Mekong River Commission

Office of the Secretariat in Vientiane
184 Fa Ngoum Road, Ban Sithane Neua,
P.O. Box 6101, Vientiane, Lao PDR
Tel: (856-21) 263 263 Fax: (856-21) 263 264

mrcs@mrcmekong.org

Office of the Secretariat in Phnom Penh
576 National Road, no. 2, Chok Angre Krom,
P.O. Box 623, Phnom Penh, Cambodia
Tel: (855-23) 425 353 Fax: (855-23)425 363

www.mrcmekong.org

The ISH 0306 Study

Development of Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries

1st Interim Report - Final

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Volume 1 – Hydropower Risks and Impact Mitigation Guidelines and Recommendations – Version 1.0

DOCUMENT HISTORY

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The Final 1st Interim Report constitutes 3 volumes:

Volume 1: Version 1.0 – Hydropower Risks and Impact Mitigation Guidelines and Recommendations

Volume 2: Version 1.0 – Hydropower Risks and Impact Mitigation MANUAL - Key Hydropower Risks, Impacts and Vulnerabilities and General Mitigation Options for Lower Mekong

Volume 3: Case Study – Objectives, Scope and Methodology

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PREFACE

This documents is the 1st Interim Report of the ISH0306 Mekong River Commission study - ***Development of Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries***. It builds on the work and results from inception period and the Inception Report (Volume 1 – 3) with emphasis in this 1st Interim Phase on developing; (i) Version 1.0 - Hydropower Risks and Impact Mitigation Guidelines and Recommendations (Volume 1) (ii) Hydropower Risks and Impact Mitigation MANUAL - Key Hydropower Risks, Impacts and Vulnerabilities and General Mitigation Options for Lower Mekong, as well as; (iii) Case Study – Objectives, Scope and Methodology for the 2nd Interim Phase (Volume 3). The study is supervised and coordinated by the Initiative on Sustainable Hydropower (ISH)/Mekong River Commission Secretariat (MRCS) with the following key personnel:

- Mr. Voradeth Phonekeo
- Mr. Simon Krohn and
- Mr. Piseth Chea

The project is executed by a team of experts from Multiconsult (Norway/UK) in association with Deltares (The Netherlands) plus two Key Experts on individual contracts (Australia and Austria). The following key-experts are involved:

- Mr. Leif Lillehammer (Team Leader, Multiconsult),
- Mr. Chris Grant (Hydropower Design and Operations Expert, Multiconsult),
- Mr. Jean-Pierre Bramslev (Hydropower Modeller and Economics Expert, Multiconsult),
- Mr. Ron Passchier (Hydrologist and Water Resources Modeller, Deltares),
- Dr. Kees Sloff (Hydraulic and Sediment Modelling Expert, Deltares),
- Dr. Lois Koehnken (Sediment and Water Quality Expert, Individual Consultant, Australia) and
- Dr. Stefan Schmutz (Fisheries and Aquatic Ecology Expert, BOKU - Vienna).

The team includes also the following non-key experts and support staff:

- Dr. Jørn Stave and Mr. Jens Johan Laugen (Environmental and Social Impact Assessment and Safeguards Experts, Multiconsult)
- Mr. Bjørn Stenseth (Power Economist, Multiconsult)
- Dr. Sanjay Giri (Hydraulic Expert, Deltares)
- Mrs. Carina Mielach (Aquatic Ecologist, BOKU-Vienna)
- Mr. Bernhard Zeiringer (Fish-Pass Eco-Engineer, BOKU-Vienna)
- Ms. Ragnhild Heimstad and Mr. Amrit Poudel (Terrestrial/Riparian Ecologists, Multiconsult)
- Mrs. Irene N. Koksæter (Livelihoods Expert, Multiconsult)

National Consultants also providing input to the study are as follows:

- Lao PDR: Ms. Thipsathiane Khamvongsa (Environment and Water Resources)
- Lao PDR: Mr. Lamphone Dimanivong (Hydropower and Energy)
- Cambodia: Dr. Sophal Chhun (Environment and Water Resources, Ecosystem Services)
- Cambodia: Dr. Heng Sokchay (Hydropower and Energy)
- Vietnam: Dr Nguyen Quang Trung (Environment and Water Resources)
- Vietnam: Dr. Hoang Minh Tuyen (Hydropower and Energy)

ABBREVIATIONS

ADB – Asian Development Bank

BDP – Basin Development Plan

BP – Bank Procedure (World Bank)

CIA – Cumulative Impact Assessment

CDP – Community Development Plan

ECAFE – United Nations Economic Commission for Asia

EMP – Environment Management Plan

ESMP – Environmental and Social Management Plan

ESIA – Environmental and Social Impact Assessment

IBRD – International Bank for Reconstruction and Development

IFC – International Finance Corporation

IHA – International Hydropower Association

ISH – Initiative on Sustainable Hydropower

IWRM – Integrated Water Resources Management

LMB – Lower Mekong Basin

MRC – Mekong River Commission

MRCS – Mekong River Commission Secretariat

MW - Megawatt

OD – Operational Directives

PDG – Preliminary Design Guidance

PES – Payment of Ecosystem Services

RAP – Ressetlement Action Plan

SEA – Strategic Environmental Assessment

ToR – Terms of References

UMB – Upper Mekong Basin

WB – World Bank

WCD – World Commission of Dams

1 Introduction

1.1 Description of, and how to use, this guidelines and supporting manual

This document is Version 1.0 of the **Hydropower Risks and Impact Mitigation Guidelines and Recommendation** (Volume 1 – 1st Interim Report) and follows due from the activities and outputs undertaken during the Inception and 1st Interim Periods of the ISH0306 Study. This Volume 1 is supported by Volume 2 which is the **Hydropower Risks and Impact Mitigation MANUAL** - Key Hydropower Risks, Impacts and Vulnerabilities and General Mitigation Options for Lower Mekong. The latter is a supporting document for this Volume 1, and goes much more in detail related to describing risks, impacts and vulnerabilities as well as in describing mitigation options. In Volume 2 there is also a wide array of examples of good industrial practise mitigation options internationally, from the Greater Mekong Sub-Region (GMS) and the Lower Mekong Basin (LMB). The manual is further supported by a **Knowledge Base** of data and document files. The guidelines, manual and knowledge base is to be further developed and refined in the 2nd Interim and Final Phases, and the architecture of the final output is described in Chapter 1.3.4.

This Version 1.0 of the **Hydropower Risks and Impact Mitigation Guidelines and Recommendation** constitutes a summary description of the overall basin and hydropower development on the Mekong (Chapter 1.2) before describing the ISH0306 project itself (Chapter 1.3). In Chapter 2 a more detailed description of the hydropower devevelopment is given covering both Lancang and the LMB, the latter also divided in mainstream and tributary developments. This development is the basis of the summary of the key LMB hydropower risks, impacts and vulnerabilities listed in Chapter 3. The hydropower risks, impacts and vulnerabilities identified is an extract from Volume 2, the Manual, and is dealth with in much more detail in the latter. Hencefort reference to the relevant section in Volume 2 is given. The hydropower risks, impacts and vulnerabilities identified constitutes 5 major themes, namely:

1. Hydrology and downstream flows
2. Geomorphology and sediments
3. Water quality
4. Fisheries and aquatic ecology; and
5. Biodiversity, natural resources and ecosystem services

For the thematic areas above a set of 5 key common overarching changes related to hydropower development has been identified, which are;

I. Annual / inter-annual changes to flow
II. Daily / short-time scale changes to flow and water level
III. Loss of river connectivity
IV. Impoundments
V. Diversion and intra basin transfers

Risks, impacts and vulnerabilities within each theme (1 to 5) for the changes (I to V) are then listed. The risks, impact and vulnerabilities chapter is the basis for the detailed mitigation guidelines, recommendations and options for LMB given in Chapter 5.3.

