hydropower stations have been built on the on the mainstream in the Upper Mekong Basin (Manwan and Dachaoshan) and six more hydropower stations are planned for development in the next 20 years. Although Chinese sources claim that these dams will have no impact on water quality in the Lower Mekong Basin, there is the danger of release of anoxic bottom waters from the reservoirs. Also, a 2.7^{o}C reduction in temperature of water is anticipated at the Xiaowan dam site.

Industrial pollution is another threat to the water quality in the project area. In 2000, the provincial government of Yunnan Province in China (located immediately upstream of the China/Lao PDR border) inspected 1042 industrial enterprises. This resulted in the forced closures of four plants. Rapid development of the Lancang basin in China and increasing pollution in Chinese rivers raise concerns about a deterioration quality of the water arriving in the Lower Mekong basin from China in the future.

Rapid demographic growth, socioeconomic development and urbanization also affect the water quality. According to Meynell (2003) the water of the Mekong water downstream of Chiang Saen, was less clean and clear than in the upstream reaches, due to urban pollution, river traffic and port construction. Dissolved oxygen and organic content of the river water was reported to be above the water quality standard, ammonia, oil and total coli-form bacteria counts were below standard.

The livelihoods of the people who live on the Mekong riverbanks in the vicinity of the project area (both on Lao and Thai sides) are mixed between land-based and river-based. They farm rice in the upland area, fish in small streams and the Mekong River and grow vegetables in gardens on sandbars and riverbanks when the water level is low in winter and summer. Local people collect Mekong seaweed (Kai), which grows on pebbles in fast-flowing shallow waters for their income and food. Although Kai products are sometimes marketed, collecting is usually for household consumption.

In some areas, villagers pan gold, digging up sand and gravel with favorable appearance, panning it to isolate gold particles, and extracting the gold with mercury. Villagers have small quantities of mercury for this purpose.

2 Ecological resources

Riverine and terrestrial habitats

For the Mekong River system a number of important habitats for conservation have been identified, they are:

- river channels;
- small islands and riverine sand-bars;
- marshes, small pools and seasonally-inundated floodplain wetlands;
- seasonally-inundated riparian forest; and
- inundated grasslands.

The river channel in the project area is vitally important for the seasonal longitudinal migration of fish species. The Mekong River hosts one of the richest freshwater fish faunas in the world. More than 1,000 species have been formally described and this diversity supports the largest inland fishery in the world, not only in terms of tonnage but also in terms of the number of people involved.

Two of the main factors that explain the high diversity and productivity of the Mekong fish fauna are the extreme habitat diversity of the river ecosystem and the state of health of the river. Not only is habitat diversity high, but the ecosystem functioning and connectivity between habitats is largely intact. Fishes are still able to exploit different habitats according to natural seasonal changes and can, for instance, migrate between upstream spawning habitats and downstream rearing habitats, and between river refuges and floodplain feeding habitats.

Key fish habitats are feeding habitats, spawning habitats and refuge habitats. Most fishes of the Mekong feed in the productive seasonally inundated floodplains. At the end of the flood season, when these habitats dry out, fishes move to refuge habitats within river channels where they wait for the next flood cycle. Most fish spawn at the onset of flood season. The main habitats used for spawning are rapids and deep pools in river channels as well as certain floodplains. Most migratory fishes, which account for a significant proportion of the fish catch of the Mekong, spawn within river channels at rapids/pools upstream from feeding and rearing habitats.

A large proportion of Mekong fish species is migratory. Many species move from one habitat to another to complete their life cycle. For instance, several important species migrate upstream to breed at the beginning of the rainy season. Then, as the water rises, the young fish are swept downstream to flooded areas.

The Mekong River and its tributaries, like the Nam Mae Kok, are also an important habitat for a distinctive guild of riverine bird species. Small islands and riverine sand-bars form a habitat for pioneer plant communities and breeding sites for waterbirds. Seasonal wetlands inundate in the wet season when water levels of the Mekong are high. Wetlands provide some of the most productive habitats in the Basin and include reed and sedge beds, swamps, and lotus ponds. Another important habitat is the seasonally-inundated riparian forest found on the gently-sloping plains adjacent to the river. Fish use this habitat as a feeding, breeding, and nursery ground and it is important for breeding colonies of large waterbirds.

In the river channel upstream of he Focal Area deep water pools are encountered. This habitat is important to many fish species, particularly as low water refuge area and as spawning ground. The high level of water turbulence in his stretch provides good oxygenation of water at times of low flows.

In the Focal Area the river broadens out and the flow rate reduces. Rocky areas and rapids are absent and the riverbank is predominantly steep. These steep river banks provide a nesting habitat for a variety birds, see Table below Extensive wide mud, sand and pebble beaches and islands are present, forming an excellent feeding, resting and nesting habitat for wading birds and ducks. The floodplain is fairly wide and the adjacent countryside is relatively flat. Natural forest is almost absent and has been replaced by shrub or agricultural areas on both banks. A narrow strip of reeds is often present on both sides of the river. There is an extensive area of reeds at the junction between the Mae Nam Kok river and the Mekong on the Thailand side below Chiang Saen. The reed mashes are an important nesting habitat for birds and small mammals.

Downstream of the Focal Area, the river narrows down again to include frequent rapids. Sand and silt beaches are less frequent and mid-stream rocks are evident. The riverbank is bordered by steeply rising hills. Forest cover is present in patches on the Lao side, the Thailand side of the river is largely cleared and cultivated.

The variety of aquatic and terrestrial habitats in the upper Mekong has contributed to a high level of biodiversity. Ecosystems and habitats in the vicinity of the Focal Area that are important for the conservation of this high biodiversity are rapids, deep pools, long pools and whirlpools, sand bars (with and without pebbles) and islands, wetlands and seasonally flooded shrub areas on the floodplain and the riparian forest. These habitats are very important as a source of fish food and as spawning ground for fishes.

Wildlife and rare and endangered species

The total number of aquatic bird species documented along the upper Mekong stretch includes about 100 species, comprising rare and nationally endangered species. Nearly 40 per cent of the aquatic birds documented from this region are annual migrants, whereas some 30% of the species is associated with wetland ecosystems. Lazarus et al. (2006), identified in total 29 species that are dependent on either the riverbanks, the sandbars, the mudflats of a combination of these habitats. They are listed in Table ….

For 17 bird species observed during the survey, the riverbanks are an important habitat. Of these 17 species 4 were only rarely observed. Of the observed mammals, the Fishing Cat (*Prionailurus viverrinus)* is dependent on the riverbanks.

The herpetofauna include 15 species of amphibians and 19 species of reptiles, including six globally threatened freshwater turtles. There are several globally significant sites for biodiversity conservation. Segments of the upper Mekong form part of the Indo-China Biodiversity Hotspot.

Although fish diversity is generally considered to be lower in upper reaches of rivers compared to the lower reaches, an IUCN inventory (Meynell (2003) and Dubeau (2004)) confirmed that a large number of fish species inhabit the upper Mekong. During interviews, sampling of fish catches and observations on markets 86 fish species were identified.

Habitat dependence and relative abundance of birds observed during the 2005 IUCN survey (Lazarus et al., 2006)

Family	Common & Scientific Name	Habitat*)			Abundance**)		
		RB	SB	MF	C	UC	R
Anatidae	Ruddy Shelduck – *Tadorna ferruginea*		X	X			X
	Spot-billed Duck – *Anas poecilorhyncha*		X	X			X
Scolopacidae	Common Sandpiper– *Actitis hypoleucos*		X	X	X		
Burhinidae	Great Thick-knee – *Esacus recurvirostris*		X	X			X
Charadriidae	Little-ringed Plover – *Charadrius dubius*	X	X	X	X		
	Long-billed Plover – *Charadrius placidus*		X	X			X
	Kentish Plover – Charadrius alexandrianus		X	X		X	
	River Lapwing – *Vanellus duvaucelii*	X	X	X		X	
	Grey-headed Lapwing – *Vanellus cinereus*	X	X	X		X	
	Red-wattled Lapwing – *Vanellus indicus*	X	X	X		X	
	Temminck's Stint – *Calidris temminckii*		X	X		X	
Glareolidae	Small Pratincole – *Glareola lactea*	X	X	X	X		
Ardeidae	Little Egret – *Egretta garzetta*	X	X	X	X		
	Intermediate Egret – *Mesophoyx intermedia*	X	X	X		X	
	Great Egret – *Casmerodius albus*		X	X			X
	Chinese Pond Heron – *Ardeola bacchus*	X	X	X	X		
	Grey Heron – *Ardea cinerea*		X	X		X	
	Little Heron – *Butorides striatus*	X					X
Alcedinidae	Common Kingfisher – *Alcedo atthis*	X				X	
	Blyth's Kingfisher – *Alcedo hercules*	X					X
Halcyonidae	White-throated Kingfisher – *Halcyon Smyrnensis*	X			X		
Motacillidae	White Wagtail – *Motacilla alba*	X	X	X	X		
	Grey Wagtail – *Motacilla cinerea*	X		X			X
	Paddyfield Pipit – *Anthus rufulus*			X		X	
Hirundinidae	Barn Swallow – *Hirundo rustica*		X		X		
	Red-rumped Swallow – *Hirundo daurica*		X		X		
	Wire-tailed Swallow – *Hirundo smithii*	X					X
	Plain Martin – *Riparia paludicola*	X	X			X	
Apodidae	Asian Palm Swift – Cypsiurus balasiensis	X			X		
Total		17	21	20	10	10	9

*) RB = Riverbank, SB =Sand bar, MF = Mudflat
**) C = Common, UC = Uncommon, R = Rare. Note: Relative abundance is given, as observed during a limited field survey of IUCN in 2005 reported by Lazarus et al. (2006)

However, it was also noted that many of the species, particularly the large species such as the Mekong Giant Catfish (*Pangasianodon gigas*) and *Pangasius sanitwongsei*, have experienced quite drastic declines in recent years.

Aquatic vertebrates such as fish, amphibians, reptiles and waterfowl are important indicators of the overall ecological integrity of the Mekong region. While freshwater fish form a major source of protein for local communities, other aquatic vertebrates such as amphibians, reptiles and waterfowl provide supplementary food resources for local communities. The insectivorous and carnivorous vertebrate species (e.g., amphibians and reptiles) function as important biological control agents of agricultural pests such as insects and rodent pests, especially in paddy cultivation. The species richness and abundance of avifauna along the river could play a key role in promoting eco-tourism in the region.

2.3 Protected areas

According to ICEM (2003) no protected or proposed protected areas are located in the project area.

Birdlife International identified the Mekong River in northern Lao PDR, as an important bird area (IBA). It comprises a 377 km section of the Mekong channel, from Ban Xiangkhok on the Lao-Myanmar border to Ban Bo on the boundary between the Oudomxai and Xaignabouli Provinces. The project area falls within this reach.

The section supports three basic habitat types: stretches with a well defined channel but no, or negligible, exposed bed; stretches with many sandbars and stretches of channel mosaic habitat, comprising sand and gravel bars and islands, rock outcrops, bushland and braided streams. The stretches of channel mosaic habitat support a relatively rich riverine bird community, including River Lapwing *Vanellus duvaucelii* and Jerdon's Bushchat *Saxicola jerdoni*. The stretches with many sandbars are important for Small Pratincole *Glareola lactea*; the IBA supports 5% of the estimated world population of this species. The IBA also supports large numbers of Plain Martin *Riparia paludicola* and significant numbers of Grey-headed Lapwing *V cinereus*, and is the site of the only recent Lao records of Great Cormorant *Phalacrocorax carbo*. Finally, there are single records of both Swan Goose *Anser cygnoides* and Black-bellied Tern *Sterna acuticauda* from the IBA, although it is unlikely that it regularly supports significant numbers of either species.

Key bird species for the IBA status are the River Lapwing *Vanellus duvaucelii* and Small Pratincole *Glareola lacteal.* The area holds on a regular base more than 1% of the Asean biographical population of these species. The River Lapwing population at the IBA is of high national (Lao) significance but moderate to low global significance. The IBA population of Small Pratincole is of moderate national and global significance.

Most of the IBA is easily accessible from along the banks of the Mekong River, and levels of human activity are high. Major threats to biodiversity at the IBA are active persecution, in the form of hunting and egg collection, and incidental disturbance, including boat traffic and accidental nest destruction.

Close to the project area in the lower Nam Mae Kok Basin, another protected area is located, the Nong Bong Khai, or Chiang Saen lake which is a Ramsar site (Wetlands International

website). It is a permanent freshwater lake with an area of 2 km^2 at the centre of the Chiang Saen Basin, known for its extraordinary bird life and diversity of freshwater fish.

The Chiang Saen Basin is located on a plateau surrounded by low hills at the border of northern Thailand's Chiang Rai province. The northeast of the basin, which is almost 18 km wide and 10 km long, opens out onto the Mekong River to which the basin ultimately drains. At the south of the basin is a permanent swamp while to the north lies the lake.

The site is an important area for local and migratory birds, particularly waterbirds, including globally vulnerable species of duck. A total of 225 species of bird have been recorded at Chiang Saen Lake. In addition to the birdlife, some 21 fish species have found in the area, many of which are attracted by the rich aquatic plantlife which includes at least 24 species of aquatic plants.

3 Fisheries

Fisheries is practiced mainly for subsistence rather than for income. Deep pools, whirlpools and sand bars are the most important fishing grounds. The 2005 IUCN (Lazarus, 2006) assessment made clear that more than 106 fish species contribute to the food security of local people in the region. This includes both small and large species, such as groups of cyprinids (*Morulius chrysophekadion, Puntioplites protozyscron, Cosmocheilus harmandi* and *Henicorhynchus spp*.), Bagrids (*Mystus nemurus* and *Mystus wyckoides*), Silurids (*Hemisilurius erythrospila*), and Pangasids (*Pangasius bocourti*). Fishing activities in rural communities rely on migratory fish species and utilise seasonally-specific types of traditional fishing gear. The fishing gear used in the area during the wet season is dominated by bamboo traps (60%), gill nets(20%), longlines (15) and bag nets (5%). Drifting gill nets and cast nets are more commonly used during the dry season. The use of the different types of gear also depends on habitats. The survey made also clear that fishing is a way of life for the communities living along the Mekong River. Where there are people, there is fishing.

4 Tourism

The ancient town of Chiang Saen was originally called Wiang Hiran Nakhon Ngoen Yang. It served as the capital of the Lanna Thai Kingdom until King Mengrai established Chiang Rai as the capital in 1262. Ruins of the old double city walls and many other antiquities remain both inside and outside the town. Most notable is the distinctive style of Buddhist sculpture which evolved in Chiang Saen during the late thirteenth century providing proof of the city's historical importance. Rich cultural heritage, coupled with natural tourist attractions, has made Chiang Saen a unique tourist destination. Tourism is rapidly expanding in the area and generally attracts the younger, lower-budget foreign travellers as well as a great many Thai nationals. Income from this source at present goes directly into the pockets of local people since there are no outside, large-scale tourist developments. Already, such tourists include a small proportion of bird-watchers.

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11.3 Environmental baseline Se Bang Fai Focal Area

1 General characteristics

The Xe Bang Fai has a catchment area of about 10,240 km^2. The river takes its rise in the Annamite mountain range near to the border with Viet Nam, west of Thakhek and joins the Mekong at km 1,166, opposite of the city of That Phanom in Thailand. The Xe Bang Fai has a number of tributaries, the largest of these, the Xe Noy, joins the Xe Bang Fai just upstream of the Focal Area. The Xe Bang Fai catchment downstream of this junction is called the Xe Bang Fai Plain. The plain is about 15 km wide, bounded by the Mekong River to the west and upland forest on an old alluvial terrace to the east. The length of the river in this stretch is approximately 70 km. The area is fairly densely populated with some 60 villages and about 400 km^2 of rice paddy fields. It is a major area of rice production for the Khammouane Province.

The Xe Bang Fai plain is rather flat. Along the river narrow natural levees have developed, further from the river the area consists of low lying basins, old river channels with oxbow lakes that have silted up, separated from each other by relatively high lying old river levees. Most of the flood plain has an elevation of less than 140 m amsl, and floods frequently. The natural levees along the river and in the floodplain have a somewhat higher elevation and are less frequently and less deeply inundated.

In the period July till early October high discharges of the Se Bang Fai coincide with high water levels on the Mekong. When the water surface in the Xe Bang Fai exceeds a certain level, usually late in the rainy season, backwater from high Mekong River discharges causes the flow in the river channel to be reversed and flooding takes place through the tributaries and by overtopping of the river banks. Flooding may last for several months in the areas below 140m amsl.

Rice cropping and vegetables growing are the main agricultural activities in the project area. Agriculture is the area's largest sector of employment, with 92 percent of the inhabitants having rice production as part of their livelihood systems. Vegetables and other crops are grown by residents on the Xe Bang Fai river banks, as well as in the flood plains around natural lakes as water recedes. Lowland wet rice is cultivated in the lower lying areas.

Dry season river bank vegetable cultivation is done mainly by women, it is an important activity which provides food and income to local families. Crops grown include corn, yam, water melon, long bean, vegetables (cucumber, lettuce, garlic, and eggplants) and tobacco. Part of the produce is sold on local markets and tobacco forms an important source of cash income.

In the project area, where irrigation systems are fairly well developed, focus is changing from riverbank gardens to gardens watered from the irrigation systems, and thus located next to or in the vicinity of irrigated paddy fields.

In general, pest attack on rice crops is low in Lao PDR. Consequently, also the pesticide use is low. Rice diseases are rarely treated with chemicals (e.g. fungicides), and weed control with herbicides is also very rare. Pesticide use for vegetable growing is believed to be significant. The number of treatments applied is apparently not excessive, but every farmer treats his vegetables with insecticides.

Inorganic fertilizers are used predominately on the dry season rice crop, but increasingly also in the wet season. Some inorganic compound fertilizers appear to be used on the basis of availability from donors rather than on need.

In the dry season the Se Bang Fai is the most important water source for the villagers in the area, although for cooking and drinking other sources, mainly deep (bore) and shallow wells, are also important. In the wet season, rain water and the Se Bang Fai are equally important as a source for domestic water.