In Chapter 4, international practice policy and safeguards for mitigating hydropower risks and impacts relevant for LMB is described. These are not part of the **LMB Hydropower Risks and Impact Mitigation**

Guidelines and Recommendations itself (Chapter 5) but meant as supporting sustainable hydropower directions for the latter. Chapter 5 constitutes the following

- Overall guiding principles (Mekong 1995 Agreement, etc.)
- General principles and processes for sustainable hydropower development
- Detailed mitigation guidelines, recommendations and options for the LMB
- Enginering responses to environmental risks
- Indicators and monitoring
- Multicriteria evaluation of mitigation recommendations

The detailed mitigation guidelines, recommendations and options for the LMB builds on the risks, impacts and vulnerabilities as described in Chapter 3. Since many of the mitigation options are integral across themes (1 to 5) they are organized according to the overarching changes related to hydropower (I to V above), in order to avoid repetition. As for the risks, impacts and vulnerabilities the mitigation options are dealth with in much more detail in Volume 2, the Manual, including good industrial practice examples.

Lastly, in this Volume 1, Dam Safety Guidelines and Recommendations is given, which is stand alone related to the mitigation guidelines, albeit a specific delivery in the ToR of the ISH0306.

1.2 Overall Context and Background

1.2.1 Overall Basin Development Context

The Mekong Basin is home to some 70 million people, from which this great river is a source of livelihoods, the basis of their ecosystems and a foundation for their economies (Matthews and Geheb, 2015). With its extensive wetlands and floodplains, the basin supports the largest inland fisheries in the world with an annual catch of 2.6 million tonnes and over 500 000 tonnes of other aquatic annimals valued at between USD 3.9 – 7 million (Hortle, 2007).

MRC's "IWRM Strategic Directions" (2005) Eight priority IWRM key result areas:
- Economic development & poverty alleviation
- Environmental protection
- Social development and equity
- Dealing with climate variability
- Information based planning and management
- Regional cooperation
- Governance
- Integration through basin planning

The Mekong is one of the world's largest rivers ranking 12th in terms of length at 4880 km (Gupta and Liew 2007) and 8th in terms of mean annual discharge at the mouth, which is about 14 500 m^3/s (Meade, 1996; MRC 2005). It has a catchment area of 795 000 km2 within the six countries of China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam. The Mekong Basin has been commonly divided into Upper Mekong Basin (UMB-Lancang Jiang) and the Lower Mekong Basin (LMB). The UMB, in China, constitutes 24% of the total basin area whilst the LMB the rest (MRC-Planning Atlas, 2011).

The upper Mekong in China contributes to approximately 16% of the total flow in an average year, while 55% comes from the left bank tributaries in Lao PDR along with the Se Kong, Se San and Sre Pok (3S) River systems (Vietnam Central Highlands, Lao PDR and Cambodia. However, during the dry season, snowmealt from China contributes 24.1 % of the total flows (MRC, 2010; Pech, 2013).

Compared to other global regions in the world in terms of actual renewable water resources per capita, the Mekong basin is not water stressed. However a number of locations currently faces a series of critical water issues, such as (MRC, 2010; Pech, 2013):

- Water shortages in Thailand coupled with increasing irrigation water demands
- Increasing salinity intrusion in the Mekong delta in Vietnam
- Threats and declines in basin fisheries and the degradation of natural habitats in many parts of the basin
- Recurring un-seasonal floods and droughts
- Reduced water quality, land-subsistence and morphological changes in the floodplains and delta areas; and
- Intensification of sectoral competition within and amongst the Mekong countries

Concurrently, hydropower dams development is happening on Mekong mainstream and tributaries and will intensify in the near future. The critical water issues and hydropower dams development cater for cooperation on the Mekong and its resources. The history of cooperation on the Mekong is described in Chapter 1.1.2, whilst a brief description of the context of hydropower development on the Mekong is described in Chapter 1.1.3.

Figure 1.1. *Overview over Mekong and the LMB study area (Source: MRC, 2013 - ISH11 draft Phase 2 Report).*

1.2.2 *Mekong and its history of cooperation*

Agreements on utilization of the basin prescribes back to the 19th Century already with the 1856 Treaty of Friendship, Commerce and Navigation followed by the 1893 Treaty for Regulating the Position of the Kingdom of Cambodia. These agreements and subsequent treaties in 1926, 1937 and 1950 focused on the role of navigation and established the thalweg as the precise border between Thailand and Lao PDR. In 1950, France, Cambodia, Laos and Thailand signed an agreement to use the waters flowing in their territory for hydropower and irrigation, on condition that these interventions did not impact the legitimate interest of the other countries, or navigation. In 1957 the United Nations regional office in Bangkok, the United Nations Economic Commission for Asia and the Far East (ECAFE) studied the basins hydroelectric and irrigation potential and emphazised the need for cooperative development, including the establishment of a joint body for exchanging information and development plans between the riparian states. The same year Thailand, Laos, Cambodia, Vietnam and an observer from the United Nations Development Programme (UNDP) signed an agreement establishing the Committee for the Coordination of Investigations in the Lower Mekong Basin (Mekong Committee - MC). From the outset, the Mekong Committee's task was to promote, coordinate, supervise, and control water resources development projects in the Lower Mekong Basin. The hydropower development on Mekong progressed slowly, but the stage was set for its development to begin in earnest from the 1970s. The MC Indicative Basin Plan from this period recommended 180 possible hydropower projects in LMB, including 4 mainstream dams. In 1995 the Mekong River Commission was established with the Megong Agreement (Matthews and Geheb, 2015). The MRC's mandate was "*to cooperate in all fields of sustainable development, utilization, management and conservation of the water and related resources of the Mekong River Basin*" and "*to ensure reasonable and equitable use*" of the Mekong River System (MRC, 1995). Subsequent initiatives and programs has been initiated and implemented by MRC since its establishment in 1995, in which the Initiative for Sustainable Hydropower (ISH) is but one.

1.2.3 *Overall Context for Hydropower Development on the Mekong*

Situated within the water, food (fisheries, agriculture e.g.) and energy nexus hydropower can help meet the realities of climate change[1], and as a renewable energy it also contributes directly to a low carbon energy future. Hydropower's flexibility also supports the deployment of intermittent renewable energy sources such as wind and solar power. Multipurpose hydropower schemes can also support adaption to an increasingly difficult water resources situation by providing the means to regulate and store water to resist flood and drought shocks (WB, 2009). Thus, climate adaption in the Lower Mekong is essential for a safe, prosperous and sustainable future. Dealing with climate variability is also one of 8 priority areas in Mekong River Commission's (MRC) own "Integrated Water Resource Management Strategic Directions" (MRC, 2013).

Hydropower is recognized as an important development opportunity for the Mekong River Basin and the people living within it. As set out in the Mekong River Commission's Strategic Plan (2011 to 2015) and the Basin Development Plan (BDP, approved January 2011), the development of LMB should follow Integrated Water Resource Management (IWRM) principles. Within the IWRM context the need to improve the sustainability of the basin's hydropower developments is a key Strategic Priority. With the significantly increasing scale and prevalence of this energy option, all MRC member countries are taking steps to understand and employ sustainable hydropower considerations. The MRC Strategic

[1] E.g. changes in temperature, precipitation and runoff.

Plan has now been updated and a draft verion has been issued for the period 2016-2020 (MRC, 2015). The latter also includes a detailed roadmap for organisational reform of MRC and its functions currently under implementation.

Hydropower in the Mekong is embedded in a closely woven social and environmental fabric. The region's people derive a substantial proportion of their livelihood and nutrition from the tributaries and mainstream Mekong. Ecosystem services support the livelihood as well as a rich globally unique biodiversity. The planning and implementation of hydropower should aim to ensure that the livelihoods are preserved, enhanced and made resilient to adapt (amongst others through implementation of benefit sharing mechanisms[2]) and that the supporting biodiversity is maintained wherever possible (ToR).

Thus for the LMB sustainable hydropower development incorporating Good Industrial Practise for environmental impact mitigation and risk management is of critical importance for the future. The Good Industrial Practise covers assessments of risks and mitigation practises at various stages of the project life cycle, e.g. Strategic Environmental Assessments (SEA's) for multiple projects or plans at policy, program or regional levels (Keskinen and Kummu, 2010), Cumulative Impact Assessment (CIA) of cascades or catchment development and Environmental and Social Impact Assessments (ESIA's) for individual projects. Improving the effectiveness of these processes and highlighting risks and vulnerabilities is the subject of ongoing improvement efforts in responsible agencies, and hence the ISH0306 **Hydropower Risks and Impact Mitigation Guidelines and Recommendations** with its associated **Manual** and **Knowledge Base** will be a valuable tool at the local and regional level.

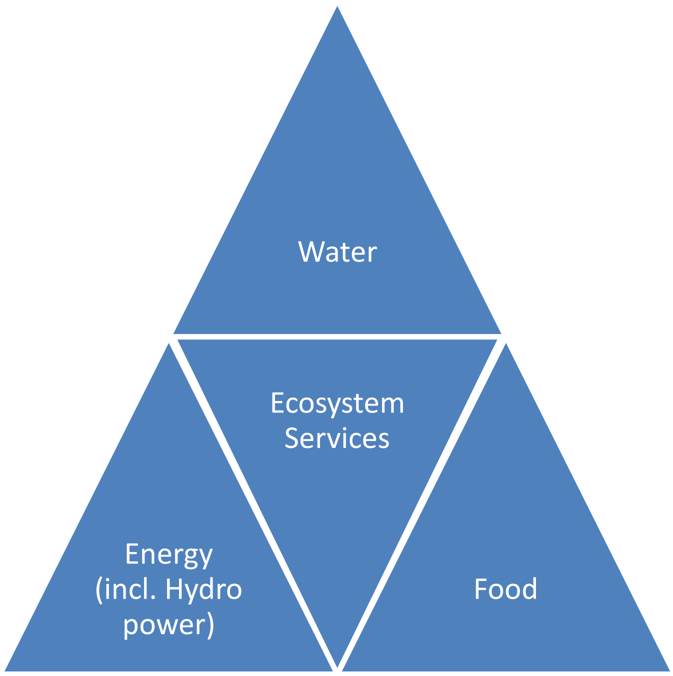

Figure 1.2. *The Water, Energy, Land Use/Agriculture Nexus (Adjusted from Lillehammer, 2013 and based on the Nexus approach).*

[2] Benefit sharing as defined by Lillehammer et al. 2011 – «A framework for governments and project proponents to maximize and distribute benefits across stakeholders, through relevant spatial and temporal scales by use of various mechanisms, and consistent with the principles of sustainability».

As there is multiple cascade developments planned or in operation in the LMB, developing risks and mitigation guidelines and recomemndations for these will be of high importance for the ISH0306, as this is currently lacking. Cumulative Impacts are impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project (Walker et al. 1999). Moreover, assessing and mitigating cumulative impacts implies more than just adding up all impacts from individual projects or developments, since interaction between them can be either synergistic, antagonistic or strictly additive (Marchand et al. 2014 and Bain et al. 1986).

Hydropower development on the Mekong is treated in more detail in Chapter 2.

1.3 Project Background, Objectives, Study Logical Framework and Scope of ISH0306

1.3.1 Project Background

The MRC has established the **Initiative for Sustainable Hydropower (ISH)** with the aim of seeking to embed sustainable hydropower considerations into the regulatory frameworks and planning systems of member countries and into project level planning, design, implementation and operational activities. The ISH 2011-2015 Strategy (MRC, 2010), followed up by the 2016-2020 Strategy, emphasizes this requirement as well as the need to understand the scale and distribution of risks associated with hydropower development on the main stream and tributaries. In addition, the Strategy seeks the exploration and documentation of possible avoidance, mitigation as well as benefit and risk sharing options. Necessary frameworks must be in place to provide assurance that risks can be effectively minimized.

In this context ISH is seeking to enhance the **Preliminary Design Guidance** for Mainstream Dams (PDG) and to provide more effective and detailed documentation of the options and methods that may be used to cover the mitigation of hydropower risks in the Mekong (the PDG is described in Chapter 5.1.4 of this document). This will be based on the latest research and practice from around the world and the region. In addition the MRC is seeking to expand the applicability of these Guidelines to the tributary developments (as set out in the MRC Strategy 2011-2015).

The MRC/ISH will work with developers and implementing agencies to get industry support for these methods. The ISH0306 work specifically supports the ISH Goal, which is aimed at ensuring:

"……. **Sustainable hydropower practices are employed in project-level hydropower planning, preparation, design, implementation and operation practices.***"*

This will be undertaken in a manner that accords with national policies and regulations and is realistic about likely capacities to implement such approaches within existing project implementation.

1.3.2 Objectives

The overall goal of the study has been outlined in the ToR and is embedded in the Mekong Vision of *an economically prosperous, socially just and environmentally sound Mekong River Basin* and reads as follows:

"Development of relevant measures and guidelines for hydropower impact mitigation and risk management in the Lower Mekong mainstream and tributaries"

The specific objectives of the study thus are to:

- Thoroughly document regionally relevant hydropower impact avoidance, minimisation and mitigation options for development of hydropower on the Mekong mainstream and tributaries;
- Scope and commission specific research to improve technical and scientific understanding towards improved mitigation options and the adaptation of existing methods to the region; and
- Document in consultation with regional agencies and developers engineering and scientific options, for the avoidance, minimisation and mitigation of risks of mainstream hydropower dams.

1.3.3 Study Logical Framework and Scope

The study logical framework and thematic scope is henceforth to:

- Understand the baseline natural resource processes in the Mekong Basin and the nature of hydro developments proposed;
- Describe the potential impacts of these developments as assessed by existing studies;
- Research regional and global experience on mitigation options for these Mekong hydropower developments;
- Undertake analysis and research into the effectiveness of these mitigation options;
- Make recommendations on improvements and approaches to impact mitigation;
- Commission further research to cover significant knowledge gaps;
- Provide mitigation guidelines and a substantial knowledge base on mitigation approach and solutions based on research and case studies. These will be made suitable for dissemination through the MRC web site or other media; and
- Build capacity in all areas of assessment avoidance, minimization and mitigation options within industry and line agencies.

The geographic scope is twofold:

1. The mitigation guidelines and recommendations will be developed to be generally applicable at basin level for the Lower Mekong mainstream and its tributaries.
2. A more detailed assessment will be undertaken related to the applicability and operational implications of the mitigation guidelines for 5 mainstream cascade dams north of Vientiane.


Photo: Lois Koehnken

The ***main output*** of the ISH0306 study is the **Hydropower Risks and Impact Mitigation Guidelines and Recommendations** (this Volume 1) that builds especially on the PDG but also other MRC initiatives. Version 1.0 of these guidelines (this Volume, with its supporting Manual in Volume 2) is the main deliverable of the 1st Interim Phase. These guidelines will be further developed, tested and detailed during the next two phases of the study (2nd Interim and Final Phases). Version 1.0 includes guidelines and recommendations on fisheries and aquatic ecology, geomorphology and sedimentation, water quality, environmental flows, biodiversity and natural resources, ecosystem services and engineering response to environmental risks, amongst others.

1.3.4 Overall Architecture of Final Output

The proposed basic architecture of the **Hydropower Risks and Impact Mitigation Guidelines and Recommendations** and supporting **Manual,** to be delivered after the 2nd Interim and Final Phases is outlined below. The **final** manual will also be web-based and interactively linked to the data, documentation and literature in the supporting **Knowledge Base**.

1. Hydropower Risks and Impact Mitigation Guidelines and Recommendations

- This will be an extended and refined document of this Version 1.0, and will also include descriptions of suitable stakeholder involvement during the different phases of the HPP project cycle.

2. Manual (Plannng Kit) to support implementation of Guidelines

- Manual overview (description of contents, purpose and how to use the manual)
- Thematic overview of status, risks and mitigations
  - Hydrology and downstream flows
  - Geomorphology and sediments
  - Water quality
  - Fisheries and aquatic ecology
  - Biodiversity, natural resources and ecosystem services
  - Links to livelihood
- Engineering response to environmental risks
- Description of approach on how to choose the most tailored and right mitigation options for LMB, including multicriteria evaluation options
- Examples and experiences of good industrial practice internationally on mitigation guidelines and recommendation suitable for the LMB.
- Description on how the mitigation selection process will be linked and supported by the knowledge base
- Description of what kind of broad type of models is needed for evaluating and quantifying risks and impacts and the associated mitigation.
- Needs for capacity building and training.