The water quality of rivers within the Lao PDR is considered to be good. The level of oxygen is high and the nutrient concentration is low. Due to rapid demographic growth, socioeconomic development and urbanization, however, water quality is deteriorating. It is common practice to dispose litter and sewage to water courses and drainage channels. As a result, the surface water is invariably contaminated with faecal matter from latrines and coliforms from septic tank effluents.

There is little information available on groundwater quality in Lao PDR, even though it is the main source of rural water supply. Arsenic contamination is not considered a high risk in Lao PDR.

2 Ecological resources

2.1 Aquatic habitats and fish

A survey for the whole of Lao PDR yielded 203 fish species in 1974, the list had grown to 481 species by 2001 (Kottelat, 2001). Even with Kottelat's significant contribution to the increase in knowledge of fish distribution in Lao PDR, information on fish distribution, biology and ecology remains basic.

The main dry season fish habitat types in the lower Xe Bang Fai river and floodplain are pools and slow water stretches in the river and swamps and stagnant pools on the floodplain. The river bed is characterised by a muddy to sandy bottom, with occasional rocky outcrops and rapids. The water is turbid, although compared to most other lowland streams in the Mekong basin it is still clear, with a visibility of about 50 cm. The depth is variable, from several metres to a few centimetres on some sandbars.

During the wet season, most of these habitats change completely and some are displaced to other areas. In this period fish populations frequently use habitats that are not available during the dry season for spawning, incubation of eggs, and rearing of fry. In the lower Xe Bang Fai basin, flooded areas are important as nursery grounds and refuges for juvenile fish.

One hundred and thirty-one fish species have been observed in the Xe Bang Fai, sixty-seven (67) of these in the lower Xe Bang Fai. No endemic species were recorder in the latter stretch. The fish fauna of the lower and middle Xe Bang Fai fauna can clearly be described as a middle Mekong fauna. According to Kottelat (2001), the standing stock ranges between 6 and 23 kg per hectare. This is considerably less than what can be expected considering the high nutrient concentrations. This could be the result of fishing activities by local fishermen and because samples were taken during the dry season when few fish from the Mekong were in the river to spawn. Abundance was lowest at Dan Pakse at the confluence with the Mekong. Monthly variations in abundance along the river channel reflect seasonal migratory behaviour of fish. Most of the catch consists of medium size cyprinids (*Puntioplites spp*, *Hypsibarbus spp*, *Barbodes spp*, *Labeo chrysophekadion*, *Puntius orphoides*). Catfishes (*Pangasius siamensis*, *Clarias batrachus*, *Mystus wyckioides*, *Hemibagrus nemurus*) and snakehead (*Channa striata*) are less important.

Three geographically-defined fish migration systems exist in the Mekong Basin: lower, middle and upper Mekong migration systems, the Xe Bang Fai basin fall within the middle Mekong migration system. Within this river section floodplain spawning and nursery habitats are

associated with the tributaries. Adults and juveniles spend the dry season in deep refuge pools in the mainstream channel. At the onset of the wet season, they migrate upstream along the Mekong until they encounter a tributary, and then swim up the tributary until they reach a floodplain or another possibly suitable spawning habitat. Many species spawn only once, soon after arriving on the floodplain, while others spawn several times during the flood season, and a few others spawn only once at the end of the wet season or beginning of the dry season. The fry grow out on the floodplain which acts as a nursery and contains rich forage. As the flood water begins to recede from the floodplain, adults and juveniles migrate back in the tributaries and move downstream to the Mekong. There are over thirty medium and large size species of cyprinid and pangasiid catfish which exhibit this general migration pattern. The first major fish migration of the year commences at the beginning of the wet season. At that time, according to villagers, a large number of fish species begin migrating up the Xe Bang Fai, and its larger tributaries, while other fish species are believed to move from deep-water pools to spawning areas in the Xe Bang Fai.

These two migrating groups include the following taxa: Cyprinids *(Labeo chrysophekadion, Labiobarbus sp., Sikukia gudgeri, Hypsibarbus sp., Puntioplites sp.),* Catfish *(Pangasius larnaudii, P. macronema, P. pleurotaenia, P. bocourti, Wallago attu, W. leeri, Bagarius sp, Hemibagrus wyckioides, H. nemurus, Helicophagus waadersi, Laides sp., Mystus spp.),* Mud perch *(Pristiolepis fasciata),* Glassfish *(Parambassis siamensis),* River loach *(Schistura sp. or Nemacheilus sp.)*. During overbank flooding events fish migrate laterally to temporally inhabit adjacent flood plains for spawning and feeding.

2.2 Wetlands and terrestrial habitats

For the Lower Mekong River system a number of Important habitats for conservation can be distinguished, they are:

- river channels;
- small islands and riverine sand-bars;
- marshes, small pools and seasonally-inundated floodplain wetlands;
- seasonally-inundated riparian forest; and
- inundated grasslands.

The river channels are vitally important for the seasonal longitudinal migration of fish species. The Mekong River and its low gradient tributaries, like the Se bang Fai, are also an important habitat for a distinctive guild of riverine bird species.

Small islands and riverine sand-bars are formed by natural deposition during seasonal high river flow. They form a habitat for pioneer plant communities and breeding sites for waterbirds.

Seasonal wetlands inundate in the wet season when water levels of the Mekong are high. Groundwater and seasonal monsoonal rains maintain other wetlands year-round. Wetlands provide some of the most productive habitats in the Lower Mekong Basin and include reed and sedge beds, swamps, lotus ponds, and inundated forest. They are usually shallow, filled by seasonal rainfall and typically are connected to the river system which in the wet season form the inundated plain of the Lower Mekong Basin. Submerged communities are dominated by *Ceratophyllum demersum* and *Utricularia aurea*. The seasonal changes in water level of the Mekong inundated plain drives a seasonal migration of large waterbirds between wetlands. In the dry season, many species move to permanent wetlands and grassy plains around Lake Tonle Sap and the Delta, while in the wet season they retreat to higher seasonal wetlands in northern Cambodia and Lao.

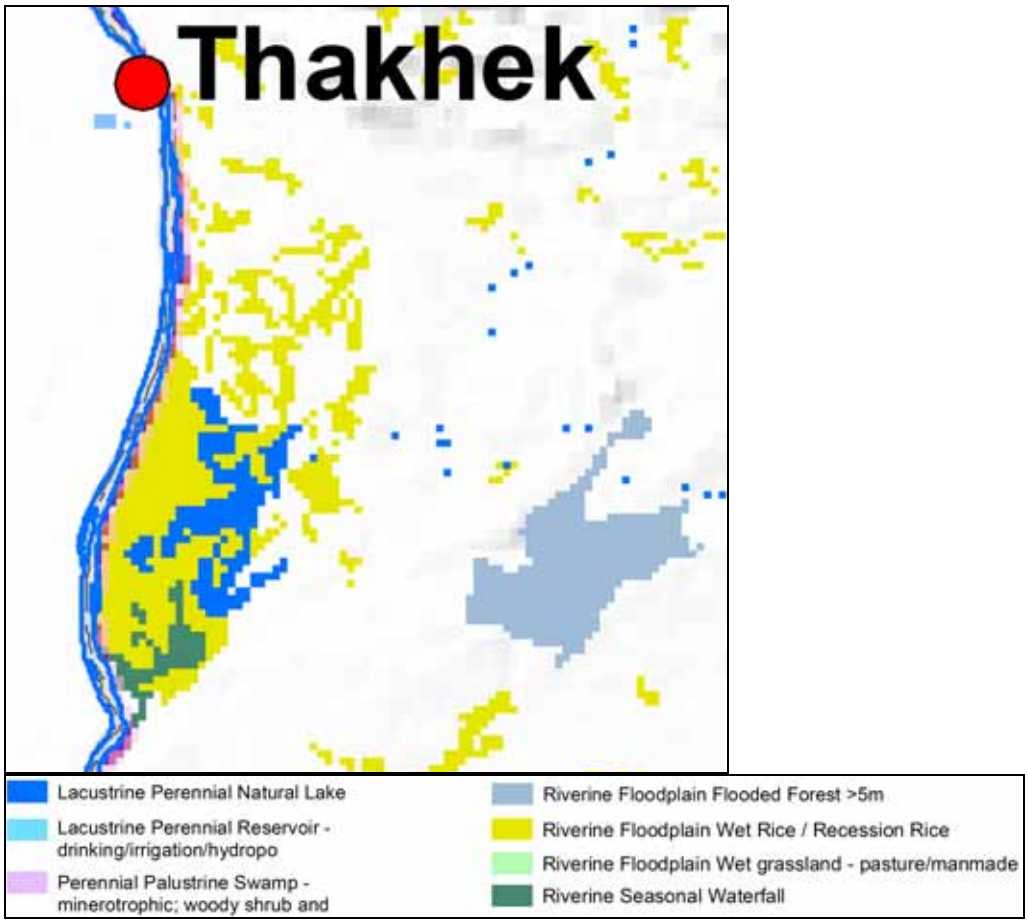
In the dry season, these wetlands are vital in maintaining breeding stocks of floodplain fish, including air-breathing species (e.g. gouramies, walking catfish), while in the wet season they function as breeding and nursery grounds for many fish species, the black fish. These wetlands are important for almost all waterbirds in the Lower Mekong Basin, particularly cormorants, Oriental Darter, Spot-billed Pelican, Greater and Lesser Adjutants, Milky Stork, Woolly-necked Stork *Ciconia episcopus*, Black-necked Stork *Ephippiorhynchus asiaticus*, Painted Stork, The Globally Endangered White-shouldered Ibis *Plegadis davisoni,* Glossy Ibis *P. falcinellus*, Black-headed Ibis *Threskiornis melanocephalus*, White-winged Duck, Pallas's Fish Eagle *Haliaeetus leucoryphus,* Grey-headed Fish Eagle, and the Globally Vulnerable Masked Finfoot *Heliopais personata*.

One of the most important wetland habitats of the Lower Mekong Basin is the seasonally-inundated riparian forest found on the gently-sloping plains adjacent to lakes, rivers and tributaries and submerged by the seasonal flood of the wet season. Fish use this habitat as a feeding, breeding, and nursery ground and it is important for breeding colonies of large waterbirds.

Seasonally inundated grasslands are common on the floodplains of the Lower Mekong Basin. Close to the water edge, floating or emergent vegetation forms dense mats. As water levels rise, dense mats may dislodge and float, propelled by currents or the wind. The main species include *Achyranthes aquatica, Brachiaria mutica, Eichornia crassipes, Polygonium barbatum* and *Sesbania javanica*. Other plant species found on the upper reaches of the inundated plain include several grasses, including *Echinochloa stagina,* sedges including *Cyperus pilosis, Rhynchospora* sp., and dicotyledons such as *Aeschynomene indica, Impatiens sp., Ludwigia hyssopifolia* and *Nelumbo nucifera* (lotus). They are of crucial importance for a number of rare and endangered bird species.

According to the Inventory of Wetlands in Lao PDR (Claridge, 1996), the project area is a fairly important wetland area, consisting of a mosaic of fresh water lakes, river ponds, rice paddy and fresh water marshes. Most of the wetland is located north of the Xe Bang Fai and is associated with the Houay Vay and the Houay Sayphay. Close to the river there are several old river channels with oxbow lakes, that silted up and form fairly large marshes. Bung Xuak on the southern side of the river, just west of Bung Veun Nua, is the best example. It is possibly the only wetland in the area that retained a significant proportion of its original vegetation. It is also the largest, about 3 km^2, and has open water at the end of the dry season.

Nearly 9% (2,726 ha) of the Nongbok District, the district covering most of the project area) consists of wetlands. Some 30% of the district (9,400 ha) is under forest.



Wetlands in the Lower Se Bang Fai area

2.3 Wildlife and rare and endangered species

No information is available about the fauna in the project area. However, it is known that the wetlands of the Lower Mekong Basin support some 15 globally-threatened bird species, namely the Critically Endangered Giant Ibis *Pseudibis gigantea*, the globally Endangered Sarus Crane *Grus Antigone*, Greater Adjutant *Leptotilos dubius*, White-shouldered Ibis *Pseudibis davisoni*, White-winged Duck *Cairina scutulata*, Bengal Florican *Eupodotis bengalensis* and Nordmann's Greenshak *Tringer guttifer*, the globally Vulnerable Spot-billed Pelican *Pelican Pelecanus Philippensis*, Lesser Adjutant *Leptoptilos javanicus*, Milky Stork *Mycteria cinerea*, Greater Spotted Eagle *Aquila clangula*, Green Peafowl *Pavo muticus*, Masked finfoot *Heliopais personatus*, Black-bellied Term *Sterna acuticauda*, and Indian Skimmer *Rynchops albicollis*.

Of the reptiles the Siamese Crocodile *Crocodilius Siamensis* is Critically Endangered. It was formerly widespread thoughout the Lower Mekong Basin but has declined drastically due to excessive hunting and habitat destruction. It is reported to be present in the vicinity of the project area. Also over twenty species of turtles occur in the Lower Mekong Basin, ten of which are listed in the Red Data book including the Chinese three-striped box turtle *Cuora trifasciata* that is Critically Endangered.

Possibly the wetlands in the project area are of importance for one or more of these rare or endangered species.

2.4 Protected areas

According to ICEM, 2003, Lao PDR National Report on Protected Areas and Development. Review of Protected Areas and Development in the Lower Mekong River Region, no protected or proposed protected areas are located in the project area.

BirdLife International in Indochina, on its website, indicates that there is an important bird areas (IBA) located in the project area. Details are not available.

2.5 Fisheries

After rice, fish is the most important item on the diet for all ethnic groups in the area. Besides, the sale of fish on local markets adds considerably to the income of most households. Fish is caught with a variety of gear and equipment including explosives, poisonous plants, nylon monofilament gill nets, spears, hook and line, cast nets, scoop nets and many types of trap. Drift and fixed gillnets are the most important gear in terms of the size of fish landings made by fisherman from the Xe Bang Fai. Fish is caught all year round by men, women and children. The seasonal fish migrations between the Mekong River and the Xe Bang Fai are important periods for fisheries.

The main Xe Bang Fai channel is the most important fishing ground during the dry season (when fish concentrate in refuge habitats), while habitats on the floodplain (flooded forests, swamps, backyard ponds, paddy fields) are important during the wet season. Catches consist mainly of cyprinids and catfishes, many of which in-migrate from the Mekong mainstream. Catches in the floodplains also include resident species such as snakehead, mud perch, spiny eels, climbing perch, walking catfish, and gouramies.

Families in the lower reach of Xe Bang Fai catch on average 168 kg fish/fam/year, sufficient for daily consumption and the production of 2 - 8 jars (= 22 kg) of 'Padek' /family/year Padek, salted fermented fish, is the second staple food in Laos, after rice. The remaining catch, on average 20% or some 35 kg/household/y, is sold on the market. Anecdotal information suggests that production has declined over the last 10-15 years. Average fish size and the number of species caught have also declined. The reason for the decline is thought to be overfishing and use of small mesh monofilament gillnets.

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11.4 Environmental Baseline Kratie Focal Area

1 General characteristics

The Kratie Province is located in the northeastern part of Cambodia. Most of the province consists of the Mekong floodplain, which has elevations below 100 m. The mainstream of the Mekong River runs through the central part of the province in a general north to south direction, before sharply turning to the west at Chhlong near the southern boundary of the province. In the project area, the width of the main river ranges between 1.2 and 3.5 km. The river bed, at low water levels, is characterized by numerous sand and gravelbanks and islands. Just upstream of the project area, a series of rapids has developed.

The river deposits in the project area consist of fine sand, silt and clay with layers of coarse sand and rounded quartzite pebbles. In the river bed from Sambok to Kratie and further downstream to Chhlong the underlying bedrock (sandstone) is almost totally submerged even in the dry season.

The river banks are steep and rise 14 to 20 m above the low water level. On the top of the river banks natural levees have developed. Further from the river, after some 100 m, the surface slopes away to form depressions in which swamps have developed. Examples are the Boeng Long Leach, south-east of Kratie Town, and Phum Russei Char, between Sambok and Kratie town.

A number of tributaries flow into the Mekong River, like the Prek Te that joins the Mekong some 5 km downstream of Kratie. These tributaries have natural levees at a lower level than the Mekong and fall dry for several months during the dry season. In the flood season, water flows into the low lying areas behind the Mekong levees through these river channels.

The Mekong floodplain is slightly undulating and extends some 5 to 10 km from each bank.

2 Ecological resources

2.1 Riverine and terrestrial habitats

For the Lower Mekong River system a number of important habitats for conservation have been identified, they are:

- river channels;
- small islands and riverine sand-bars;
- marshes, small pools and seasonally-inundated floodplain wetlands;
- seasonally-inundated riparian forest; and
- inundated grasslands.

The river channel in the project area is vitally important for the seasonal longitudinal migration of fish species. Key fish habitats are feeding habitats, spawning habitats and refuge habitats. Most fishes of the Mekong feed in the productive seasonally inundated floodplains. At the end of the flood season, when these habitats dry out, fishes move to refuge habitats within river channels where they wait for the next flood cycle. Most fish spawn at the onset of flood season. The main habitats used for spawning are rapids and deep pools in river channels as well as certain floodplains. Most migratory fishes, which account for a significant proportion of the fish catch of the Mekong, spawn within river channels at rapids/pools upstream from feeding and rearing habitats.
A large proportion of Mekong fish species is migratory. Many species move from one habitat to another to complete their life cycle. For instance, several important species migrate upstream

to breed at the beginning of the rainy season. Then, as the water rises, the young fish are swept downstream to flooded areas.

The Mekong River and its tributaries are also an important habitat for water bird species. Small islands and sand-bars form a habitat for pioneer plant communities and breeding sites for birds. Seasonal wetlands inundate in the wet season when water levels of the Mekong are high. Wetlands include reed and sedge beds, swamps, and lotus ponds. Another important habitat is the seasonally-inundated riparian forest found adjacent to the river. It is an important habitat for breeding colonies of large waterbirds. Fish use this habitat as a feeding, breeding, and nursery ground.

In the river channel upstream of he Focal Area deep water pools are encountered. This habitat is important to many fish species, particularly as low water refuge and as spawning ground.