3. Knowledge Base

- Reference list plus all data and documents grouped and organized according to the Chapters and main themes and issues in the Manual.

2 Hydropower Development on the Mekong

2.1 Lancang River

2.1.1 Introduction

The upper reach of the Mekong River rises as the Zaqu River on the Tibetan Plateau in Qinghai province, China and flows through the Tibetan Autonomous Region and then through the Yunnan Province as the Lancang River until it arrives at the meeting point of the borders of Burma, Laos and China.

Figure 2.1 identifies the majority of locations of existing and planned hydropower projects on the mainstream of the Lancang (Zaqu) River. The approximate number of hydropower projects under construction, planned and in operation on the Lancang River in China are summarised in Table 2.1 and are listed in greater detail in Table 2.2.

Table 2.1. *Existing, under construction and planned hydropower schemes per province.*

Province	Existing, Under Construction & Planned Hydropower Schemes (No.)
Qinghai, China	10
Tibet Autonomous Region	13
Yunnan, China	14
Total	**37**

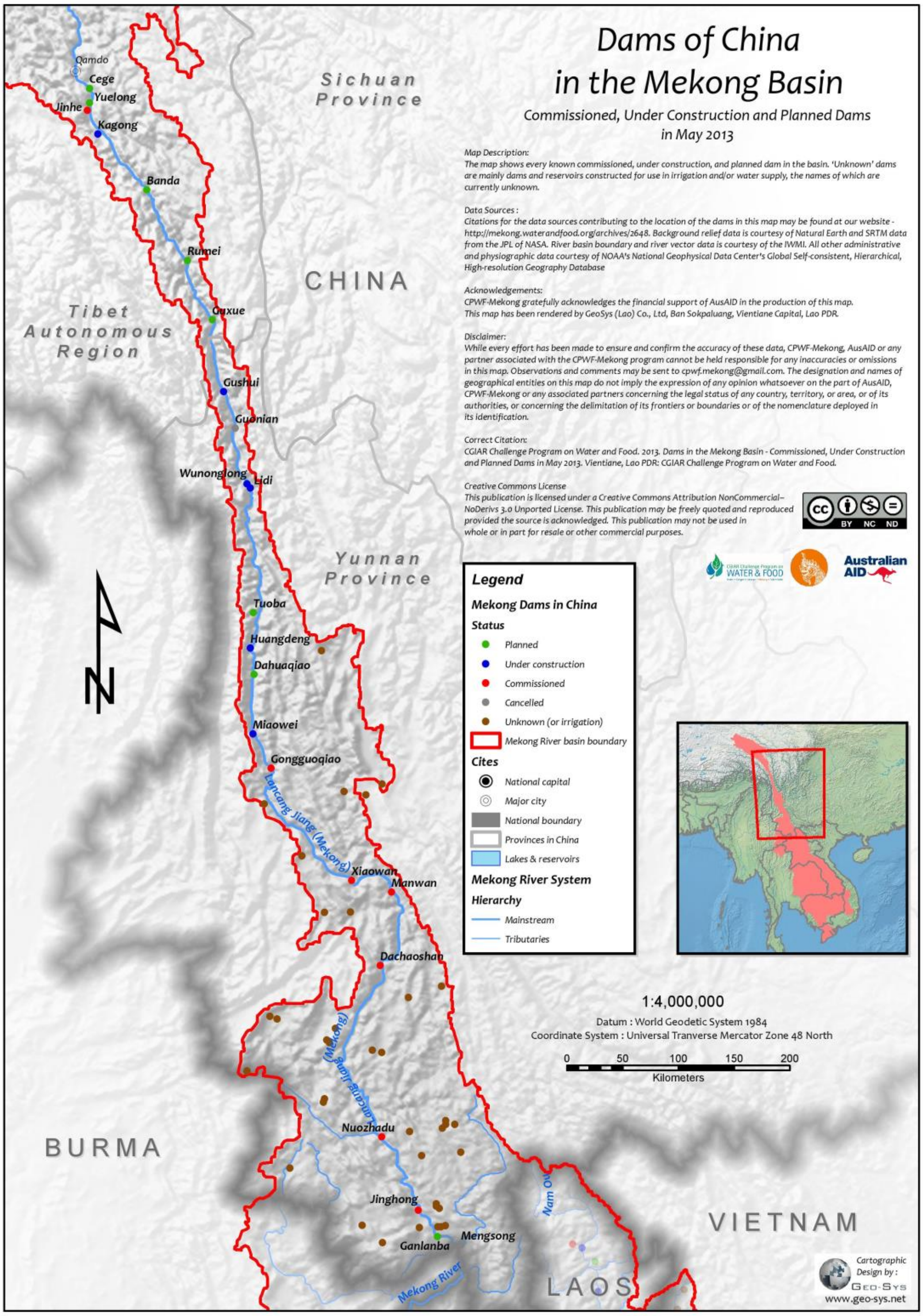

Figure 2.1. *Hydropower Projects Planned, under Construction or in Operation on the Lancang River.*

2.1.2 Lancang River Hydropower Schemes

A summary of the hydropower projects that are planned, under construction or in operation is presented in Table 2.2. (Ref: Major Dams in China, International Rivers, November 2014, combined with information from the same document dated 2012; 2013 Update: Dams on the Drichu (Yangtze), Zachu (Mekong) and Gyalmo Ngulchu (Salween) rivers on the Tibetan Plateau; and Dams and Development in China: The Moral Economy of Water and Power).

Table 2.2. *Planned or constructed hydropower schemes on Lancang River, China and Tibet Autonomous Region.*

Name of Project	Province, Country	Status	Installed Capacity (MW)
Ganlanba	Yunnan, China	Operational	155
Jinghong	Yunnan, China	Operational	1750
Nuozhadu	Yunnan, China	Operational	5850
Dachaoshan	Yunnan, China	Operational	1350
Manwan	Yunnan, China	Operational	1500
Xiaowan	Yunnan, China	Operational	4200
Gongguoqiao	Yunnan, China	Operational	900
Miaowei	Yunnan, China	Under Construction	1400
Dahuaqiao	Yunnan, China	Under Construction	920
Huangdeng	Yunnan, China	Under Construction	1900
Tuoba	Yunnan, China	Planned	1400
Lidi	Yunnan, China	Under Construction	420
Wunonglong	Yunnan, China	Under Construction	990
Gushui	Yunnan, China	Planned	1800
Baita	Tibet Autonomous Region	Planned	Unknown
Guxue	Tibet Autonomous Region	Site Preparation	2400
Bangduo	Tibet Autonomous Region	Under Active Consideration	Unknown
Rumei	Tibet Autonomous Region	Site Preparation	2400
Banda	Tibet Autonomous Region	Site Preparation	1000
Kagong	Tibet Autonomous Region	Site Preparation	240
Yuelong	Tibet Autonomous Region	Planned	100
Cege	Tibet Autonomous Region	Planned	160
Linchang	Tibet Autonomous Region	Planned	72
Ruyi	Tibet Autonomous Region	Planned	114
Xiangda	Tibet Autonomous Region	Planned	66
Guoduo	Tibet Autonomous Region	Under Construction	165
Dongzhong	Tibet Autonomous Region	Planned	108
Niangla	Qinghai, China	Unknown	Unknown
Zhaqu	Qinghai, China	Operational	Unknown
Gongdou	Qinghai, China	Unknown	Unknown
Dariaka	Qinghai, China	Unknown	Unknown

Name of Project	Province, Country	Status	Installed Capacity (MW)
Atong	Qinghai, China	Unknown	Unknown
Angsai	Qinghai, China	Planned	55
Saiqing	Qinghai, China	Unknown	Unknown
Longqingxia	Qinghai, China	Operational	2.5
Aduo	Qinghai, China	Unknown	Unknown
Shuiasai	Qinghai, China	Unknown	Unknown
		Total	**31467.5**

The scale and pace of the exploitation of Lancang River for its hydropower potential has gained momentum since the 1980's. As noted from Table 2.2, there are nine operational schemes with combined installed capacity of 15,757.5 MW, and a further six schemes with a combined installed capacity of 5,795 MW under construction. In addition there are four schemes where site preparation has commenced with a combined installed capacity of 6,040 MW.