In the Focal Area, rocky areas and rapids are absent and the riverbanks are predominantly steep. These steep river banks provide a nesting habitat for a variety of birds. Extensive wide sand and pebble beaches and islands are present, forming an excellent feeding, resting and nesting habitat for wading birds and ducks.

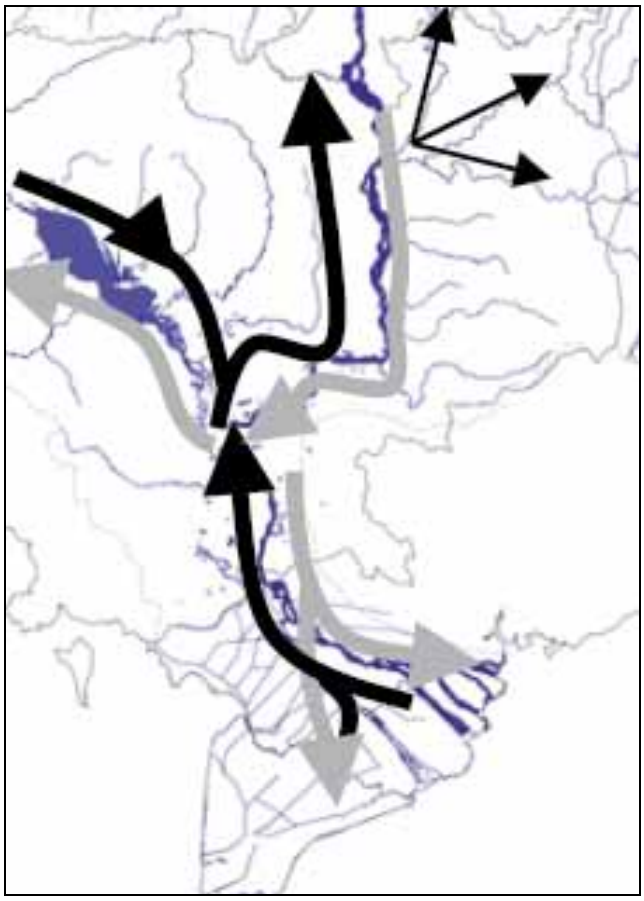
The variety of aquatic and terrestrial habitats in the Mekong has contributed to a high level of biodiversity. Ecosystems and habitats in the vicinity of the Focal Area that are important for the conservation of this high biodiversity are deep pools, sand bars and islands, wetlands and seasonally flooded shrub areas and grasslands on the floodplain.

2.2 Fish and other aquatic fauna

The Mekong has a very high fish diversity, more than 1,000 species of fish are known. A large percentage of these fish, over 80%, follow the inundation spawning pattern: lateral migrations from the mainstream and tributaries into the inundation zones to spawn and rear young between July and September.

Two groups of fish are distinguished: 'white fish' and 'black fish'. Fish that migrate between the river and the floodplain are referred to as 'white fishes', whereas the species of fish which remain in lakes and swamps on the floodplain are known as 'black fishes'. The Kratie sub area is considered a vital corridor for the seasonal longitudinal migration of 'white fish' species, including the commercially important cyprinids, *Henicorhynchus lobatus* (locally called 'trey reil') and *H. siamensis*, which migrate over 800 km from Tonle Sap Lake into Laos. Other highly migratory groups are catfish species, including the endangered Giant Catfish *Pangasianodon gigas, Pangasius sanitwongsei, P. sutchi, P. larnaudi* and Jullien's Barb *Probarbus jullieni.*

Numerous deep pools are located in the main stream of the Mekong River near Kratie. They are widely acknowledged as important dry season refuges for fish. In Kratie and Stung Treng provinces, 58 deep pools are identified to be primary rearing and dry season refuges for large catfish and carp. Some of these areas are important feeding grounds and dry season refuges for the Irrawaddy dolphin as well as a spawning area for Giant carp. The protection of these pools is considered imperative to maintain fishing productivity and some endangered species. The region of Kratie, where most deep pools are located, has high fish populations and surveys indicated that anywhere along the stretch between 6 and 25 different species occur (Poulsen et al., 2002).



Main fish migration routes in the Lower Mekong Basin

2.3 Protected areas and rare and endangered species

BirdLife International identified the Mekong River channel and associated riverine vegetation from Kratie to the border with Lao PDR, as an important bird area (IBA).

Along this river section, the Mekong is very varied; some sections form a single channel with a vast expanse of water, in other sections the river is braided into a number of islands and channels. Several types of river channel vegetation occur: small periodically flooded, predominantly grass covered islands and shrubs and trees that become partly submerged for most of the wet season. However, much of the riverine fringing forest is degraded.

The IBA supports a large proportion of the global population of the Mekong Wagtail, *Motacilla samveasnae*, a recently described species, which is thought to be endemic to the Mekong River and its tributaries. In addition, the IBA supports a number of riverine bird species that have declined severely throughout mainland South-east Asia, including the River Lapwing *Vanellus duvaucelii,* Great Thick Knee *Esacus recurvirostris* and River Tern *Sterna aurantia*. Furthermore, a number of globally threatened and near-threatened species have been recorded in the IBA in small numbers, including White Rumped Vulture *Gyps bengalensis*, Red-headed Vulture *Sarcogyps calvus* and Darter *Anhinga melanogaster*. Small but significant numbers of White-shouldered Ibis, *Pseudibis davisoni* have been recorded along forested parts of the river. Finally the IBA may be one of the last remaining sites in Indochina to support Black-bellied Tern *Sterna acuticauda*.

Key bird species in the IBA are given in Table below.

Key bird species

Common name	Scientific name	IBA criteria*
Small Pratincole	***Glareola lactea***	**A4i**
Black-bellied Tern	***Sterna acuticauda***	**A1**
Whited Rumped Vulture	***Gyps bengalensis***	**A1**
Red-headed Vulture	***Sarcogyps calvus***	**A1**
Darter	***Anhinga melanogaster***	**A1**
White-shouldered Ibis	***Pseudibis davisoni***	**A1**
Mekong Wagtail	***Motacilla samveasnae***	**A1, A2**

* A1: Globally threatened species, the site regularly holds significant numbers of a globally threatened bird species.
A2: Restricted range species, the site is known or thought to hold a significant component of the restricted range bird species whose breeding distributions define an Endemic Bird Area (EBA) or Secondary Area (SA)
A4i: Congregations: the site is known or thought to hold, on a regular basis >1% of a biogeographical population of a congregatory waterbird species

The most important threats to the riverine bird communities are hunting, egg collection and disturbance due to human activities on the sandbanks during the breeding season, as well as cutting of trees and clearance for agriculture on the riverbanks. Bird species that occur in the area and are dependent on either river banks or sandbars are given in the table below.

Habitat dependence of birds observed in the project area

Common name	Scientific Name	Habitat*	
		RB	**SB**
Small Pratincole	***Glareola lactea***	**X**	**X**
Black-bellied Tern	***Sterna acuticauda***		**X**
River Tern	***Sterna aurantia***		**X**
Darter	***Anhinga melanogaster***		**X**
Mekong Wagtail	***Motacilla samveasnae***	**X**	
River Lapwing	***Vanellus duvaucelii***	**X**	**X**
Great Thick Knee	***Esacus recurvirostris***		**X**

*** RB = River bank, SB = Sand bank**

The IBA also supports one globally threatened primate species, the Long-tailed Macaque, *Macaca fascicularis*, one globally threatened crocodile, the Siamesa Crocodile, *Crocodylus siamensis* and a globally threatened turtle, the Asian Giant Softshell Turtle, *Pelochelys cantorii*.

Of special importance are also the Irrawaddy Dolphins, *Orcaella brevirostris.* Smith, B.D. and Beasley (2004) estimated their abundance in the stretch from Kratie to the Khone Falls at 69 individuals. This number is probably close to the actual size of the Mekong sub-population.

The effective range of Irrawaddy dolphins in the Mekong River is a 190 km segment from Kratie to slightly upstream of the Laos/Cambodia border at Khone Falls, which physically obstructs further upstream movement. Based on visual surveys, dolphins are frequently found during the low-water season in nine deep pools in the Kratie to Khone Falls segment. Kampi pool, located 15 km north of Kratie, is currently considered the most important dolphin habitat in the Mekong.
No quantitative estimates of population trends are available, but significant range declines imply that the number of dolphins in the Mekong River has declined substantially over the past several decades.

Three main endangered fish species are found in the Mekong River and its tributaries within Sub Area 8, namely *Jullien's Golden Carp*, *Dwarf Botia*, and *Laotian shad*.

According to the WWF website (Bezuijen, 2008), a 55-km section of the Mekong River in Kratie and Stung Treng provinces has recently (February 2008) been proposed as a 'special management site' because of its high biodiversity values. The site was nominated by agencies from the provinces and the Ministry of Agriculture, Forestry and Fisheries (MAFF).

In 2006-2007 MAFF and WWF conducted biodiversity surveys along the Mekong River between Kratie and Stung Treng, a distance of 125 km. This region was already known to support the critically endangered Irrawaddy Dolphin, but during the survey many new discoveries were made, of which the most important was locating a section of Mekong of about 55 km long with very high biodiversity values. This particular part of the river, the so-called "central section", has remained relatively untouched by human activities. At least 8 endangered mammals, including the region's last remaining Hog Deer, Silvered Leaf-monkey, Long-tailed Macaque and Otters, were documented. It also it the home of the endangered White-shouldered Ibis, River Tern, Woolly-necked Stork, Lesser and Greater Adjutant, and the rare Cantor's Giant Soft-shell Turtle, which may already be extinct in many other parts of the Mekong Basin.

3 Fisheries

Fish in the Mekong and its tributaries provide an especially important food source to local people. An estimated 90% of the population relies on fishing for part of their nutrition. Fish are estimated to provide 40 - 60% of animal protein intake for people in rural areas in Cambodia. An average of 25 kg of fish is consumed per person per year, in the Kratie province. This estimate is fairly low as compared to the national average.

Aquaculture in the area is low developed, due to high levels of capture fisheries and low prices, aquaculture development has been very slow throughout most of Cambodia. Increasing aquaculture for this region is one of the government's aims for reducing poverty and increasing fish production.

4 Tourism

Kratie Province is considered a new destination for tourism with a high growth potential. However, poor infrastructure and a limited number of tourism sites are still constraints to investment in the region.

The endangered Irrawaddy Dolphins are the region's most popular attraction. As few as 70 of these dolphins survive in the Mekong after years of over-fishing and hunting, and tourism is considered important to their conservation, as local communities depend highly on the income from visitors. An important Dolphin sighting site is locate just upstream of Sambok.

Phnom Sambok, a low hill along the river near the Thmor Kre Commune, 11 km north of Kratie is a cultural and historic sites which attracts many visitors. According to a legend a king named Cha Krey Sara Varman, son of Preah Bat Hathak Athi Reach Varman, ordered his officials to find a place where gold could be mined. They found a place called 'Kan Leng Sam Bo Meas' meaning 'a place very rich in gold'. Later the name of the site changed to 'Phnom Sambok Meas' to finally become 'Phnom Sambok'. The site is presently a tourist resort.

Another tourist resort is located some 15 km upstream of Kratie, near the Prek Kampy bridge. The area has a sandy riverbank and the scenic Mekong channel consists of thousands of islands. Services to visitors include crossing bridges, floating cottages, soft-drink shops, restaurants, emergency and security provisions.

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11.5 Environmental baseline Cambodian Delta

1 General characteristics

The environmental conditions in the East Mekong and West Bassac Focal Areas are to a large extent comparable, therefore these areas are described here in conjunction.

Floodplains in the Cambodian Delta are essentially flat. The elevation ranges from about 1 to 10 meters above mean sea level in the West Bassac area and from about 2 to 5 meters above mean sea level in the West Mekong area. At some locations the plains are bordered by low hills. The Bassac and Mekong Rivers and the smaller tributaries are bordered by natural levees that are formed through silt depositing. The levees are intensively used for housing and transportation since they are the last to flood. The levees separate the rivers from depressions that flood during the flood season. A system of colmatage canals has been developed over the centuries to (partially) control the water flow in and out of the floodplain depressions to support the cultivation of rice. All soils in the project area are of alluvial origin. The soils on the natural levees have favorable properties for agriculture, the soils in the lower parts of the floodplains are characterized by frequent waterlogging and low fertility.

During the flood season (July-September) the water levels in the Mekong and Bassac Rivers rise sharply. In the West Bassac area part of the Bassac flood flow is diverted to the flood plain through colmatage canals. The relatively high lying natural levees directly bordering the rivers are only affected by shallow flooding during relatively short periods. Deep flooded areas are located directly west of this shallow flooded area and in the area extending from Takeo in southeastern direction, covering most of the Cambodia/Viet Nam border area.

In the East Mekong area, flooding starts when the Mekong at Kampong Cham reaches a discharge of about 30,000 m^3/s or a water level of about 13.0 m. The River starts to overflow it's banks and in the vicinity of the project area the flood waters are forced to follow two river branches, the Prek Veal Robang (Stung Slot) and the Prek Trabek. With rising levels, the flood waters start to spread over the low-lying (3 - 4 m amsl) floodplains of these two rivers. The central area between the rivers has a somewhat higher elevation (above 5.0 m amsl) and floods less deeply. This area is more densely populated with communities of subsistence rice farmers. Towards the Cambodian/Viet Nam border, the low lying areas bordering the two rivers practically join together to form a vast, deep flooded area.

Agriculture in the area is closely linked with the annual cycle of flooding. Normal floods improve soil moisture and fertility, restore ground and surface water resources, and replenish fisheries and forests. Normal floods likewise have no adverse physical impact on village settlements and only a limited effect on wet season rain-fed rice fields. Annual floods become disasters for rice farming only when they come too early or when they are too high or last too long.

Except for the small levee zones along the rivers, where cash crops are grown, rice is the main crop in the area. Depending on soil type, elevation, flood frequency, flood depth and flood duration, different rice farming systems and rice varieties are used.

A study by Chamroeun et al. (2001) indicated that more farmers (60 to over 90%) use chemical fertilizers in the dry season than in the wet season (less than 10%). Most farmers (15 to 50%) apply chemical fertilizers in amounts far exceeding the recommended levels. Also pesticide use is more common during dry season (70 to 100% of the farmers) than in the wet season (about 50%). Most farmers spray pesticides when they notice their crops damaged by pests or see a large number of insects in their rice field. Since very few farmers can distinguish between beneficial insects and actual pests, they may be spraying pesticides unnecessarily. Regarding the disposal of

pesticide resieduals, over 90% of farmers in Prey Sva and Prey Tamao dispose cans, bottles and wash sprayers in their rice fields and/or irrigated canals.
As compared to Vietnam, the floodplains in Cambodia are largely undeveloped. The floodplains of Cambodia can be characterized as in Table below after Douven (2008).

General characteristics of the East Mekong Floodplain

Floodplain	still quite natural
Infrastructure	few roads, colmatage irrigation systems, a few small-scale irrigation schemes
Housing and development	mainly along levees bordering rivers
Economy	extensive agriculture and fisheries
Land use and ecology	no national parks, but floodplains and flooding essential for biodiversity in the region
Hydraulics	largely natural flooding, only obstructed by roads and to some extent levees

2 Ecological resources

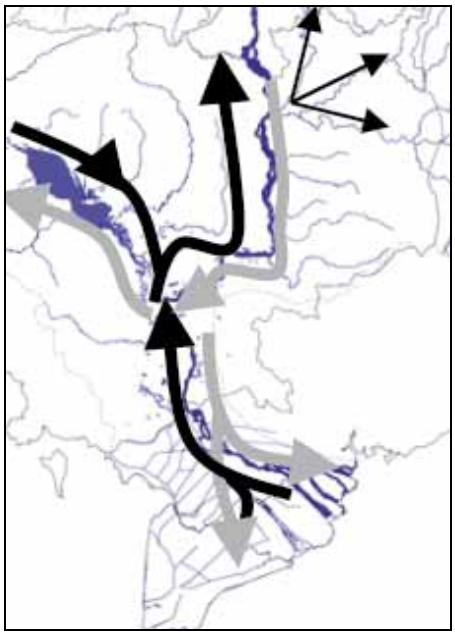
2.1 Fish and other aquatic fauna

According to Baran (2005) the Mekong hosts over 1,000 species of fish, one of the highest species counts of any river system in the world. The large variation in hydrology and the variety of habitats allow the persistence of many species, which all require different conditions. Some species are abundant on the floodplain and its wetlands, some favor lowland rivers and some are found mainly in tributaries. Nearly all migrate within or between habitats to complete their life cycles. For Cambodia 477 fresh water fish species are recorded of which 40% is endemic. Ten species are endangered (FishBase 2004).

The fish fauna of the Mekong River is dominated by species of carp (Cyprinidae; 54%), catfish (Siluridae, Clariidae, Schilbeidae, Bagridae, Sisoridae and Akysidae; 19%) and murrels (Chanidae and Ophicephalidae; 8%). The remaining 19% consist of featherbacks (Notopteridae), herring (Clupeidae), climbing perch and gouramis (Anabantidae) and other miscellaneous groups. Some 85 - 95% of the freshwater fish populations in the Mekong basin follow the inundation spawning pattern, undertaking lateral migrations from the mainstream and tributaries into the inundation zones to spawn and rear young between July and September.

Basically two groups of fish are distinguished: white fish and black fish. When floodplains drain at the end of the wet season, water remains in lakes and scattered depressions, which continue to shrink in size and number during the dry season. Floodplain water bodies become hot, oxygen is depleted and food and shelter diminish, with many ponds drying-out completely. So the fish, which feed and grow on flooded areas must either return to the river as the waters recede, or remain and endure the poor conditions on the floodplain.

Species which leave flooded areas and return to rivers are referred to as ‘white fishes’, as they spend most of their lives in turbid (white) river water. Most white-fish species migrate into flooded areas during the monsoon season and migrate over long distances to dry-season refuges at the end of the flood season. Representatives of this group are some of the cyprinids, such as *Cyclocheilichthys enoplos* (Soldier river barb or Chhkok) and *Cirrhinus microlepis* (Small mud carp or Prul/Kralang), as well as the river catfishes of the family Pangasiidae. The main migration routes in the Lower Mekong Basin are displayed in Figure below.



Main fish migration routes in the Lower Mekong Basin

The species of fish which remain in lakes and swamps on the floodplain are known as 'black fishes', as they spend their lives in relatively clear water that is tea-colored by chemicals dissolved from floodplain vegetation. Decomposition of vegetation causes floodplain water to be acidic and depleted in oxygen, stresses which black fishes can tolerate. Most black fishes can breathe air, while many species can survive out of the water for long periods, and most can move overland in search of new water bodies. A few species can bury themselves deep in the mud and wait until the next flood. Many black fishes are used in aquaculture and are transported alive to markets.

They are normally referred to as non-migratory, although they perform short seasonal movements between permanent and seasonal water bodies. Examples of black-fish species in the Mekong are the climbing perch (*Anabas testudineus*), the clarias catfishes (e.g. *Clarias batrachus*) and the striped snakehead (*Channa striata*).

Apart from fish, inland waters support a high diversity of other aquatic animals including vertebrates - reptiles, birds, mammals and amphibians, and invertebrates, such as insects, crustaceans and mollusks, all of which depend upon maintenance of aquatic ecosystems.

2.2 Wetlands and terrestrial vegetation

Important habitats for conservation are described by BirdLife International in Indochina (2005). They are:

Main river channels

Water height in the main river channels varies by up to 10 metres between the wet and dry seasons. These channels are vitally important for the seasonal longitudinal migration of white fish species. Although the main channels support a rich assemblage of aquatic species, they exhibit little endemism.

The Mekong River and its wider low gradient tributaries are important for a distinctive guild of riverine bird species. The Globally Vulnerable Indian Skimmer *Rynchops albicollis* may have already disappeared from this habitat in Cambodia. and the Globally Vulnerable Black-bellied Tern *Sterna acuticauda* and Little Tern *Sterna albifrons* appear to be on the verge of doing so. Other significant species in this habitat include the Globally Near-Threatened Grey-headed Fish

Eagle, and Great Thick-knee *Esacus recurvirostris*, River Lapwing *Vanellus duvaucelii*, and Small Pratincole *Glareola lactea.*

Small islands and riverine sand-bars
Small islands and riverine sand-bars are common on stretches of the Mekong and its tributaries. They are formed by natural deposition during seasonal high river flow. The plant *Anogeissus rivularis* dominates the pioneer community of low-lying vegetated sandbars. The older, larger sandbars, built up into islands over many years, have more substantial vegetation similar to the neighbouring gallery forest.

The smaller sand bars and islands provide safe breeding sites for many species of waterbirds, some of which are globally rare and endangered. The only recent confirmation in Indochina for the breeding of the Globally Vulnerable Black-bellied Tern was recorded on such islands. They also support the largest numbers of Great Thick-knee, River Lapwing, and Small Pratincole in South East Asia.

Permanent and Seasonally-inundated Floodplain Wetlands
A number of permanent and seasonal lotic and lentic wetlands are found in the Lower Mekong Basin. The high wet season water levels of the Mekong inundate many of these wetlands seasonally; groundwater and seasonal monsoonal rains maintain others. These provide some of the most productive habitats in the Lower Mekong Basin and include reed and sedge beds, swamps, lotus ponds, inundated grasslands and inundated forest.

The seasonal changes in water level of the Mekong inundated plain drives a seasonal migration of large waterbirds between wetlands. In the dry season, many species move to permanent wetlands and grassy plains around Lake Tonle Sap and in the Delta, while in the wet season they retreat to higher seasonal wetlands in northern Cambodia and southern Lao.

The following wetland types are distinguished:

Seasonally-inundated riparian forest
One of the most important wetland habitats of the Lower Mekong Basin is the seasonally-inundated riparian forest found on the gently-sloping plains adjacent to lakes, rivers and tributaries and submerged by the seasonal 8-10 metre flood levels of the wet season.

The composition of this forest type shares little with swamp forests and mangrove systems. Over 200 species of plants have been found in these inundated forests. Major communities include *Barringtonia acutangula, Elaeocarpus madopetalus* and *Diospyros cambodiana*; floating and emergent herbs including *Brachiaria mutica, Eichornia crassipes*, *Polygonium barbatum, P. tomentosum* and *Sesbania javanica,* and a diverse mixed scrubland containing over 60 species. The woody species of this forest are often laden with fruits and seeds at the time of inundation, providing food for the 34 species of fruit-eating fish of the Lower Mekong Basin. Over 200 species of fish use this habitat as a feeding, breeding, and nursery ground and it is vitally important for breeding colonies of large waterbirds.

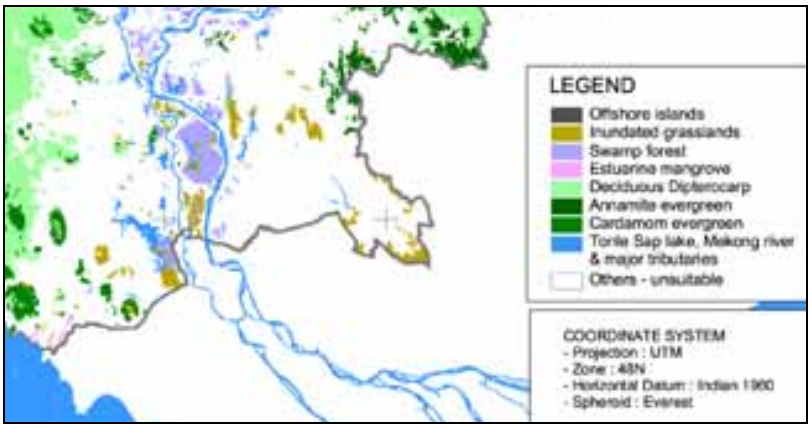
Marshes, small pools and seasonal wetlands in the lowland plain
Extensive seasonal and permanent marshes, small lakes, and other wetlands occur throughout the Lower Mekong Basin. They are usually shallow, filled by seasonal rainfall and typically are connected to river systems which in the wet season form the inundated plain of the Lower Mekong Basin. They contain a mosaic of wetland habitats including reeds, sedge, lotus beds and open water. Submerged communities are dominated by *Ceratophyllum demersum* and *Utricularia aurea*.

In the dry season, these wetlands are vital in maintaining breeding stocks of floodplain fish, including air-breathing species (e.g. gouramies, walking catfish), while in the wet season they function as breeding and nursery grounds for many fish species, the black fish. These wetlands are important for almost all waterbirds in the Lower Mekong Basin, particularly cormorants, Oriental Darter, Spot-billed Pelican, Greater and Lesser Adjutants, Milky Stork, Woolly-necked Stork *Ciconia episcopus*, Black-necked Stork *Ephippiorhynchus asiaticus*, Painted Stork, The Globally Endangered White-shouldered Ibis *Plegadis davisoni,* Glossy Ibis *P. falcinellus*, Black-headed Ibis *Threskiornis melanocephalus*, White-winged Duck, Pallas's Fish Eagle *Haliaeetus leucoryphus,* Grey-headed Fish Eagle, the Globally Vulnerable Masked Finfoot *Heliopais personata*, and the Globally Near-threatened Sarus Crane *Grus antigone*.

Inundated grasslands

Seasonally inundated grasslands are common on the floodplains of the Lower Mekong Basin. Close to the water edge, floating or emergent vegetation forms dense mats or stands up to 3 metres tall. As water levels rise, dense mats may dislodge and float, propelled by currents or the wind. The main species include *Achyranthes aquatica, Brachiaria mutica, Eichornia crassipes, Polygonium barbatum* and *Sesbania javanica*. Other plant species found on the upper reaches of the inundated plain include several grasses, including *Echinochloa stagina,* sedges including *Cyperus pilosis, Rhynchospora* sp., and dicotyledons such as *Aeschynomene indica, Impatiens sp., Ludwigia hyssopifolia* and *Nelumbo nucifera* (lotus).

These areas support Sarus Crane, White-shouldered Ibis and Greater and Lesser Adjutants. Although, in the Lower Mekong Basin, these areas are greatly disturbed, they do hold more substantial grasslands that other parts of S.E. Asia and thus are a priority for conservation. They are of crucial importance for the Globally Endangered Bengal Florican *Houbaropsis bengalensis*.



Location of important wetland habitats in the project area (Source BirdLife International)

2.3 Wildlife and rare and endangered species

Wetland mammals known to occur in the project area include the Smooth-coated Otter *Lutra perspicillata* (quite rare) and Fishing Cat *Felis viverrina.*

According to Baran (2005) the main endangered large fish species in Cambodia are the Giant Mekong catfish (*Pangasionodon gigas*), the Giant Mekong carp (*Catlocarpio siamensis*) and the seven-line barb (*Probarbus jullieni*). Other endangered species are *Balantiocheilos melanopterus, Botia sidthimunki, Chela caeruleostigmata, Dasyatis laosensis, Himantura chaophraya, Himantura oxyrhyncha, Scleropages formosus* and *Tenualosa thibaudeaui.*

The number of bird species found in Cambodia is 435 (Ministry of Environment, 2000). Of these 106 species are water birds. The wetland of the Lower Mekong Basin support 15 globally-threatened bird species, namely the Critically Endangered Giant Ibis *Pseudibis gigantea*, the

globally Endangered Sarus Crane *Grus Antigone*, Greater Adjutant *Leptotilos dubius*, White-shouldered Ibis *Pseudibis davisoni*, White-winged Duck *Cairina scutulata*, Bengal Florican *Eupodotis bengalensis* and Nordmann's Greenshak *Tringer guttifer*, the globally Vulnerable Spot-billed Pelican *Pelican Pelecanus Philippensis*, Lesser Adjutant *Leptoptilos javanicus*, Milky Stork *Mycteria cinerea*, Greater Spotted Eagle *Aquila clangula*, Green Peafowl *Pavo muticus*, Masked finfoot *Heliopais personatus*, Black-bellied Term *Sterna acuticauda*, and Indian Skimmer *Rynchops albicollis*.
Of the reptiles the Siamese Crocodile *Crocodilius Siamensis* is Critically Endangered. It was formerly widespread throughout the Lower Mekong Basin but has declined drastically due to excessive hunting and habitat destruction. These populations, are of extreme global importance as the last wild populations. Over twenty species of turtles occur in the Lower Mekong Basin, ten of which are listed in the Red Data book including the Chinese three-striped box turtle *Cuora trifasciata* that is Critically Endangered.

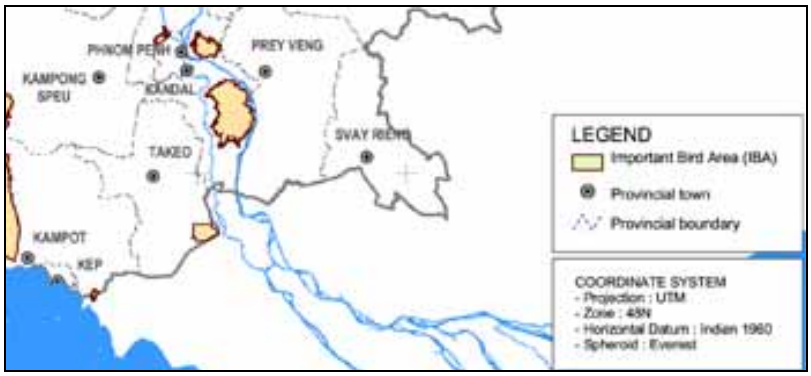
Not clear is which of these species that are endangered in Cambodia are actually present in the project area.

2.4 Protected areas

According to ICEM (2003) no protected or proposed protected areas are located in the West Bassac Focal Area nor in the East Mekong Focal Area. BirdLife International (Bauld, 2005) declared the Boeung Prek Lapouv in the south eastern part of the Takeo Province an Important Bird Area (IBA).

The Boeung Prek Lapouv area consists of seasonally inundated grasslands and is located in the Borey Chulsar and Koh Andeth districts. The site is an important dry season refuge for fish and birds and is inundated for about four months each year, during which some 30 species of aquatic vegetation can be found. It forms part of one of the largest areas of adjoining natural habitats remaining in the Mekong Delta. More importantly, the area provides critical wetland habitat to 25% of the world's population of endangered, non-breeding Eastern Sarus Cranes *(Grus antigone sharpii),* as well as numerous other globally threatened bird species.

The Eastern Sarus Crane (the tallest flying bird in the world) is present in the area from December to April. After Ang Tropeang Thmor, this area supports the largest non-breeding population in Cambodia. In the dry season from late November to April, the site provides an abundance of food for a variety of birds, including the Sarus Crane. During this time as many as 350 cranes may be present in the area. Populations of Egret, Pond Heron, Cormorant and Spot-billed Duck are present from July-March, with populations of the Painted Stork and Asian Openbill from November-March.



Location of the Boeung Prek Lapouv Important Bird Area

Surveys conducted in the area have recorded 58 bird species including 34 water bird species. In addition to bird diversity, the site also supports other wildlife and plants including species of reptiles, amphibians, mollusks, fish, aquatic vegetation, and inundated forest vegetation. Of the 58 bird species present, 6 are globally threatened: Sarus Crane (*Grus antigone*), Bengal Florican (*Houbaropsis bengalensis*), Spot-billed Pelican (*Pelecanus philippensis*), Painted Stork (*Mycteria leucocephala*), Darter (*Anhinga elanogaster*) and Black-headed Ibis (*Threskiornis melanocephalus*).

Because of the importance of the area, the Forestry Administration proposed Boeung Prek Lapouv (10.787 ha) as a Sarus Crane conservation area to the Ministry of Agriculture, Forestry and Fisheries in August 2002. The site has not yet been officially approved by the Royal Government of Cambodia.

2.5 Fisheries

The productivity of the Lower Mekong Floodplains is the highest worldwide and ranges between 139 and 230 kg/ha/year. This is the result of 3 uniquely interconnected factors: high biodiversity, large accessible floodplains, and a very high exploitation rate.

Cambodian people in rural areas rely heavily on fisheries for their subsistence. Fish provide from 40 - 60% of animal protein intake for people in rural areas, even those living far from water. An average of 76 kg of fish is consumed per person/year (Baran, 2005). The total value of fish catches in SA 10C is estimated at approximately US$ 45 million.

During the flood, fish are dispersed in a large volume of water. When water levels lower, fish are forced off the floodplain and become concentrated in channels, streams and rivers. Various kinds of traps and large stationary trawls (dais) set across flowing waters in the flood recession season catch many fish and other aquatic organisms. Most households in the project area fish for some time each year on land they own, or in nearby water bodies, flooded forest and floodplain areas. Production from rice fields fisheries is very important to most rural families. In the Takeo Province 17,535 families in 62 communities (49% of all communities) are involved in fisheries, in Kandal province these figures are 3,190 and 17 respectively. Large companies are not operating in the area. Fish production in the Takeo province is reported to be 11,182 ton/year, in Kandal Province 32,769 ton/year. In the Prey Veng Province 43,450 families in 22 communities (17% of all communities) are involved in fisheries. Capture fish production in the province is reported to be 2,082 ton/y (McKenny & Tola, 2002).

3 Cultural, historic and archeological values

In the area around Angkor Borei remains of pre-Angkorian canals have been found (Bishopa et al., 2003). The archeological evidence indicates a flourishing local economy early in the first millennium AD. It is also suggested that the area experienced major re-organization or re-structuring in the early fifth to early sixth century. This restructuring probably did not involve major de-population, but a change from rice cultivation in bunded fields with dry season burning, to flood recession cultivation of rice.

Archeological sites and ancient canals in the Cambodian Delta

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11.6 Environmental baseline Vietnam Delta

1 General characteristics

Two Focal Areas are located in the upper Vietnamese Mekong Delta, the Long Xuyen Qaudrangle, west of the Bassac River and the Plain of Reeds, east of the Mekong River. Characteristics of these two areas are largely comparable and they are described here together.

The Mekong floodplains of Viet Nam ranges in elevation between about 1 and 5 meters above mean sea level. In the Long Xuyen Quadrangle there are a few very small hills in an otherwise flat landscape. The Mekong river (Song Tien in Vietnamese) enters the floodplain at the border with Cambodia and braches into several rivers in its lower reaches. Song Hau is the continuation of the Bassac river from Cambodia and runs more or less parallel to the Mekong river. The two rivers are interconnected in the upper reaches of the Vietnamese Mekong floodplain. The rivers are bordered by low natural levees and man-made dikes. The levees and dikes are used for housing and roads.

In Viet Nam the Mekong delta is intensively developed, especially if compared to the Cambodian Mekong floodplain. Agriculture and an extensive system of canals has been developed since the 1700's for navigation, irrigation, flood management and management of saline water intrusion. The floodplains of Viet Nam can be characterized as in Table below after Douven (2008).

General characteristics of the Viet Nam Mekong Floodplain

Floodplain	highly developed
Infrastructure	dense network of canals, levees and roads; irrigation and flood management systems
Housing and development	mainly along roads, rivers, levees and canals
Economy	intensive agriculture, fisheries and aquaculture
Land use and ecology	Tram Chin national park, otherwise most of the land in use for agriculture
Hydraulics	Floods partly controlled by sluices and other water infrastructure

In most provinces of the Vietnamese Mekong delta agricultural land use covers more than 80% of the available land. Farming and fisheries are the major economic activities and are strongly linked to the floodplain. The original land use cover included wetlands, inundated forests and mangroves along the coast.

The floodplain in the northern part of the delta consists of natural levees, sandbars, and backswamps. The eastern, 'closed' section of the upper floodplain is known as the Plain of Reeds, where drainage of floodwaters is slow and difficult, and flooding to a depth of up to 3 m occurs for part of the year. The western, 'open floodplain' section is called so because it slopes gently towards the Gulf of Thailand so that floodwater can easily drain away, and flooding is only 1.5 - 2 m deep. This region is known as the Long Xuyen Quadrangle, and includes the Ha Tien plain.

Acid sulphate soils occupy more than 40% of the Mekong Delta, water draining from these soils is usually highly acidic, a pH of less than 3 is not uncommon. The low pH in itself is not a major problem. The main impact comes from highly toxic levels of aluminum and ferrous iron and the unavailability of phosphorus for plant uptake.