There are approximately eight hydropower projects in the Qinghai province of China currently planned. Two further hydropower projects, Zhaqu and Longqingxia, are operational. In Tibet Autonomous Region, there are approximately 13 hydropower projects, of which one is currently under construction. Construction of the 165 MW Guoduo hydropower project is planned to be completed in 2015. The 240 MW Kagong hydropower project is reported to be commencing site preparation.

Reliable information concerning hydropower development in the upstream reach of the Lancang River, both in Tibet Autonomous Region, and Qinghai province of China, is difficult to obtain. There are approximately seven projects with an unknown status and installed capacity.

In China, hydropower is promoted as the best possible alternative to coal-fired power stations. It is intended that hydropower development will significantly contribute to the target of 15 % of renewable energy by 2020.

The main operational hydropower schemes on the Lancang River are reported from various sources to be as follows:

Jinghong Dam

The Jinghong Dam hydropower project is located in the southern part of Yunnan Province, China. The project is designed for power generation but also for flood control and navigation purposes. The construction of the scheme started in 2005, with the first unit entering commercial operation in 2008. The project was reported to be fully operational in 2009.

The scheme has an installed capacity of 1,750 MW, and comprises the following main structures:

- Main Dam (RCC gravity dam, 704.5 m long and 108 m high).
- Power house containing 5 x 350 MW Francis turbine generator units
- Spillway structure
- Ship lock

Figure 2.2. *Jinghong Dam (Source www.flickr.com).*

Nuozhadu Hydropower Project

The Nuozhadu hydropower project is located in the Yunnan Province of China. The project is designed mainly for power generation but also fulfils multifunctional purposes such as flood control and improvement of downstream navigation. The scheme has an installed capacity of 5,850 MW, which is reported to be the largest hydropower station along the Lancang River and in Yunnan Province. The project comprises the following main structures:

- Main Dam (central core rockfill dam, 608 m long and 261.5 m high).
- Power house containing 9 x 650 MW turbine generator units
- Gated side channel spillway.

The scheme has been operational since 2012, with the last unit commissioned in 2014. The reservoir created by the dam allows for major seasonal regulation.

Figure 2.3. *Nuozhadu Hydropower Project (Source www.flickr.com).*

Dachaoshan Hydropower Project

The Dachaoshan hydropower project, located on Lancang River, Yunnan province, is a single purpose project for power production. The project has an installed capacity of 1,350 MW and commenced commercial operation in 2003. The project comprises the following main structures:

- Main Dam (RCC gravity dam, 460 m long and 111 m high).
- Power house containing 6 x 225 MW Francis turbine generator units
- Crest overflow gated spillways

Figure 2.4. *Dachaoshan Hydropower Project (Source www.flickr.com).*

Manwan Hydropower Project

The Manwan hydropower project, located on Lancang River, has an installed capacity of 1,500 MW and comprises the following main structures:

- Main Dam (concrete gravity dam, 418 m long and 132 m high).
- Power house containing 5 x 250 + 1 x 300 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

The Manwan Hydropower Station began operation in 1996 and has been subject of extensive studies as the first large scale hydropower station on the Lancang River.

Figure 2.5. *Manwan Hydropower Project. (Source: www.flickr.com).*

Xiaowan Hydropower Project

The Xiaowan hydropower project is a significant component of the Lancang River cascade. Its main purpose is electricity generation. It is the world's second highest arch dam at 292 m and it creates a large reservoir which is acting as a sediment retention buffer for the Manwan and Dachaoshan hydropower projects. The Xiaowan hydropower project has an installed capacity of 4,200 MW, and comprises the following main structures:

- Main Dam (double curvature arch dam, 902 m long and 292 m high).
- Power house containing 6 x 700 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

The construction of the scheme commenced in 2002. The first unit entered commercial operation in 2009 and last unit was commissioned in 2010. The size of the reservoir created by the dam allows for major seasonal regulation.

Figure 2.6. *Xiaowan Hydropower Project. (Source: Mekong River Commission).*

Gongguoqiao Dam

The 900 MW Gongguoqiao hydropower project comprises the following main structures:

- Main Dam (gravity, roller compacted concrete dam, 356 m long and 105 m high).
- Power house containing 4 x 225 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

Figure 2.7. *Gongguoqiao Dam (Source: www.flickr.com).*

The construction of the project started in 2008 and the scheme commenced commercial operation in 2011. The last unit was commissioned in 2012.

2.1.3 Implications of Hydropower Development on the Lancang River

The development of hydropower projects on the Lancing River has implications for the Mekong River downstream. However, the impact on average flow diminishes strongly downstream as the overall contribution of the Lancang to the Mekong at the delta is only approximately 16%.

Changes in flow due to the Lancang cascade may include:

- Peak flows decreased and lower annual flood volumes,
- Early flood season flows lower and later flood season flows higher,
- Later start and end of flood season conditions, and
- Increased dry season flows.

As an example, estimates for the change of flows for Chiang Saen (Northern Thailand), downstream of Lancang cascade, are 17-22% decrease in flow in June – November, and 60 – 90% increase in flow in December – May. The estimates for Kratie (Cambodia) are 8 – 11% decrease in flow in June – November, and 28 – 71 % increase in flow in December – May (Source: Mekong River Commission).

Although the annual average flows may not vary substantially, monthly and shorter time-frame changes in flow have an impact on fisheries and sediment transport. There are concerns about sediment transport and possible impacts of the dams due to sediment trapping for the Lower Mekong Basin. The river channel is responding to reduced sediment input, altered timing of flows and altered timing of sediment delivery, including increased bank erosion or channel incision, loss of riparian vegetation, increased exposure of bedrock or armouring of riverbed.

Furthermore, the water quality risks due to hydropower development on the Lancang River include nutrient growth in impoundments due to increased nutrients and light, low dissolved oxygen in impoundments and increased water temperature downstream. Water quality in Lancang reservoirs is further affected by land use as run off from rubber plantations, mining and possible increase of agricultural opportunities due to the access to water for irrigation purposes.

As an example of sedimentation on Lancang cascade, a bathymetric survey was conducted for the Manwan dam in 1996 (3 years after the closure of the dam), which showed that the elevation of the bottom of the reservoir was 30 m higher than when the dam was constructed. Since then, the Xiaowan dam, impounding a large reservoir upstream of Manwan, has been constructed, and the sediment load incoming to the Manwan reservoir has been greatly reduced. It is noted, however, that water quality has improved through co-operative operation of Manwan and Dachaoshan Dams.

The reduction in sediment load, altered timing of sediment delivery and delayed onset of flood are representing challenges for mitigation in the Lower Mekong Basin. The flow regime and sediment timing of mainstream are going to be further altered by tributary hydropower developments.

The impacts of Lancang development on fisheries and aquatic ecology are mainly due to connectivity interruptions, impoundments, sedimentation, hydrological and water quality alterations and possible cumulative impacts.

2.2 Lower Mekong Basin

2.2.1 Introduction

The lower Mekong Basin downstream of the Chinese border comprises the majority of the land area of Lao PDR and Cambodia, the northern and northeast regions of Thailand and the Mekong Delta and Central Highland regions of Viet Nam.

Figure 2.8 identifies the majority of locations of existing and planned hydropower projects on the mainstream of the lower Mekong Basin and its tributaries. With reference to Figure 2.2 and data obtained from the Lao PDR Ministry of Energy and Mines, the approximate number of existing and planned hydropower projects per country is presented in Table 2.3. It is evident from Table 2.3 that the majority of hydropower projects in the lower Mekong Basin are located in Lao PDR.

Existing and planned hydropower projects

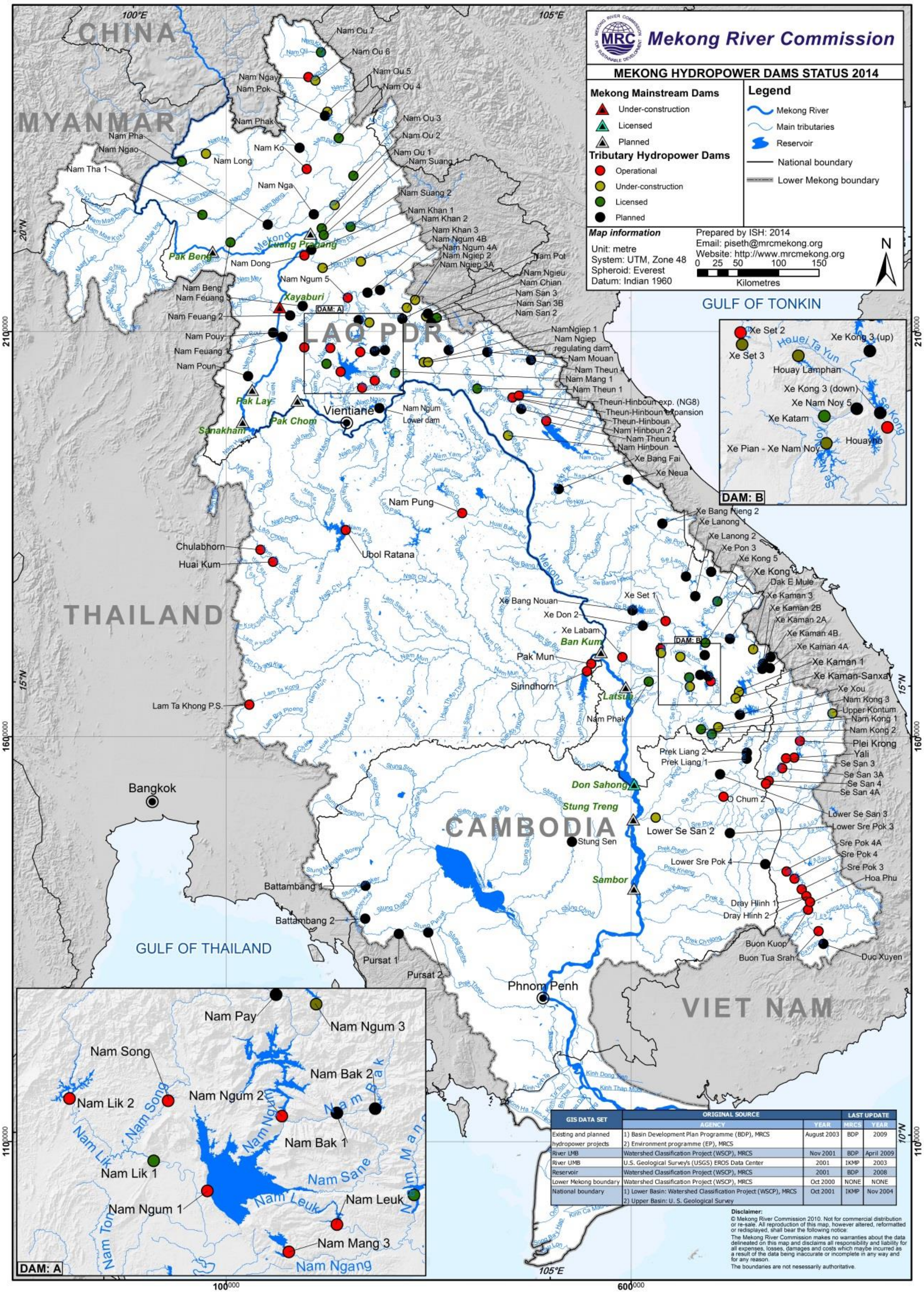

Figure 2.8. *Hydropower Dams (operational, under construction, licensed and planned) on the Lower Mekong mainstream and tributaries (Source: Mekong River Commission ISH).*

Table 2.3. *Lower Mekong Basin Existing and Planned Hydropower Schemes.*

Country	Existing & Planned Hydropower Schemes (No.)
Lao PDR	135
Viet Nam	16
Thailand	7
Cambodia	6
Total	**164**

2.2.2 Lower Mekong Basin – Mainstream

Proposed dams on the lower mainstream Mekong are listed in Table 2.4 and identified in Figure 2.8. Of these, ten would involve construction of dams across the entire river channel, eight within Lao PDR and two in Cambodia. The Don Sahong project within Lao PDR will involve commanding only the Hou Sahong Channel leaving the other channels of the Mekong at Kone Falls uninterrupted.

Table 2.4. *Mainstream Hydropower Schemes.*

Name of Project	Country	Status	Installed Capacity (MW)
Pak Beng	Lao PDR	Planned	1,230
Luang Prabang	Lao PDR	Planned	1,410
Xayaburi	Lao PDR	Under construction	1,285
Pak Lay	Lao PDR	Planned	1,320
Sanakham	Lao PDR	Planned	660
Pak Chom	Lao PDR	Planned	1,079
Ban Khoum	Lao PDR	Planned	2,000
Pou Ngoy (Lat Sua)	Lao PDR	Planned	651
Don Sahong	Lao PDR	Licensed	260
Stung Treng	Cambodia	Planned	980
Sambor	Cambodia	Planned	460
		Total	**11,335**

(Ref DEB July 2015)

2.2.3 Lower Mekong Basin – Tributaries

Hydropower schemes on the tributaries of the lower Mekong have been identified in relation to the catchments within which they are located and for clarity Figure 2.9 shows the many catchments that make up the lower Mekong basin.

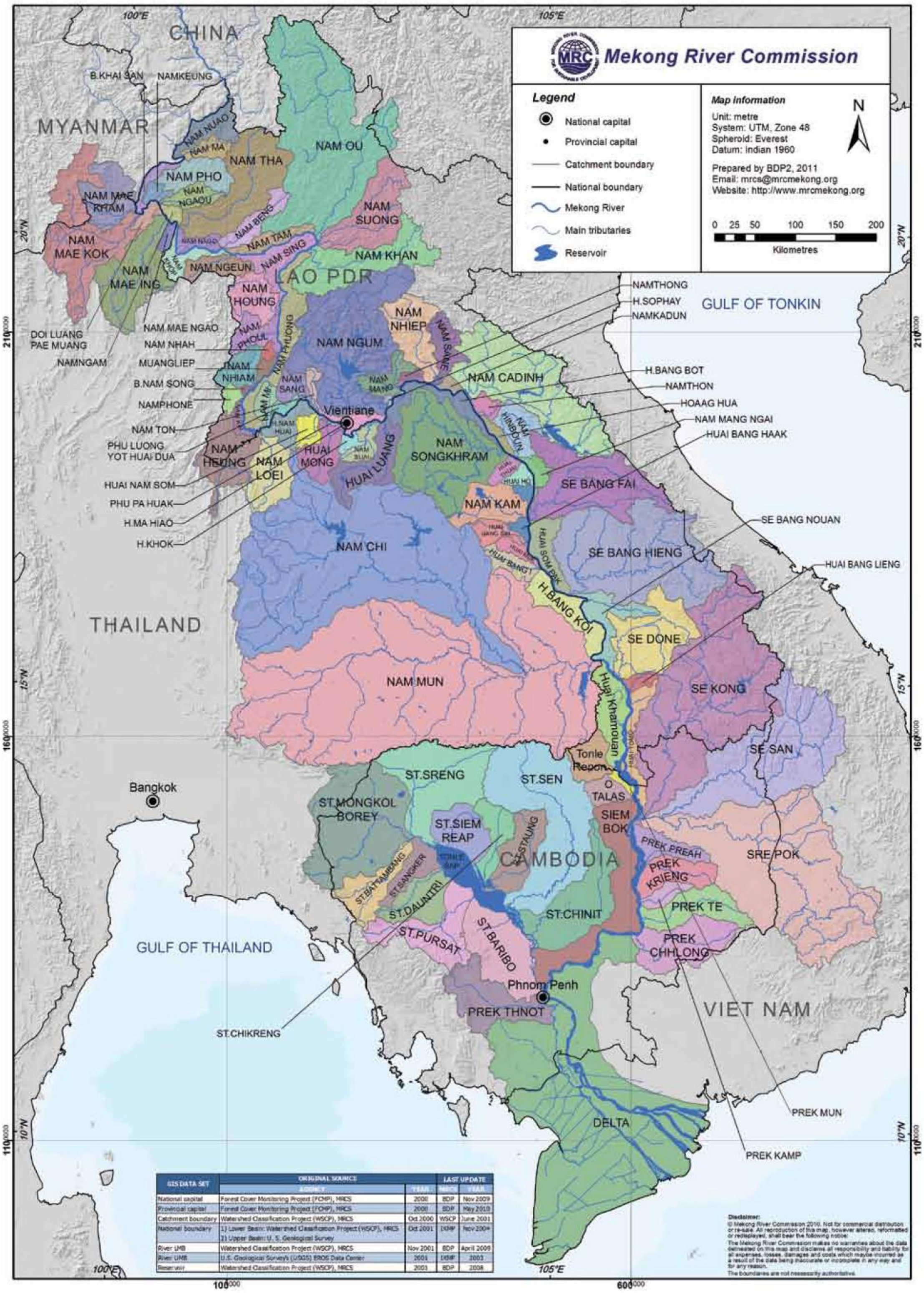

Figure 2.9. *Catchments of the Lower Mekong Basin (Source: Mekong River Commission Planning Atlas).*

Tributary hydropower schemes have been classified as either operational, under construction or licensed/planned. Tables 2.5 and 2.6 present schemes that are classified as operational or under construction. These have been arranged by catchment. Data has been sourced from Lao PDR Ministry of Energy and Figure 2.8.