Annually, a large part of the northern area of the Vietnamese Mekong Delta is inundated by floods from the Mekong river. The inundation area is about 1.4 million hectares in 'low-flood' years and about 1.9 million hectares in 'high-flood' years. Inundation depth varies between 0.5 and 4.0 m, the flooding may last between 3 and 6 months.

Inundation of the Long Xuyen Quadrangle is caused by flood waters coming from the Bassac River and from across the Vietnam-Cambodia border. Inundations in the area generally last from 3.5 to 4.5 months depending on the flood level and the location The highest inundated depth is about 4,0 m. Dredging and construction of new canals, primary and secondary, has improved irrigation and drainage in the past two decades. On the other hand the canals also convey floods to the farm areas, especially floods from Cambodia, whereas construction and embankment of roads with narrow culverts limits the drainage to the Gulf of Thailand.

Inundation of the Plain of Reeds is mainly caused by floods from the Mekong River. Flood waters flow to the Plain of Reeds from two main directions: from the Mekong River, and from across the Vietnam-Cambodia border. In years with high floods such as 1996 and 2000, flood waters reach the area from across the border at the end of September. Floods in the Plain of Reeds drain to the Mekong River through bridges under National Road No. 30 and sluices under National Road No. A smaller portion of the floodwater drains to the Vam Co River. Floods of the Plain of Reeds cause long inundations, lasting 3.5 - 5.0 months. The inundation depths range between 0.5 - 4.0 m.

Water quality in the Mekong Delta varies over the seasons. Surface water has high concentrations of dissolved substances in the dry season, and low concentrations of dissolved substances in the flood season. For suspended solids a reverse relationship is valid.

In the Delta area a number of water quality related issues are of importance: high acidity, high salinity, microbiological pollution, and pesticide and herbicide pollution. Acid water has an impact on the agricultural production and the living condition of the local people. In the Long Xuyen Quadrangle and the Plain of Reeds acid water is observed at the end of the flood season, normally from December to January. Salnity intrusion depends on a variety of factors, like the size of the previous floods, the amount of fresh water inflow from upstream, and the general weather at the beginning of the rainy season. In the Plain of Reeds, the salinity intrusion is reported to have increased in recent years, both in area and duration.

Generally microbiological pollution of the surface waters in the Mekong Delta is high. The observed average coliform concentration is about 300,000 - 1,500,000/100 ml. Discharge of untreated waste water and solid wastes from humans and livestock explains the poor water quality situation. The few studies on pesticide and herbicide pollution available for the Delta report that no significant pollution can be demonstrated.

Ground water is widely used as a source for drinking water. Ground water is exploited and pumped from shallow wells for household use and from deeper wells for a limited number of groundwater plants. Although a lot of the wells have experienced quality problems of some kind, pH, high iron content, salinity and bad smell being most common, almost all plans for the future are based on increased groundwater withdrawal.

2 Fish and other aquatic fauna

For a general description of the fishes and aquatic fauna of the area reference is made to the description given for the Lower Mekong River in section 2.5 Environmental baseline for the Cambodian Delta.

Additional information is available from a somewhat outdated publication by Le Dien Duc (1989). According to Le Dien Duc (1989) 260 species of fish are known from the Vietnamese part of the Mekong Delta. Many species are migratory, showing seasonal upstream movements to spawn. The brackish and coastal zone fauna is dominated by species in the families Clupeidae, Scombridae, Sciaenidae, Tachysauridae and Cynoglossidae. In freshwater, the fish fauna is dominated by Cyprinidae, Siluridae, Clariidae, Schilbeidae, Bagridae, Sisoridae, Akysidae, Chanidae and Ophicephalidae.

3 Wetlands and terrestrial vegetation

Although there is evidence from tree stump remains that the Vietnamese Delta was once heavily forested, the character of the delta has changed to such an extent during its long occupation by humans that little is known of the original vegetation. Natural and semi-natural vegetation communities found in the area can be divided into freshwater- and saline communities. Freshwater communities can be further divided into swamp-forest vegetation, herbaceous vegetation, riverbank vegetation, and aquatic vegetation in waterways and waterbodies. Saline communities consist largely of mangrove forest.

The dominant tree species in Mekong Delta swamp-forest is *Melaleuca cajuputi*. This species forms semi-natural forest in some small remaining areas, though the majority is plantation. Species forming the ground layer in swamp-forests vary according to local conditions, but usually include *Phragmites vallatoria* and *Eleocharis* spp. grasslands.

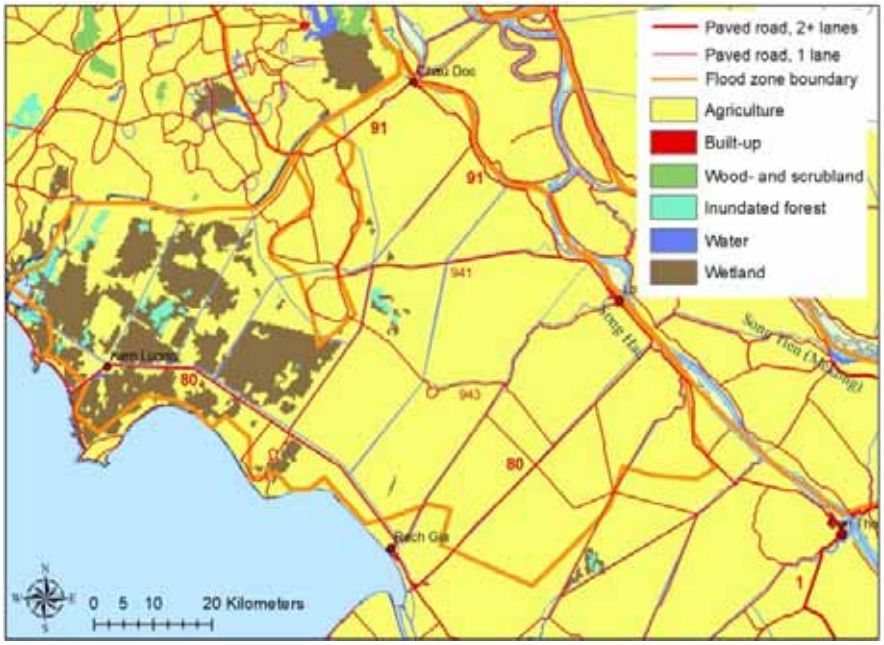
Melaleuca forests are encountered particularly in areas with acid sulphate soils. A high proportion of them are of relatively recent origin, and many are within wood production reserves. In Lang Sen, Plain of Reeds, there are patches of the former riverine delta forest comprising *Melaleuca leucodendron* associated with *Syzgium* sp., *Elaeocarpus hygrophilus*, *Ficus microcarpa* and *Cassia grandis*. Peat swamps are associated with *Melaleuca* forest in U Minh, south of the Focal Area. The remaining, scattered patches of forest are an impoverished relic of a more extensive and variable forest cover.

Although today's *Melaleuca* forests are low in plant biodiversity, they form an important habitat for fish, amphibians, reptiles and birds. These *Melaleuca* forests are of prime important for their breeding colonies of large water birds and are one of the few refuges in the Delta for freshwater species such as turtles.

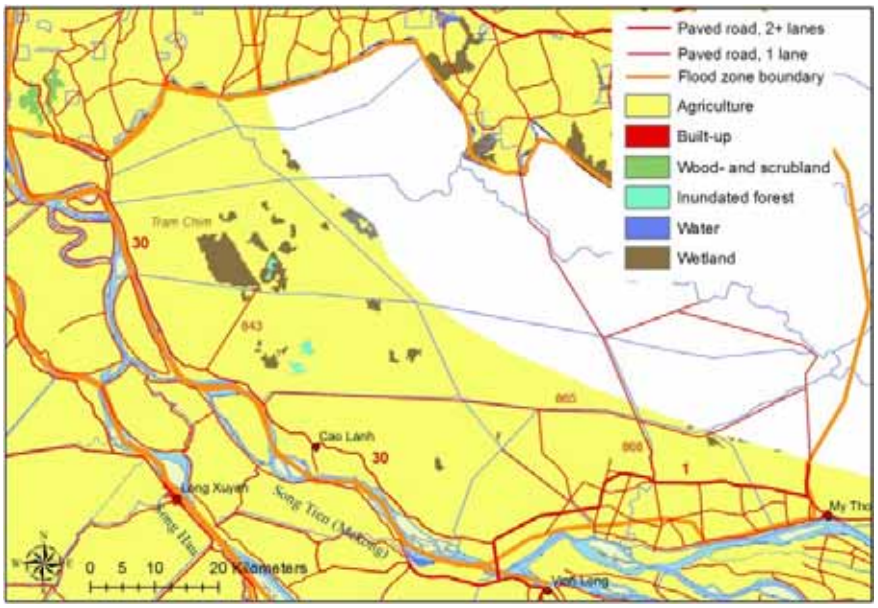
Formerly, extensive grasslands occurred throughout the Mekong Delta, today, much of this habitat is under rice cultivation. Herbaceous vegetation includes areas of seasonally inundated grassland which can be sub-divided into four main groups:

- grassland in areas of deep and prolonged freshwater inundation that are dominated by *Eleocharis dulcis*, *Oryza rufipogon* and *Phragmites vallatoria*, occurring on potential or light active acid-sulphate soils;
- grassland on active acid sulphate soils that are dominated by *E. dulcis*, *E. ochrostachys*, *Ischaemum rugosum* and *Lepironia articulata*, and inundated with freshwater to a moderate depth and for a moderate duration;
- grassland on sandy and old alluvial soils that are dominated by *Eragrostis atrovirens*, *Setaria viridis*, *Mnesithea laevis* and *Panicum repens*, and inundated only to a shallow depth and for a short time; and
- grasslands affected by brackish water that are dominated by *Paspalum vaginatum*, *Scirpus littoralis*, *Zoysia matrella*, *Eleocharis dulcis* and *E. spiralis*. They are affected by brackish water and can be inundated on a daily basis by the tide.

In the Mekong Delta seasonally inundated grasslands provide habitat for globally threatened birds, including Bengal Florican *Houbaropsis bengalensis* and White-shouldered Ibis *Pseudibis davisoni*. The habitat also supports at least 60% of the population of the eastern subspecies of Sarus Crane *Grus antigone sharpii* in the dry season. These grasslands also contain unique vegetation communities, some of which are not likely to be found elsewhere in Indochina. The saline influence and predominance of acid-sulphate soils in the delta have a strong influence on the species composition of plant communities found here. Seasonally inundated grassland in the Mekong Delta are now mainly confined to the Ha Tien plain and the Plain of Reeds. In the Ha Tien plain, substantial areas still exist, but none has any form of protection and is in imminent danger of being lost to rice cultivation. Almost all the grassland of the Plain of Reeds has been converted to rice agriculture, with only a small fragment under conservation protection in Tram Chim National Park.



Location of important wetland habitats in the Long Xuyen Quadrangle



Location of important wetland habitats in the Plain of Reeds

4 Wildlife and rare and endangered species

Much of the fauna of the Mekong Delta remains little studied and delta-wide descriptions of fauna are largely lacking. Most information presented here has been taken from a publication by Le Dien Duc (1989). More recent information was compiled during a survey of BirdLife International in 1999.

The mammal fauna of the Mekong Delta is poorly documented, and it is likely that it has been severely depleted as a result of conversion of land to agriculture and expansion of the human population.

Le Dien Duc (1989) listed 23 species of mammal as occurring in the delta, including five species of dolphin, Crab-eating Macaque *Macaca fascicularis*, Smooth-coated Otter *Lutragale perspicillata* and Fishing Cat *Prionailurus viverrina*. Recently evidence has been provided for the

continuing occurrence of the latter three species, as well as Sunda Pangolin *Manis javanica*, Cambodian Striped Squirrel *Tamiops rodolphii*, an unidentified *Callosciurus* squirrel, an unidentified otter *Lutra* sp., Common Palm Civet *Paradoxurus hermaphroditus*, Small Asian Mongoose *Herpestes javanicus*, Leopard Cat *Prionailurus bengalensis*, Wild Boar *Sus scrofa* and Sambar *Cervus unicolor* in the U Minh wetlands, south of the Long Xuyen Quadrangle. It is likely that other otter species once occurred in the delta, and some may remain, including Hairy-nosed Otter *Lutra sumatrana* and Oriental Small-clawed Otter *Aonyx cinerea*.

Le Dien Duc (1989) listed 92 species of waterfowl in the delta, and noted important colonies of cormorants, herons, egrets, storks and ibises. In the grasslands of Ha Tien 74 species have been recorded, including the globally endangered Bengal Florican *Houbaropsis bengalensis*.

BirdLife International, during their survey work in 1999, recorded a total of 194 species of birds. Of these, 73 were 'waterfowl' under the definition given by the Ramsar Convention, but a further 27 species could be described as wetland-dependent (including several kingfisher species and wetland-dependent passerines such as reed warblers *Acrocephalus* spp.). Thus, over half (100 species) were strongly associated with wetlands. Almost one third (61 species) were strictly migrants to the delta, including most of the shorebirds recorded. Most of these were non-breeding visitors that breed outside of Viet Nam. Fourteen globally threatened or near-threatened species were recorded during the survey work, of which three are classed as endangered, two as vulnerable and nine as near-threatened.

The Mekong Delta provides habitat for a significant proportion of the regional or global population of several species. Most notably, over 10% of the South-East Asian populations of Glossy Ibis *legadis falcinellus*, Little Egret *Egretta garzetta* and Cattle Egret *Bubulcus ibis*, 3% of the world population of Indian Cormorant *Phalacrocorax fuscicollis*, and 6% of the South-East Asian population of Purple Heron *Ardea purpurea* were recorded. At Bai Boi and Dat Mui up to 0.8% of the world population of endangered Chinese Egret and up to 1.1% of the near-threatened Asian Dowitcher were recorded. Likely these are underestimates and probably the sites support >1% of the global population of both species.

For several widespread species it is likely that the Mekong Delta provides important habitat for significant proportions of their regional populations. For example, the minimum estimates of the South-East Asian populations of Spot-billed Duck *Anas poecilorhyncha* (subspecies *poecilorhyncha*), Chinese Pond Heron *Ardeola bacchus*, Black Bittern *Dupetor flavicollis* and Oriental Pratincole *Glareola maldivarum* are each less than 70,000, and each species is common outside the natural and semi-natural sites in the area. The Mekong Delta populations of each species is therefore likely to constitute >1% of its South-East Asian regional population.

The passerine avifauna of the delta is species poor. Most species recorded are common and widespread throughout much of Asia, and only two species of conservation interest occur, the globally near-threatened Asian Golden Weaver, and Large-billed Crow *Corvus macrorhynchos*, which is believed to be vulnerable to human pressure and is very scarce in the Mekong Delta. Particularly common and widespread resident species included Golden-bellied Gerygone *Gerygone sulphurea*, Pied Fantail *Rhipidura javanica*, Common Iora *Aegithina tiphia*, Oriental Magpie Robin *Copsychus saularis*, Oriental White-eye *Zosterops palpebrosus* and Olive-backed Sunbird *Nectarinia jugularis*. Several winter visitors use the area, the commonest being Brown Shrike *Lanius cristatus*, Black Drongo *Dicrurus macrocercus* and Oriental Reed Warbler *Acrocephalus orientalis*. Wetlanddependent passerines included Oriental Reed Warbler, Black-browed Reed Warbler *Acrocephalus bistrigiceps*, Rusty-rumped Warbler *Locustella certhiola* and Zitting Cisticola *Cisticola juncidis*. Very few species typical of terrestrial forest were found: those recorded (e.g. Scarlet Minivet *Pericrocotus flammeus* and Indochinese Cuckoo-shrike *Coracina polioptera*) were restricted to mature *Melaleuca* forest.

The number of species recorded in each of the four main habitat categories gives an indication of the relative importance of each to biodiversity conservation. Bird species richness was highest in seasonally inundated grassland and swamps (100 species), while anthropogenic habitats (including paddy fields, aquacultural ponds and villages) had the lowest richness (83 species). *Melaleuca* forest also held a large number of species, almost as many as grassland and swamp (97 species).

Of the 14 globally threatened or near-threatened species recorded, nine were recorded in seasonally inundated grasslands and swamps, and only three were recorded in anthropogenic habitats (Greyheaded Lapwing, Spot-billed Pelican and Painted Stork). The high number of threatened species recorded in mangroves and mudflats emphasizes the importance of these sites for migratory water birds.

Number of species associated with each of four habitats from surveys carried out in the Mekong Delta, by BirdLife International, 1999.

	Agricultural and urban	Mangrove and mudflats	Seasonally inundated grassland and swamp	*Melaleuca* forest
Number of species recorded	83	92	100	97
Number of globally threatened species	3	7	9	4

Mammals, reptiles and amphibians were infrequently recorded during the survey of BirdLife International. No evidence was found of the continuing existence of dolphins or crocodiles in the waterways of the Mekong Delta. Although no specific effort was made to search for these, there was no anecdotal evidence to suggest otherwise. Anecdotal reports did suggest, however, that otters *Lutra, Lutragale, Aonyx* spp. remain at a few sites.

Historical information is available on some species known to exist in the past. Most notable amongst reptiles are Estuarine Crocodile *Crocodylus porosus*, Batagur Terrapin *Batagur baska*, four species of water snake *Enhydris* spp., Water Monitor *Varanus salvator* and Reticulated Python *Python reticulatus*.

5 Protected areas

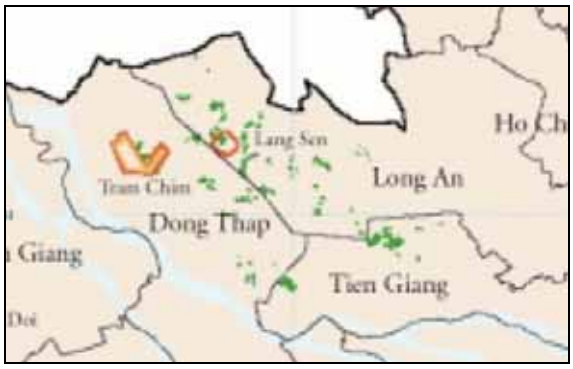
No protected areas are located within the Long Xuyen Quadrangle Focal Area. However, BirdLife International (1999) identified 10 priority wetland sites for conservation in the Vietnamese Mekong Delta. Highest priority was given to the seasonally inundated grasslands of the Ha Tien plain in the western part of the Focal Area. This area meets the criteria adopted by the Ramsar Convention on Wetlands to identify wetlands of international importance. Recommended for conservation were also the Tinh Doi and Tra Su areas.