Table 2.5. *Operational Hydropower Projects on Mekong Tributaries (2014).*

Catchment	Name of Project	Country	Installed Capacity (MW)
Nam Ma	Nam Long	Lao PDR	5
Nam Tha	Nam Nhone	Lao PDR	3
Nam Ou	Nam Ko	Lao PDR	2
	Nam Ngay	Lao PDR	1
Nam Khan	Nam Mong	Lao PDR	1
	Nam Dong	Lao PDR	1
Nam Ngiep	Nam Ngiep 3A	Lao PDR	44
Nam Mang	Nam Mang 3	Lao PDR	40
	Nam Leuk	Lao PDR	60
Nam Ngum	Nam Ngum 1	Lao PDR	155
	Nam Ngum 2	Lao PDR	615
	Nam Ngum 5	Lao PDR	120
	Nam Lik 2	Lao PDR	100
	Nam Song	Lao PDR	6
Nam Kading	Nam Theun 2	Lao PDR	1,080
	Theun-Hinboun	Lao PDR	220
	Theun-Hinboun Expansion	Lao PDR	280
Xe Bang Hieng	Tad Salen	Lao PDR	3
Xe Done	Xe Set 1	Lao PDR	45
	Xe Set 2	Lao PDR	76
	Xe Labam	Lao PDR	5
Xe Kong	Houay Ho	Lao PDR	152
	Xe Kaman 3	Lao PDR	250
Se San	O Chum 2	Cambodia	1
	Plei Krong	Viet Nam	100
	Yali	Viet Nam	720
	Se San 3	Viet Nam	260
	Se San 3A	Viet Nam	96
	Se San 4	Viet Nam	360
	Se San 4A	Viet Nam	63
Sre Pok	Sre Pok 3	Viet Nam	220
	Sre Pok 4	Viet Nam	80
	Sre Pok 4A	Viet Nam	64
	Hoa Phu	Viet Nam	29
	Dray Hinh 1	Viet Nam	12
	Dray Hinh 2	Viet Nam	16
	Buon Kuop	Viet Nam	280
	Buon Tua Srah	Viet Nam	86
Nam Kan	Nam Pung	Thailand	6
Nam Mun	Pak Mun	Thailand	136
	lam Ta Khong P.S.	Thailand	500
	Sirindhorn	Thailand	36

Catchment	Name of Project	Country	Installed Capacity (MW)
Nam Chi	Chulabhorn	Thailand	40
	Huai Kum	Thailand	1
	Ubol Ratana	Thailand	25
Unknown	Nam Ken	Lao PDR	3
		Total	**6,399**

Table 2.6. *Hydropower Projects Under Construction on Mekong Tributaries (2014).*

Catchment	Name of Project	Country	Installed Capacity (MW)
Nam Pho	Nam Pha	Lao PDR	130
Nam Tha	Nam Tha 1	Lao PDR	168
Nam Beng	Nam Beng	Lao PDR	34
Nam Ou	Nam Phak	Lao PDR	45
	Nam Ou 2	Lao PDR	120
	Nam Ou 5	Lao PDR	240
	Nam Ou 6	Lao PDR	180
Nam Khan	Nam Khan 2	Lao PDR	130
	Nam Khan 3	Lao PDR	95
Nam Ngiep	Nam Ngiep regulating dam	Lao PDR	0
	Nam Ngiep 1	Lao PDR	290
	Nam Ngiep 2	Lao PDR	180
Nam Mang	Nam Mang 1	Lao PDR	64
Nam Ngum	Nam Bak 1	Lao PDR	163
	Nam Lik 1	Lao PDR	61
	Nam Phay	Lao PDR	86
Nam San	Nam San 3A	Lao PDR	69
	Nam San 3B	Lao PDR	45
	Nam Chien	Lao PDR	104
Nam Hinboun	Nam Hinboun	Lao PDR	30
Se Kong	Xe Pian & Xe Namnoy	Lao PDR	390
	Xe Kaman 1	Lao PDR	322
	Nam Kong 1	Lao PDR	150
	Nam Kong 2	Lao PDR	66
Se San	Lower Se San 2	Cambodia	400
	Upper Kontum	Viet Nam	220
Unknown	Nam Sim	Lao PDR	8
		Total	**3,790**

In addition to schemes that are operational or under construction, there are in excess of 70 schemes planned for development on the tributaries of the Mekong. Seven planned schemes are known to be licensed with the largest, Nam Theun 1, having a planned installed capacity of 523 MW.

3 Key Lower Mekong Basin Hydropower Risks, Impacts and Vulnerabilities

This chapter summarizes the Key LMB Hydropower Risks, Impacts and Vulnerabilitie related to the hydropower development described in Chapter 2. It is treated in more detail in Volume 2, the Manual, for each thematic area (hydrology and downstream flows, geomorphology and sediments etc.). Most of the key risks, impacts and vulnerabilities are also repeated in the tables in Chapter 5, the **Hydropower Risk and Impact Mitigation Guidelines and Recommendations**, with its associated mitigation options. For all the thematic areas below, a set of 5 key common potential overarching changes related to hydropower development has been identified, which are;

1. Annual / inter-annual changes to flow
2. Daily / short-time scale changes to flow and water level
3. Loss of river connectivity
4. Impoundments
5. Diversion intra basin transfers

Within these major changes a set of sub-changes (left column) for each thematic area has also been identified. The associated risks, imacts and vulnerabilities are associated with these changes.

Table 3.1. *Hydrology and downstream flows – Key risks, impacts and vulnerabilities (see Chapter 2 in Volume 2 for details).*

Change	Key Risks, Impacts & Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality & continuous uniform release	Change of timing & duration of floods and low flows, changes in flows Tonle Sap and changes in salt intrusion in the delta
Modification of flood intervals: Reduction in occurrence of minor floods & no change in large events	Peaks in flood and low flow change, smoother hydrograph
Daily / short-time period changes in flow	
Hydro-peaking	Safety and navigation related changes caused by sudden rise or drop of water levels

Table 3.2. *Geomorphology & sediments – Key risks, impacts and vulnerabilities (see Chapter 3 in Volume 2 for details).*

Change	Key Risks, Impacts & Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality & continuous uniform release	Water logging & loss of vegetation leading to increased bank erosion Increased erosion due to increased scour (bed incision, bank erosion)
	Winnowing of smaller sediment leading to bed armouring & reduction in downstream sediment supply
	Bank scour focussed over limited range leading to increased bank erosion