Ha Tien plain contains unique aspects of biodiversity, including significant populations of several globally threatened and near-threatened birds. Of particular importance are Sarus Cranes and the endangered White-shouldered Ibis *Pseudibis davisoni*. The area also shows high diversity in flora, including unique gradients from brackish to freshwater and from acid to alluvial vegetation communities. There is an urgent need for establishment of two protected areas in the Ha Tien plain, as the grassland here is under serious threat from conversion to agricultural land. Currently, grassland is regarded as 'unused' land, and its conservation will be dependent on changing attitudes to this irreplaceable habitat.
The Tra Su and Tinh Doi areas are not suitable for gazettement as nature reserves at national level due to their small size and/or severe management obstacles to overcome. However, establishing these as provincial level nature reserves would be a first step in improving the

conservation importance and potential of these sites. The location of the proposed protected areas is given in Figure below

Location of proposed protection areas in the Long Xuyen Quadrangle Focal Area

In the Plain of Reeds Focal Area there are two protected areas. Tram Chim National Park and the Lang Sen Wetland Reserve. They are described here briefly, based on a description by Nguyen and Wyatt (2006).



Location of the two protected areas in the Plain of Reeds Focal Area

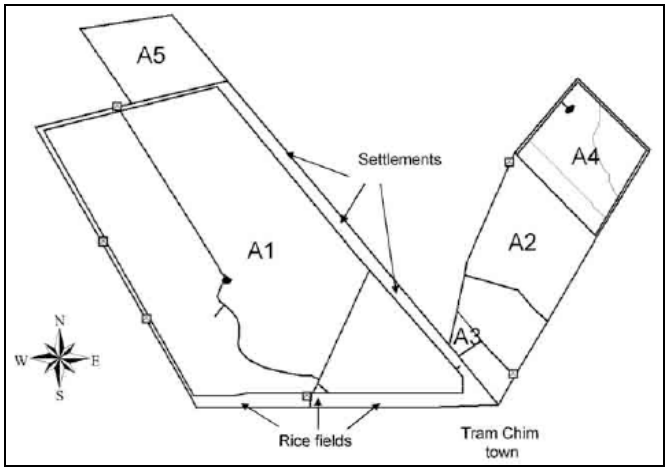
Tram Chim National Park

Tram Chim National Park is located in Tam Nong District, Dong Thap province, right in the heart of the Plain of Reeds, 38 km to the north of Cao Lanh, the capital of Dong Thap Province, 19 km to the east of the Mekong River, and 200 km to the southwest of Ho Chi Minh City. Bordering the park are the communes of Phu Hiep, Phu Duc, Phu Tho, Phu Thanh B, Phu Cuong, Tan Cong Sinh and the Tram Chim Townlet.

The name 'Tram Chim' has been in existence for a long time. Tram Chim is a depressed wetland area within the Plain of Reeds with natural *Melaleuca* forests ('*Tram*' in the Vietnamese language), an abundance of freshwater fish, and consequently many *birds* ('*Chim'*). The park topography is quite flat, and slopes slightly to the east. In the past, several natural streams and rivers flowed from west to east, distributing water from the Mekong River to the Plain of Reeds. Now these streams and rivers have been replaced by a system of canals, some of which flow through the national park.

Presently, Tram Chim National Park covers a total area of 7,588 hectares, comprising a mixture of seasonally inundated grassland, regenerating *Melaleuca* forests covering approximately 30% of the park, and open swamp. The park is surrounded by a 52 km perimeter dyke system interspersed by sluice gates, which control water flow in and out of the different zones. A

system of canals and dykes dissects the park into six pieces see Figure…. Zone A1, A2, A3 and A4 are strictly protected areas; zone A5 is an ecological rehabilitation area.



Subdivision of Tram Chim National Park in management units

BirdLife International ranked Tram Chim National Park as one of the most important sites for conservation in the Mekong Delta. The park receives international recognition as seasonal habitat for the globally endangered eastern race of the Sarus Crane *(Grus antigone)*. The site is an important feeding area along the migratory route of the Eastern Sarus Crane in the dry season, supporting as much as 60 % of the total population in the Lower Mekong Basin during the last decade. The tubers of *Eleocharis* spp. grasses found in the park are the primary food of the crane. It is also an important breeding site for water birds and other wildlife such as the Bengal Floricans (*Eupodotis bengalensis)*, another globally endangered species. Tram Chim is also one of the few places in the Mekong Delta where wild rice varieties still grow. At landscape level, Tram Chim National Park currently is a little spot of natural wetland area surrounded by a large area of agricultural lands and human settlements.

The management goals in zones A1 and A2 are to restore the native vegetation of the Plain of Reeds including the maintenance of seasonal feeding grounds for the Eastern Sarus Cranes. Management goals of zones A4 and A5 are to provide habitat for cranes as well as other bird species dependent on vegetation associated with earlier patterns of seasonal water draw-down, for example, Bengal floricans, Oriental praticoles and green bee-eaters.

The first Investment Plan of Tram Chim Nature Reserve (1994) proposed a buffer zone for Tram Chim National Park covering an area of 20,500 ha. However, the extent, boundaries and purpose of the buffer zone have not been defined in practice or in the Investment Plan. There is a proposal to expand the buffer zone incorporating land from the following communes: Phu Tho, Phu Duc, Phu Hiep, Tan Cong Sinh and Phu Thanh though this is thought not to be realistic by the present park management partly because of compensation issues.

There are approximately 32,000 people living in the communes adjacent to the boundary of the park, the majority of which are rice farmers, fishers, or agricultural laborers. At present the park suffers from constant and significant poaching and impact from the surrounding communities.

Lang Sen Wetland Reserve

Lang Sen is another remnant of the original wetland landscape of the Plain of Reeds, located in Vinh Loi commune, Tan Hung District, Long An province, approximately 23 km northeast of Tram Chim National Park. Unlike Tram Chim, Lang Sen is not connected to or drained by the Mekong River, but by the western branch of the Vam Co River. In severe flood years (such as 1996 and 2000), Lang Sen is flooded under 2.5 to 3.0 m of water for a duration of three to four

months. However, with development and enlargement of the canal network, the flood period has shortened by about one month compared to previous periods.

Lang Sen is not included in any government decision or official set of proposals regarding the national special-use forests system, as is Tram Chim. However, the establishment of a nature reserve at Lang Sen was proposed by the Long An Provincial People's Committee in 1994, at which time an investment plan was prepared. This investment plan proposed establishing a 1,124 ha nature reserve, with the name Dong Thap Muoi. This proposal to establish a nature reserve at Lang Sen is apparently still under consideration. However, in 2004, Lang Sen was officially established as a Provincial Wetland Reserve by Long An Province People's Committee. The Lang Sen Wetland Reserve covers an area of some 5,030 ha, among which 1,500 ha is swampland providing habitats for a variety of wetland fauna and fish.

In the Vietnamese language, 'Lang Sen' means 'Lotus swamp'. Substantial areas of natural lotus swamp are preserved at Lang Sen. This vegetation type is characteristic of the Plain of Reeds but is now seldom found anywhere to any great extent. The survey of key wetland sites in the Mekong Delta by BirdLife International in 1999 reported that Lang Sen was the only site visited where semi-natural *Melaleuca* forest occurs along a natural river channel, and, as such, is of notable biodiversity value. The site is listed as an Important Bird Area (IBA) because a significant number of large water birds, including the Eastern Sarus Crane (*Grus antigone*) and the globally near-threatened Painted Stork (*Mycteria leucocephala*), en-route between their breeding areas in Cambodia and their non-breeding areas in the Mekong Delta of Viet Nam, use Lang Sen as a stop-over area.

A recent biodiversity survey recorded 156 plant species, 149 vertebrate species (among which 13 species are listed in the Viet Nam Red Book for endangered species) and 11 benthic animal species. Typical habitats found in Lang Sen Wetland Reserve are:

- natural streams and rivers;
- riparian forests (average 10 - 15 m wide band of multi-species woody trees) along rivers and canals;
- seasonally flooded grasslands, flooded for five to six months per year and susceptible to fire in the dry season;
- swamp with water almost year round, providing good refuge for wildlife like snakes, turtles, tortoises and various fish species;
- *Melaleuca* forests;
- rice fields; and
- canals.

A major challenge at Lang Sen Wetland Reserve is that much of the reserve and surrounding area is inhabited by local communities, predominantly along the network of canals that criss-cross the park. This is different from the situation in the Tram Chim Nature Park where there are no communities living within the park boundary.

6 Fisheries

Fish provide 40-60% of the protein in the diet of people living in the Mekong Delta. Fishing is carried out almost everywhere, from the smallest canals to the largest river channels. In many of the major rivers, nets are placed across half the channel or more. Both fresh and saltwater species are fished for and a wide range of fishing methods used. Fish traps are widespread, the use of gill-nets is frequent and more destructive methods, such as electro-fishing, are common.

Of the 260 species of fish known from the delta, 200 contribute to the commercial fishery (Le Dien Duc, 1989). In addition, shellfish, mainly Mollusca and Crustacea, constitute an important

element of the fishery. A study by Sjorslev (2001) in the An Giang Province (Long Xuyen Quadrangle) indicated that for 40% of the households fisheries (and collecting aquatic animals) is a major part of food collection for family consumption, while for 23% of the households, fishing provides supplemental income. Seven % of the households have fishing as a major source of income.

In terms of habitats used, flooded irrigated rice lands or riverine floodplain is used for fishing by 67% of the households, followed by perennial rivers (28%), perennial canals (25%), and rainfed rice paddies (8%). All habitats are used for fishing throughout the year. The fishery is very diverse and a total of 76 species groups were reported to be caught. One species contributes most to the total catch in terms of kg, namely *Cirrhinus jullieni*. Apart from fish, freshwater mussels and prawns are also very important in catches. For 1999, the official total catch figure for An Giang province was 64,000 tons.

Main characteristics of the fisheries in the Dong Thap Province of the project area are illustrated by the results of a household survey carried out in 2004 (Nguyen Van Trong and Pham Mai Phuong: Preliminary results of socio-economic survey on fisheries in the flooded area in the Mekong Delta, Binh Thanh and an Binh A villages, Hong Ngu district in Dong Thap Province, Research Institute for Aquaculture No. 2, 2005).

Nguyen Van Trong and Pham Mai Phuong (2005) reported on the fisheries in the Dong Thap province (Plain of Reeds). During the flood season, from August to December, all paddy fields are inundated by a flood with the water depth of 1.5 - 3 m. In order to protect the Summer - Autumn rice crop from the early flood, low-dike and sluice systems have been built around most of the paddy fields. In August, after the rice harvest, the flood will be allowed into the rice fields through open sluice gates or running over dikes at the flood peak. By this measure, negative impacts on fisheries resources from the flood control systems (obstruction of fish migration and diminishing of feeding and spawning grounds) is prevented.

About 65% of the households in the surveyed area are involved in fisheries, but only some 9% full- time (or professional). Rivers and irrigation canals are main fishing grounds for local fisherman during the dry season. Flooded rice fields are the major fishing grounds during the flood season.

There were about 40 species of 12 families commonly identified in the fish catch. Besides *Henicorhynchus siamensis* that were captured in a large quantity, bringing in high income, most of the other fish species were harvested at small size, less than 10 cm in length, giving low value of production.

The most abundant family was Cyprinidae with 19 species, including (i) a small size fish group with a low production: *Paralaubuca spp., Rasbora spp., Systomus aurotaeniatus,* (ii) a small size fish group but with a large production: *Henicorhynchos siamensis, Dangilla spp.*,.and (iii) big fish with low production: *Puntioplites spp., Cirrhinus microlepis, Barbodes goinionotus, Cyclocheilichthys repasson, Labeo chrysophekadion.* Five species of Siluridae were identified in the fish catch whereas other families only consisted of 1 - 3 species recorded.

The family Cyprinidae was recorded not only to be most abundant in species composition but also in total yield. The production of fish species belonging to Cyprinidae accounted for 59% of the total production, in which, *Henicorhynchus siamensis* and *Dangila spp.* account for 37% . The bagriids were the second group in term of quantity with a production of 3.6 tons (19%), including *Mystus gulio* and *Mystus nemurus.*

Some prawn species were recorded as well.

All fishing households used part of the fish catch for consumption. Most families sold part of the catch to increase family income (93%). It was found that 50% of capture fish production was sold to markets.

7 Forestry

Melaleuca and mangrove forests provide a number of benefits to local people. The timber is valued for construction of housing, and is also used as a fuelwood. The production of honey is practiced in *Melaleuca* forest, and honey harvested from wild bees is particularly highly valued. *Melaleuca* is also now widely recognized as being suitable for planting on acid-sulphate soils, as its cultivation does not involve the creation of raised beds. *Melaleuca* cropping cycles often involve a first crop of poles taken after 8-10 years growth, after which stumps are left in the ground to regenerate. When fully re-grown, the forest crop is clear-felled and new saplings planted. During the initial eight years, other forest products are taken to provide a source of income. These include aquatic fauna for food, *Melaleuca* oil (a valuable medicine), 'chaoi' *Stenochlaena palustris* (a plant used for making rope and fish nets), 'mop' *Alstonia spathulata* (a woody plant used for making fishing floats) and *Melaleuca* bark (used for thermal insulation).

Forests are an important economic resource in the Mekong Delta. Previously, large areas were covered in *Melaleuca* and mangrove forests, but wartime conflict devastated much of this, particularly due to the spraying of defoliants. More recently, the benefits of *Melaleuca* planting have been widely recognized, and the area of this forest type has increased in recent years. Mangrove has also been widely replanted, mainly in an effort to counteract shoreline erosion.

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11.7 The Tonle Sap Great Lake ecosystem and it's importance for ecology and Lower Mekong fisheries

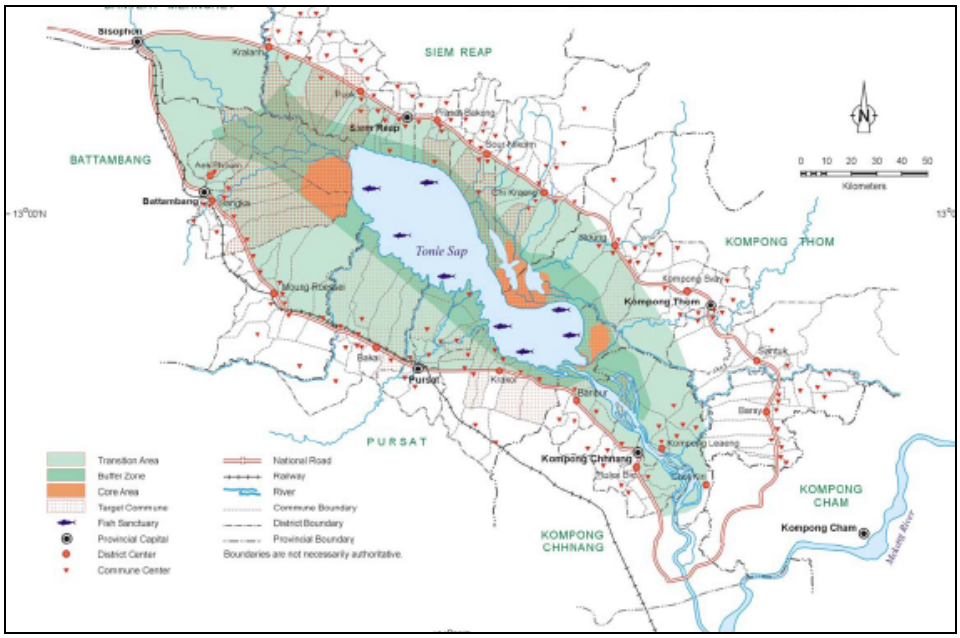
1 Introduction

This chapter aims to explain the unique role of the Tonle Sap Great Lake as a 'fish factory' for the Lower Mekong fisheries. Emphasis is on migratory fish species and the key features of the Mekong River hydrological system and flood characteristics that are important for the maintenance of theses species and their Habitats.

The information presented in this paper has been taken directly from a number of key publications on the Tonle Sap ecosystem, fish migration and spawning patterns and inland fish production. The most important publications used are listed in the Reference list at the end of this chapter.

The Tonle Sap Great Lake is one of the largest freshwater lakes in Southeast Asia. It appears that the lake originated about 5,000 years ago. The unique hydrological regime of Tonle Sap Lake is characterized by an annual inflow of Mekong waters into the lake basin during the wet season, when the water levels in the Mekong fall. At the end of the wet season, the flow reverses and the lake empties again. This hydrological cycle supports and maintains high biodiversity and productivity, particularly fish, plant communities, and wildlife, which are the resource base for the national economy of Cambodia. Nearly half of the Cambodian population depends on the Lake's resources, about one million of which is fish dependent community. Tonle Sap Lake furthermore plays a vital role in Khmer cultural identity, which is reflected in the traditions, livelihood, festivals, and taste. It is believed that the Khmer Angkor civilization and many temples could not prosper without the rich natural resources of Tonle Sap Lake as sources of wealth. Evidence of cultural influence of Tonle Sap Lake can be found in the bas-reliefs of the Bayon temple. Figure below shows the general lay-out of the area (After ADB, 2005).

Recognizing the ecological, economical, and socio-cultural value of the Lake, the Royal Government of Cambodia decided to designate the whole Tonle Sap Lake as Biosphere Reserve under the Man and Biosphere Program of UNESCO in October 1997. Parts of its wetlands are included in the list of Ramsar sites (Ramsar Convention on Wetlands, 1971).



General lay out of the Tonle Sap Great Lake (After ADB, 2005)

2 Physical resources

2.1 Climate

Cambodia's climate is dominated by the tropical wet and dry monsoons. The southwest monsoon brings the rainy season from mid-May to mid-September or early October, while the northeast monsoon's flow of drier and cooler air lasts from early November to March. Temperatures are fairly uniform at around 25°C throughout the Tonle Sap Basin area. Average annual rainfall is between 1,300 and 1,900 millimeters, with the largest amounts in the southeast.

2.2 Topography and soil

The Tonle Sap Lake is surrounded by a rather flat floodplain. The soils are mainly developed in unconsolidated alluvial deposits, comprising clay, silt, sand, and gravel.

2.3 Groundwater

Groundwater depth in the area varies considerably. The water table changes with rainfall, specific local geomorphologic conditions, and the distance to the permanent water of the Tonle Sap Lake. Manganese is reported to be found in the groundwater in concentrations that might cause some consumer inconvenience (e.g., staining of laundry and sanitary ware, taste), though it is not believed to have any negative health effects. Although arsenic concentrations are found in the groundwater throughout Cambodia, they commonly do not pose a problem.

2.4 Surface water

The Tonle Sap Lake is connected to the Mekong River through the 100 km long Tonle Sap River. Fifty seven percent of the water in the Tonle Sap Lake comes from the Mekong River. During an average wet season, about 52 percent comes in directly through the Tonle Sap River, and 5 percent flows overland through the floodplain from the Mekong. Another 30 percent comes from rivers that flow directly into the lake and about 13 percent comes from rainfall over the lake itself.

The annual 'flood pulse', the cyclical changes between high and low water levels, is crucial in maintaining this highly productive system that has adapted to the exceptionally high natural variability of the lake level. Between the dry and the wet season the volume of the lake ranges from about 1.3 km^3 up to 75 km^3, its surface area varies from 2,500 km^2 up to about 15,000 km^2, and its water level increases from 1.4 m to 10.3 m above sea level.

The quality of surface water shows extreme variations. In the dry season, pollution by human and household waste can be high near densely populated areas.

3 Ecological resources

3.1 Fisheries and aquatic biology

The flooding of the extensive plain covered with forest and other types of vegetation enables the transfer of terrestrial primary products into the aquatic phase and entry into lake-wide food webs. Sedimentation occurs almost exclusively in the floodplain. The floodplain vegetation plays a crucial role in ecosystem productivity by providing habitats, substrate area, and food for aquatic organisms. Many varieties of fish have commercial value, and more than 100 species are caught regularly. However, about a dozen make up the bulk of the catches, by weight and value. A wide variety of active (seining, lifting, casting) and passive (traps, hooks and line, gillnets)

fishing gear and methods are used. Fish behavior (migration, habitat preference, reaction to water quality changes, feeding strategies) is exploited in the fishery. The use of destructive gear and practices (poisoning, electrocution, brush parks, damming, and pumping of channels) are widespread. The importance of the area for fisheries in the entire Lower Mekong Basin is discussed in more detail in Section 6.

Other aquatic animals with direct livelihood significance include water snakes, mollusks, and invertebrates such as shrimp. Water snakes are common in the Tonle Sap ecosystem, and five species commonly are caught and traded. Around the lake, commercial rearing of captive crocodiles is practiced. Indicators suggest that the current use of the Tonle Sap's natural resources has exceeded optimum ecosystem productivity.

3.2 Timber and non-timber forest products

The natural floodplain vegetation is used for the collection of a variety of wood and non-wood forest products. Wood is collected for domestic use, including for (i) fuel wood or charcoal, (ii) construction material, (iii) use in brick kilns, (iv) fish processing (smoking and drying), and (v) the construction of fishing gear. The dominant species include *Barringtonia acutangula, Diospyros cambodiana*, *Terminalia cambodiana*, *Gmelina asiatica*, *Ficus heterophylla*, and *Vitex holoadenon*. Non-wood forest products include a wide range of plants used as food, and for medicinal purposes for humans and animals. Lianas (in particular *Combretum trifoliatum*, *Breynia rhamnoides*, *Tetracera sarmentosa*, and *Acacia thailandica*) are collected for furniture and fishing gear production. Other plant products include fruits, seeds, resins, tubers, bark, and mushrooms. Some forest animals and their products are collected, including bee wax and honey. Some larger animals are used as pets (macaques, iguanas, birds), traded, or consumed as food. Birds are hunted for food, pets, and trade. Eggs are collected for consumption. Aquatic plants are collected for human consumption, as feed for farm animals, or for further cultivation (e.g., lotus).

3.3 Biodiversity

With the global loss of wetlands, the Tonle Sap Lake and its relatively intact ecosystem processes are exceptionally important for global biodiversity. The species richness of the Tonle Sap ecosystem is only partly known. In a recent inventory, 885 species of floodplain plants and animals were found in the Tonle Sap. However, this does not include, for instance, the 197 species of phytoplankton that have been identified separately. The 2004 International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species mentions 197 species in Cambodia considered at risk of extinction, endangered, critically endangered, or vulnerable. Many of these are found in the Tonle Sap ecosystem. Of the 197 species mentioned by IUCN, 24 are critically endangered, 39 are endangered, and 53 are vulnerable. In the Tonle Sap ecosystem, 5 critically endangered species (2 fish species, 2 bird species, and the Siamese crocodile) are potentially still present. However, none of these species is endemic to Tonle Sap. As a consequence of 3 decades of unrest, access to the project area has been at times difficult, and a biodiversity inventory of the Tonle Sap ecosystem is far from complete.

In Cambodia, 22 species are classified as data deficient. This could mean that some of these species are threatened, though data are insufficient to assess their condition in full. Several fish species, particularly among those that grow large, are endangered. In its 2004 Red List, IUCN classified the giant Mekong catfish (*Pangasianodon gigas*) as critically endangered. The heavy exploitation of crocodile and the endemic Tonle Sap watersnake (*Enhydris longicauda*) also is of particular conservation concern. The Siamese crocodile (*Crocodylus siamensis*) is critically endangered in the wild, though it is widely bred and kept in captivity. *Orcaella brevirostris*, the freshwater Irriwaddy dolphin that is found in the Mekong, is occasionally also seen in the Tonle Sap Lake. The biodiversity in the Tonle Sap is best known for birds. Of the 104 water bird species

that have been recorded in the Tonle Sap, 89 are abundant, while 14 are considered internationally significant. The two core areas of the Tonle Sap Bird Reserve, Prek Toal and Lake Chhmar, have the most endangered species. Prek Toal is the most important breeding area.

3.4 Land and Crops

The continuous expansion of agricultural land into the floodplain to address the rising population and low productivity of paddy fields has come at the expense of the natural flooded forest vegetation. The competition between the natural assets of flooded forest and rice and other agriculture crops is increasingly undermining the productivity of the Tonle Sap ecosystem. The foreshore of the Tonle Sap's permanent lake and the river banks provide land, even only seasonally, to the landless poor, who also benefit from being in the vicinity of water for their crops.

3.5 Livestock

Livestock is important for the livelihood of many people. Pigs are held widely in floating villages and throughout the floodplain. Cattle provide traction for rice farmers, and flooded forest is burned in places to promote the growth of grass for cattle grazing. Even the poorer households can afford ducks and chicken. Ducks also generate income through their use in pest control in rice fields.

4 Economic development

Most of the activities in the project area are based on fisheries or agriculture. Fish processing is widespread, while agriculture focuses on rice production in most places. Infrastructure facilities are largely absent, particularly in the floating or stilted villages. The few access roads are mostly in poor condition. Although ports and landing sites lack basic infrastructure, they contribute effectively to livelihood generation. The lake is used for transportation of people and goods, including petroleum products and fish. Most of the people transported are foreign tourists. Low water levels in the dry season limit the size and traffic of boats.

5 Social and cultural resources

More than 1.2 million people in the Tonle Sap area depend on fishing for their livelihood. People typically live in villages, grouped in communes. Many fisher folk are highly mobile, migrating within the floodplain and lake to find fishing opportunities. The Tonle Sap fish and floodplain resources are also part of the livelihood strategies for many people living outside the project area. The distribution and quality of health and education facilities vary. Both are lacking in lake-based communities. The historic temple complex of Angkor Wat, located in the area, is an important tourist attraction. Buildings and features of archaeological and historical significance (e.g., Khmer Empire era temples and shell mounds) are scattered throughout the project area.

6 Importance of the Tonle Sap wetland system for fisheries

Cambodia has the world's most productive inland fishery. A single hectare of floodplain can produce up to 230 kilograms of fish a year. In terms of value, the overall fishing sector accounts for 10 to 12 percent of gross domestic product (GDP) and contributes more to income, jobs and food security than in any other country. The inland fisheries has an annual catch conservatively estimated at about 400,000 tons. Tonle Sap fisheries account for almost two-thirds of the total catch in Cambodia. In 2006, the Inland Fisheries Research and Development Institute of the Fisheries Administration estimated the value of fisheries and other aquatic resources of the Tonle Sap Lake conservatively at $233 million a year (Baran et al., 2007).

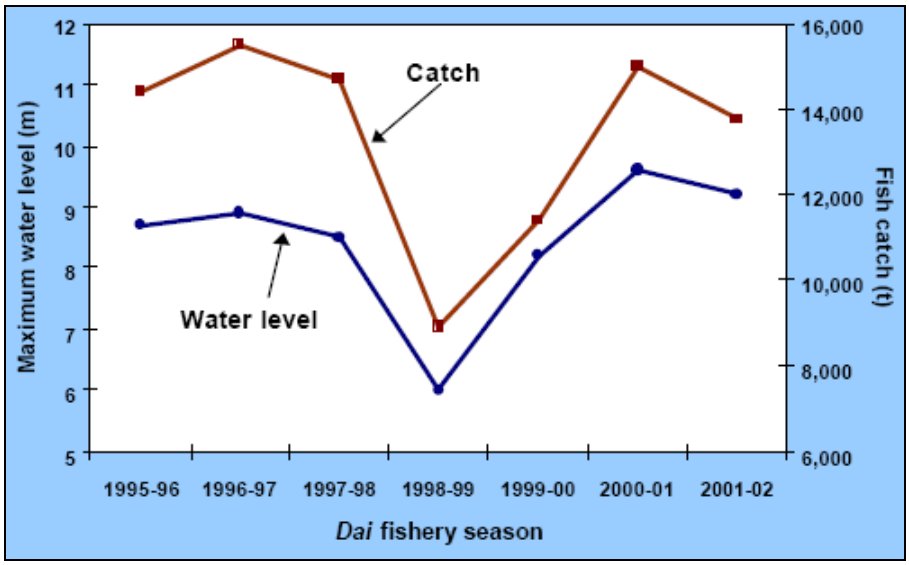
6.1 Relationship between fish production/catches and flood characteristics

Based on literature on other large river systems elsewhere in the world Baran et al. (E. Baran, N. van Zalinge, Ngor Peng Sun, Floods, floodplains and fish production in the Mekong Basin: present and past trends, MRC miscellaneous publications, not dated) identified a number of factors that determine fish production in the Mekong Basin. They are discussed below:

6.1.1 Water level

The correlation between the *total catch* and the river discharge in the same year has been extensively documented for large river systems around the world. It has also been shown more specifically that catches could be strongly related to the high-water flood regime at the beginning of each season, and that fish grow more quickly when flood levels are higher.

Also for the Lower Mekong it has been shown that higher floods directly result in higher fish production. Although many factors are involved, higher floods produce larger amount of fish and keep a number of important habitats viable. Observations on the bag-net (Dai) fishery for migrating fish in the Tonle Sap River during 1995–2002 indicate that year-to-year variations in maximum Mekong River flood levels and related Tonle Sap floodplain inundation strongly affect the fish yield, see figure below.



Relationship between the maximum flood level of the season and the fish catch of the Dai or Bag net fishery in the Tonle Sap River.

High fish yields in years with high floods is explained by a number of factors. Firstly spawning success of fishes is related to available spawning grounds: higher floods inundate larger floodplain areas, so creating larger spawning areas. Secondly, a high flood also means that fishing activities are dispersed more evenly over larger areas giving better possibilities for young fishes to survive. The above stated is not valid for all fish species: the fishing lot catch of snakehead (*Channa micropeltes*) was highest one year after a high flood (Van Zalinge et al. 2003).

Other factors of importance are the sediment concentrations of the floodwater and the dissolved oxygen conditions. Sediments carried by the Mekong waters to the Tonle Sap Lake bring in the essential nutrients that enter into the lake's food webs. The higher the flood the more sediment is brought in. This leads to improved survival and growth of fish and hence to higher fishery yields (see also Section 6.1.6).

6.1.2 Duration of the flood

A longer period of flood provides a longer growth period for fishes, and therefore a higher yield. This strong correlation between the annual fish production and the duration of the flood has been clearly demonstrated for many river systems. However, as the process is linked to organic matter decay and nutrient release, the relationship seems to be asymptotic, a plateau being reached after a certain duration.

6.2.3 Timing of the flood

Most tropical fish species release eggs just before or during the flood, which results in their spreading into floodplains. In the Mekong River, rising waters trigger spawning in adults of many species such as Pangasiids and juveniles drift towards the Tonle Sap system where they grow. Timing of the flood and duration of the flood season during which the juveniles can grow are therefore two parameters that will influence the total production (see also Section 7).

Delays in the onset of the flood will result in delays in the arrival of oxygen-rich waters. Dissolved oxygen levels in Tonle Sap water generally decline during dry season, until the inflow of oxygen-rich water at the beginning of flood season. While fish may swim to more oxygenated waters, eggs and larvae are unable to move and may be adversely affected if the arrival of the flood is delayed. Flow changes also have an impact on the drift of fish larvae and juveniles.

6.1.4 Regularity of flooding

After early rainfalls and river level rise have prompted migration and spawning, small drought periods can cause massive mortality of eggs, fish larvae and fry as well as amphibians. Sticky fish eggs can become suddenly exposed on vegetation, while larvae and juveniles can get killed as the water recedes and small ponds dry up. This factor has scarcely been mentioned in the literature, but sometimes happens in the Tonle Sap region where it can result in massive mortality.

6.1.5 Characteristics of the flooded zone

For fishes, floodplains are favorable as a feeding zone (release of nutrients, primary production and detritus- based food chain), and because they provide shelter to juveniles against predation (shallow water, flooded vegetation). The importance of different flood plain habitats for the ecosystems functioning is partly unknown, but the diversity of food resources and habitats allows multiple strategies, species, sizes, stages and life cycle strategies. Flooded forests are essential in providing shelter and living habitats for large variety of biota, but on the other hand shrub and grass land provides often the largest variety of biodiversity. Grass land is obviously playing a major role in nutrient cycling and supports a high fish production.

6.1.6 Physical/chemical conditions

The quality of flood waters has an impact on the flood plain ecosystem e.g. by bringing sediments and nutrients to the system. Nutrient bearing sediment is important for primary production driving the fish growth. Changes in the sediment load can cause major changes in the fish production.

In the Tonle Sap area, sediments are largely being trapped at the interface between the oxygen-rich waters of the lake and rivers and the oxygen-poor waters of the floodplain, giving rise to a rich riparian vegetation of tall trees. The waters above the floodplain are much clearer than the lake waters, as nearly all sediments have been filtered out.

According to Van Zalinge (2003) this explains why the catch per hectare appears to be stable no matter whether natural habitats or agricultural lands are flooded. The biological productivity is derived from the sediments in the waters of the lake, rivers and especially their border areas and not from the extensive floodplains themselves. The sediments contain the nutrients needed by the phytoplankton. Phytoplankton blooms do not occur in the lake, because of intensive grazing by zooplankton and fish.

Oxygen conditions obviously affect where fish can live and reproduce and how different species have developed strategies for avoiding unfavorable conditions. Floodplains are by and large oxygen poor environments. Because of oxygen transport and dispersion, border areas between the well oxygenated lake proper and tributaries and floodplains have more favorable oxygen conditions than areas deeper in the floodplains. Open areas inside the floodplains such as lakes and fields offer better oxygen environments and safety zones for fish. Flow can transport large masses of anoxic water both in the horizontal and vertical direction and trap or kill fish in these limited areas. One explanation for the observed fish deaths may be the anoxic water inflow.

7 Fish migration

7.1 Introduction

The importance of migratory behavior among Mekong River fishes has been acknowledged for long, many economically important fish species are known to be highly migratory. Some species undertake longitudinal migrations, while others make only localized and lateral migrations. Longitudinal migratory fish species begin to spawn in the Mekong River at the beginning of the rainy season (May-August). Fish eggs and fry are carried by the current and swept into the floodplain areas around the Tonle Sap Great Lake and the areas south of Phnom Penh. When the flood recedes, most of fish species migrate to deeper waters in the lakes, rivers or tributaries (lateral migration), but many species will undertake longer migrations (longitudinal migrations) to the Mekong River

Based on their migration behavior two groups of fish are distinguished: white fish and black fish. When floodplains drain at the end of the wet season, water remains in lakes and scattered depressions, which continue to shrink in size and number during the dry season. Floodplain water bodies become hot, oxygen is depleted and food and shelter diminish, with many ponds drying-out completely. So the fish, which feed and grow on flooded areas must either return to the river as the waters recede, or remain and endure the poor conditions on the floodplain.

Species which leave flooded areas and return to rivers are referred to as longitudinal migrants or ‘white fishes’, as they spend most of their lives in turbid (white) river water. Most white-fish species migrate into flooded areas during the monsoon season and migrate over long distances to dry-season refuges at the end of the flood season. Representatives of this group are some of the cyprinids, such as *Cyclocheilichthys enoplos* (Soldier river barb or Chhkok) and *Cirrhinus microlepis* (Small mud carp or Prul/Kralang), as well as the river catfishes of the family Pangasiidae.

The species of fish which remain in lakes and swamps on the floodplain are known as lateral migrants or ‘black fishes’, as they spend their lives in relatively clear water that is tea-colored by chemicals dissolved from floodplain vegetation. Decomposition of vegetation causes floodplain water to be acidic and depleted in oxygen, stresses which black fishes can tolerate. Most black fishes can breathe air, while many species can survive out of the water for long periods, and most can move overland in search of new water bodies. A few species can bury themselves deep in the mud and wait until the next flood. Many black fishes are used in aquaculture and are transported alive to markets. They are normally referred to as non-migratory, although they perform short seasonal movements between permanent and seasonal water bodies. Examples of black-fish species in the Mekong are the climbing perch (*Anabas testudineus*), the clarias catfishes (e.g. *Clarias batrachus*) and the striped snakehead (*Channa striata*).

An additional group, intermediate between black-fishes and white-fishes is formed by the so-called greyfish. Species of this group undertake only short migrations between floodplains and adjacent rivers and/or between permanent and seasonal water bodies within the floodplain.

7.2 Spawning habitats

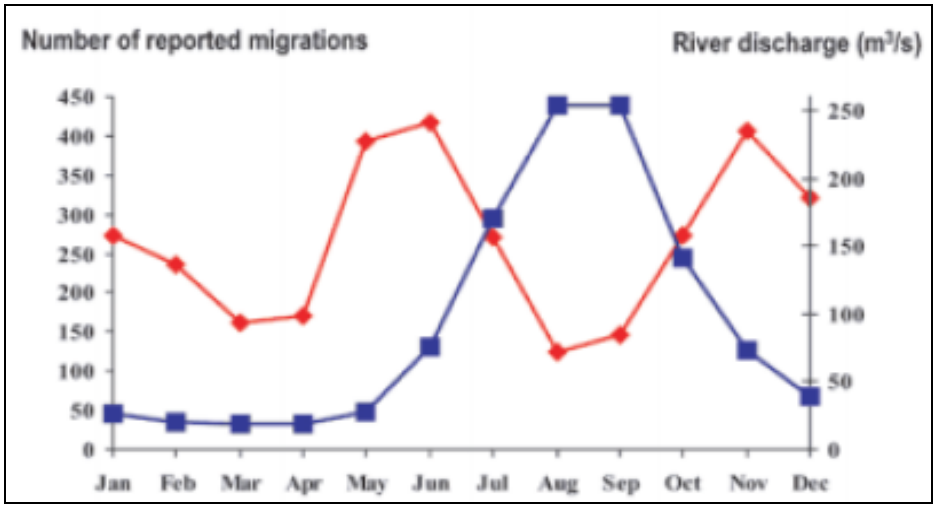
Spawning habitats are generally believed to be associated with either rapids and deep pools of the Mekong mainstream and tributaries or with floodplains (e.g. among certain types of vegetation, depending on species). River channel habitats are, for example, used as spawning habitats by most of the large species of pangasiid catfishes and some large cyprinids such as *Cyclocheilichthys enoplos*, *Cirrhinus microlepis*, and *Catlocarpio siamensis*. Floodplain habitats are used as spawning habitats mainly by black-fish species.

Many species that spawn in river channels in the open-water column rely on particular hydrological conditions to distribute the offspring (eggs and/or larvae) to downstream rearing habitats. Information on spawning habitats for migratory species in the river channels of the Mekong Basin is scarce. Only for very few species, spawning habits are well described. For many species, in particular for deep-water mainstream spawners such as the river catfish species, spawning is virtually impossible to observe directly. Information about spawning has been obtained indirectly from observations of ripe eggs in fishes

For fishes that spawn in main river channels, spawning is believed to occur in stretches where there are many rapids and deep pools, e.g. (1) the Kratie - Khone Falls stretch; (2) the Khone Falls to Khammouan/Nakhon Phanom stretch; and (3) from the mouth of the Loei River to Bokeo/Chiang Khong. The Kratie-Khone Falls stretch and the stretch from the Loei River to Luang Prabang are particularly important for spawning.

7.3 Fish migration and hydrology

There is a clear relationship between fish life cycles, fish habitats, and hydrology. Migrating fishes respond to hydrological changes and use hydrological events as triggers for the timing of their migrations. This is illustrated in the figure below, where peak migration periods are correlated with the annual hydrological cycle. Most species migrate at the start of the annual flood and return at the end of the flood, producing the two peaks shown in the figure below.



Relationship between migratory activity levels and water discharge in the Lower Mekong Basin. Blue Line: average monthly discharge (m^3/sec) of the Mekong River at Pakse, Red Line: number of migrations reported (based on 50 species from 51 sites along the Mekong mainstream). (After Poulsen et al, 2002)

Also, the spawning season is tuned according to river hydrology, and almost all species spawn at the onset of the monsoon season. Only a few species, spawn during the dry season.

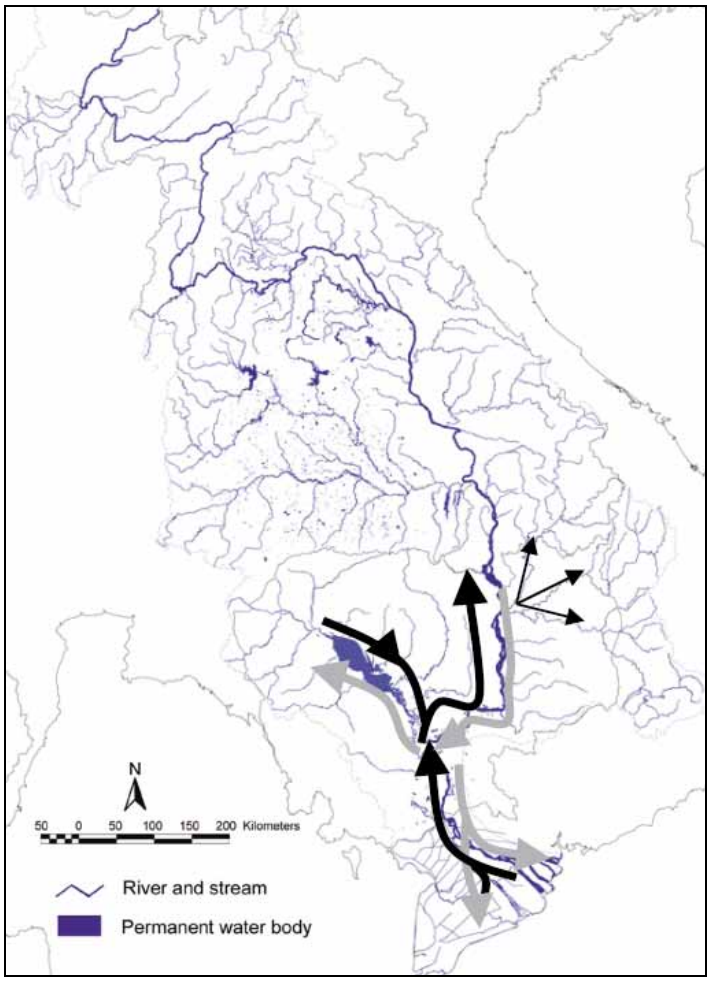
7.4 Major migration systems in the Mekong

Different species have developed different life strategies to cope with the environmental circumstances, however, generalizations can be made, e.g. on migratory patterns. Three main migration systems associated with the lower Mekong River mainstream have been identified. These three systems are called the Lower Mekong Migration System, the Middle Mekong Migration System, and the Upper Mekong Migration System. Although these different systems are inter-connected and, for many species, overlapping, the Lower Mekong Migration System is the most important system for the Tonle Sap fisheries.

The Lower Mekong Migration System covers the stretch from the Khone Falls downstream to southern Cambodia, including the Tonle Sap system, and the Mekong Delta in Viet Nam. The migration is driven by the spatial and temporal separation of flood-season feeding and rearing habitats in the south with dry-season refuge habitats in the north. The rise in water levels at the beginning of the flood season triggers many migrating fishes to move from the dry season habitats just below the Khone Falls, e.g. in deep pools along the Kratie - Stung Treng stretch, towards the floodplain habitats in southern Cambodia and the Mekong Delta in Viet Nam. Here they spend the flood season feeding in the fertile floodplain habitats. Some species spawn on, or near the floodplain, whereas others spawn far upstream, i.e. above Kratie, and rely on the water current to bring offspring to the floodplain rearing areas. The Tonle Sap Great Lake system is one of the key factors for the integrity of this system.

As a result of increasing water discharge from the Mekong River at the onset of the flood season, the water current of the Tonle Sap River changes its direction, flowing from the Mekong into the Tonle Sap River and towards the Great Lake. This enables fish larvae and juveniles to enter the Tonle Sap from the Mekong by drifting with the flow. Together with the floodplains of the Mekong Delta in south Cambodia and Viet Nam, these floodplains are the main 'fish factories' of the lower basin.
An important group of species, which undertakes this type of migration, belongs to the genus *Henicorhynchus*. In terms of fisheries output, these fishes are among the most important of the Lower Mekong. For example, in the Tonle Sap River Dai fishery, species of the genus *Henicorhynchus* account for 40 percent of the total annual catch. Larger species, such as *Catlocarpio siamensis*, *Cirrhinus microlepis*, *Cyclocheilichthys enoplos*, and *Probarbus jullieni*, as well as several members of the family Pangasiidae, also participate in this migration system.

The Sesan tributary system (including the Sekong and Srepok Rivers) deserves special attention here. This important tributary system is intimately linked with the Lower Mekong Migration System, as evidenced by many species such as *Henicorhynchus* sp. and *Probarbus jullieni* extending their migration routes from the Mekong River mainstream into the Sesan tributary system. In addition, the Sesan tributary system also appears to contain its own migration system. Many of the species (e.g. all the species mentioned above) are believed to spawn within the Mekong mainstream in the upper stretches of the system (from Kratie to the Khone Falls, and beyond) at the beginning of the flood season in May-June. Eggs and larvae subsequently drift downstream with the current to reach the floodplain feeding habitats in southern Cambodia and Viet Nam. The main characteristics of the Lower Mekong Migration System are shown in Figure below.



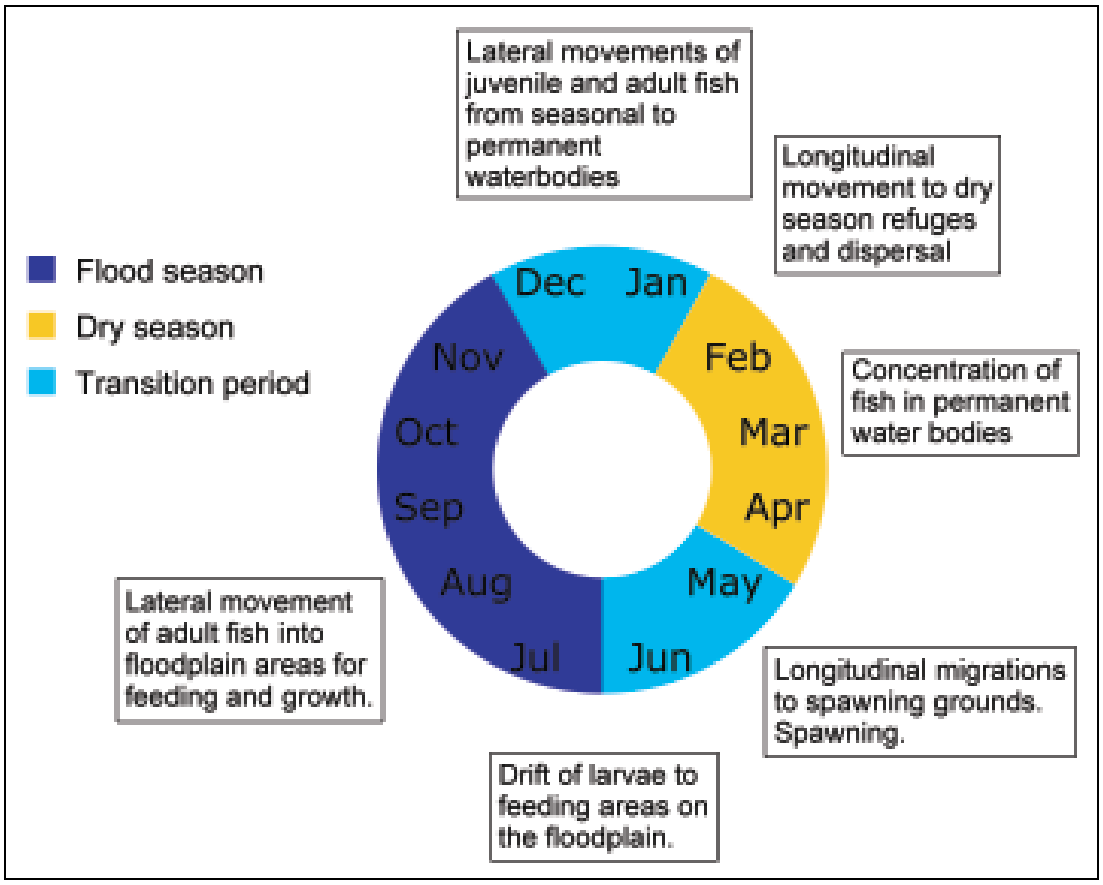
The Lower Mekong Migration System. Black arrows indicate migrations at the beginning of the dry season, grey arrows indicate migration at the beginning of the flood season

The importance of drifting larvae and juveniles has been documented through intensive sampling of larvae fisheries in the Mekong Delta in Viet Nam. During a sampling period of only 45 days in June-July 1999 127 species were identified from the larvae and juvenile drift.

A general 'migration calendar', as it is valid for an average year and the 'average Mekong fish species is given in **Error! Reference source not found.** after Poulsen et al (2004). Triggers for initiation of migrations are not well understood, although it is generally assumed that increased discharge in itself is a main trigger for migrations: fish typically start to migrate upstream to spawning grounds when the water level starts to increase, spawning while the water level is still increasing to ensure that the current brings eggs and larvae into nursery areas on the floodplain further downstream.

After spawning, the adult fish also move into the flooded areas. During the flood season the fish feed intensively in the flood zone, growing and building up fat layers for the following dry season, when food is scarce.

As the water level starts to drop and the floodplain dries, most fish seek refuge in permanent water bodies, mainly in deeper parts of the main river channel. Fish following this pattern thus utilize three distinct habitats (spawning grounds, feeding habitats and dry season refuges).



General migration calendar for Mekong fish species

7.5 Key issues for the maintenance of the Tonle Sap/Lower Mekong fisheries

Although emphasis is on issues related to migratory fishes, the issues are equally relevant for all fish species and indeed for the ecosystem as a whole. Basically, the most important issue in relation to the ecological functioning of the Mekong River from the point of view of migratory fishes is that critical habitats are maintained in time and space. This includes the maintenance of connectivity between them, i.e. through migration corridors. The annual hydrological pattern, including its role in the creation of seasonal floodplain habitats, as well as its role as a distributor of fish larvae and juveniles through passive drift, is of a high importance.

The following key ecological attributes for migratory species are identified:

Dry season refuge habitats	Deep pools in the Kratie-Stung Treng stretch of the Mekong mainstream. These habitats are extremely important for recruitment for the entire lower Mekong Basin, including floodplains in southern Cambodia (including the Tonle Sap Great Lake System) and the Mekong Delta in Viet Nam.
Flood season feeding and rearing habitats	Floodplains in the Mekong Delta in Viet Nam, in southern Cambodia, and in the Tonle Sap system. These habitats support the major part of Mekong fisheries.
Spawning habitats	Rapids and deep pool systems in the Kratie - Khone Falls, and in the Sesan catchment. Floodplain habitats in the south (e.g. flooded forests associated with the Great Lake).
Migration routes	The Mekong River from Kratie - Stung Treng to southern Cambodia and the Mekong Delta in Viet Nam. Between the Mekong River and the Tonle Sap River (longitudinal connectivity). Between floodplain habitats and river channels (lateral connectivity). Between the Mekong mainstream and the Sesan sub-catchment (including Sekong and Srepok Rivers).
Hydrology	The annual flood pattern responsible for the inundation of large areas of southern Cambodia (including the Tonle Sap system) and the Mekong Delta is essential for fisheries productivity of the system. The annual reversal of the flow in the Tonle Sap River is essential for ecosystem functioning. If the flow is not reversed (or if reversal is delayed), fish larvae drifting from upstream spawning sites in the Mekong River cannot access the important floodplain habitats of the Tonle Sap System. A delayed flow reversal would also lead to a reduced floodplain area adjacent to the river and lake, and thus, reduced fish production. Changed hydrological parameters e.g. as a result of water management schemes, result in changed flow patterns, which in turn may change sedimentation patterns along the river. Examples of this already exist in some tributaries where hydropower dams have been constructed, resulting in sedimentation, and thus in disappearance of deep pool habitats.

The importance of (longitudinal) migratory fish that rely strongly on the ecological connectivity between floodplains and river channels, in the total fish catch is considerably. Van Zalinge et al. (2000) estimate that longitudinal migrants contribute 63% to the catch of the major Tonle Sap fisheries. Poulsen et al. (2002) estimate the contribution to be 48%.

The remaining proportion of the floodplain yield originates from the black-fish species, i.e. species that spend their entire life on the floodplain. However, many black-fishes are predators, including the abundant *Channa* (snakeheads), and it may be assumed that they feed heavily on whitefishes which have moved into their floodplain habitat.

8. Implications for the proposed Mekong - Tonle Sap diversion

Based on above review of the literature a number of conclusions can be drawn that may have implications for the proposed diversion of part of the Mekong flood flow to the Tonle Sap Great Lake via a diversion channel connecting the Mekong mainstream near Roka Kong with the Tonle Sap near Prek Chic:

- Tonle Sap Great Lake has a high and unique ecological value, harboring a large number of rare and endangered flora and fauna species;
- the socio - economic value of the Tonle Sap fisheries is extremely high. Longitudinal migrating (between Tonle Sap and the main river) fish make up for probably more than 50% of the yield;
- to maintain ecosystem integrity and ecosystem production, the system should be operated with great care taking into account that:
    - fish migration should not be hindered. It is extremely important that free floating eggs and larvae should be allowed to drift into he Tonle Sap area in the period May till mid-July;
    - early flooding of the area is also important because at the end of the dry season the water quality in the remaining refuges may become very poor (anoxic). Inflow of oxygen-rich floodwater has to improve this situation, if not the lateral migrating species (black fish) may not survive;
    - the deeper the flood and the larger the flooded area, the higher the fish production will be;
    - inflow of fine sediments is of crucial importance for the maintenance of the productivity of the system;
    - a variety of floodplain habitats is important for the functioning of the system. Although shrub and grasslands are probably more important than flooded forests, the latter habitat is of crucial importance as well. The impacts of deeper and longer flooding on the flooded forests is not well known at the moment and requires further investigation; and
    - at the start of the dry season (February) longitudinal migration to the dry season refuges should be possible.

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