Change	Key Risks, Impacts & Vulnerabilities
Modification of flood intervals: Reduction in occurrence of minor floods & no change in large events	Channel narrowing through encroachment of vegetation Increased risk in upstream of flooding and floodplain stripping during large (>1:10 ARI) flood events
Change in relationship of flow & sediment transport	Decoupling of tributary & mainstream flows Erosion and / or deposition due to tributary rejuvenation
Daily / short-time period changes in flow	
Hydro-peaking	Rapid wetting & drying of banks increases susceptibility to bank erosion and seepage processes
	Increase in shear stress during flow changes increases erosion and bed incision
Loss of river connectivity	
Disconnect between flow and sediment delivery	Sediment availability not timed with periods of recession leading to decreased deposition
	Loss of sediment 'pulse'
Creation of impoundments	
Trapping of sediments	Reduction in sediment availability downstream of dam leading to increased erosion
	Changes to the grain-size distribution of sediment downstream contributing to channel armouring and alteration of habitats
Water level changes within impoundment	Lake bank erosion, increased risk of landslips
Diversions or intra basin transfers	
Decreased flow in donor basin	Channel narrowing due to vegetation encroachment
	Armouring of beds and bars due to reduced sediment transport
	Decrease in frequency of high flow events increases impacts of extreme events (upstream flooding, floodplain stripping)
Increased flow in receiving basin	Increased bank erosion and bed incision to accommodate increased flow

Table 3.3. *Water Quality – Key risks, impacts and vulnerabilities (see Chapter 4 in Volume 2 for details).*

Change	Key Risks, Impacts & Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality & continuous uniform release	Changes / loss of seasonal temperature patterns downstream
Change in relationship between flow and sediment delivery	Increased water clarity increasing risk of algal growth Increased water clarity increasing water temperature

Change	Key Risks, Impacts & Vulnerabilities
Daily / short-term changes in flow	
Hydro-peaking or fluctuating discharge	Fluctuating water quality including increase in variability of temperature and nutrients
	Altered concentrations of downstream discharges or inputs
Loss of river connectivity	
Changes to nutrient transfer	Trapping of nutrients within impoundment leading to change in downstream delivery
Creation of impoundments	
Conversion of river to lake	Lake stratification leading to low dissolved oxygen bearing water and release of nutrients, metals or pollutants from sediments
	Increased water clarity in lake increases risk of algal blooms
	Temperature change in lake (warmer or cooler)
	DO and temperature of discharge affected by impoundment – Low DO or high gas supersaturation
Diversions or intra basin transfers	
Diversion of water from one catchment to another	Change in nutrient and other water quality parameters in both donor and receiving catchments

Table 3.4. *Aquatic ecology and fisheries – Key risks, impacts and vulnerabilities (see Chapter 5 in Volume 2 for details).*

Change	Key Risks, Impacts & Vulnerabilities
Annual / inter-annual changes to flow	
Change	Key Risks, Impacts & Vulnerabilities
Changes in seasonality (delayed floods, increase of dry and decrease of wet season flows)	Morphological alterations and habitat loss
	Loss of migration/spawning triggers
	Loss of productivity due to reduced flood pulse (increase in permanently flooded and decrease in seasonally flooded area).
	Stress due to water quality changes
Daily / short-time period changes in flow	
Fast increase of flow velocity	High drifting rate of fish and macroinvertebrates; offset of migration triggers
Fast decrease of flow velocity	Stranding of fish and macroinvertebrates
Morphological alterations	Bank erosion, increased erosion and bed incision causes habitat degradation
Thermopeaking	Stress, disturbance/ offset of migration triggers.
Barriers/ loss of river connectivity	
Disconnect between flow and sediment delivery	Morphological alterations, habitat loss
Habitat fragmentation	Blocked spawning and feeding migrations, isolation of sub-populations
Turbine passage	Fish damage and kills

Change	Key Risks, Impacts & Vulnerabilities
Spillflow passage	Fish damage and kills
Creation of impoundments	
Trapping of sediments	Morphological alteration and habitat loss. Upstream: filling up of deep pools, reduced vertical connectivity, Downstream: loss of habitat structures (sand bars), reduced connectivity to tributaries and floodplains (incision).
Loss of free flowing river sections	Delay/ deposition of drifting eggs & larvae
	Loss/ reduction of fish species adapted to free flowing rivers
	Loss of orientation for upstream migrating fish
Increased visibility	Algae growth and changes in temperature, oxygen
Stratification & temperature changes	Stress due to water quality changes (temperature, oxygen)
Water level changes within impoundment	Stranding of fish and macroinvertebrates
Reservoir flushing	Fish damage and kills; alteration of habitats
Diversions or intra basin transfers	
Reduction of river dimension	Reduced productivity, species alteration (e.g. loss or large species), reduced depth may impact connectivity, water quality changes
Homogenisation of flows	Armouring of beds and bars due to reduced sediment transport. Habitat loss
Increased flow in receiving basin	Increased bank erosion and bed incision to accommodate increased flow
Water quality changes	Stress

Table 3.5. *Biodiversity, natural resources and ecosystem services- Key risks, impacts and vulnerabilities (see Chapter 6 in Volume 2 for details).*

Change	Key Risks, Impacts & Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality to flow	Changes in timing of flow to wetlands and floodplain riparian habitats
Modification of flood recurrence intervals	Dispersal of species to and between floodplain habitats
Change in relationship between flow and sediment/nutrient delivery	Changes in wetlands functions, dynamics and ecosystem services due to timing of sediment and nutrient delivery
Change inundation/exposure of downstream floodplains and wetlands	Loss of wetland/floodplain habitats
Daily / short-time period changes in flow	
Fast increase and decrease of flow veliocity	Degradation of function, dynamics and ecosystem services of wetland and riparian habitats

Change	Key Risks, Impacts & Vulnerabilities
Loss of river connectivity	
Change to sediment and nutrient transfer (amount)	Changes in wetland funcions, dynamics and ecosystem services due to decrease in transfer of sediments and nutrients
Impoundments	
Change to/loss of riparian areas	Loss of riparian- ecosystems, habitats and biodiversity
Diversion scheme / inter basin transfers	
Alternation of flow regime of contributing and receiving (sub) catchments	Flow changes to wetland and floodplain areas (decrease or increase) leading to changes in ecosystem- functions, dynamics and services as well as biodiversity

4 International Practise, Policy and Safeguards on Mitigating Hydropower Risks and Impacts

This section describes Good Industrial Practise internationally related to mitigation of risks, impacts and vulnerabilities from hydropower development (as summarazed for LMB in Chapter 3). ***Hencefort it is not part of the guidelines and recommendations as such but meant to support the latter***. In the following is the most relevant practises, policys and safeguards from important agencies, organisations and initiatives internationally.

4.1 Asian Development Bank (ADB) Safeguard Policies

The Safeguard Policy Statement approved in June 2009 comprises the safeguard requirements for lending and project financing by the Asian Development Bank (ADB). ADB's safeguard policy framework is composed of three operational policies on the environment, Indigenous Peoples and involuntary resettlement. The operational policies are further elaborated in operational manuals on environmental considerations in ADB operations. Finally, ADB has issued two handbooks on Resettlement (1998) and Environmental Assessment (2003) that are providing information on good practise approaches to implementing safeguards.

In Appendix 1 of the safeguard requirements regarding environmental impacts are set out. The requirements do not specifically address hydropower deployment but lists Environmental Assessment and preparation of an Environmental Management Plan as the basic requirements associated with developments. As a part of the Environmental Assessment project impacts and risks on biodiversity and natural resources shall be assessed. The aspects most relevant for hydropower development in general, and Mekong mainstream and tributary hydropower development projects in particular, are the requirements regarding natural habitats. The main requirement is that a project shall not adversely affect and significantly convert or degrade natural habitats unless alternatives are available or it is demonstrated through a comprehensive analysis that the overall benefits from the project will substantially outweigh the project costs, including environmental costs. In addition any conversion or degradation shall be appropriately mitigated and the mitigation measures shall aim at achieving at least no net loss of biodiversity.

4.2 World Bank Safeguard Policies

The World Bank's (IBRD) Set of Safeguard Policies consist of a number of Operational Policies (OPs) Operational Directives (ODs) and Bank Procedures (BPs). The Environmental Assessment (EA) Policy (OP/BP 4.01) is the Bank's umbrella safeguard policy which sets out a number of specific requirements for environmental and social investigations that shall be carried out for major infrastructure projects, including hydropower projects, before a support in terms of guarantees and loans can be considered.

The EA Policy does not deal with or mention hydropower development projects specifically but states in general terms that the Environmental Management Plan (EMP) *identifies feasible and cost-effective measures that may reduce potentially significant adverse environmental impacts to acceptable levels.* It is furthermore required that the EMP describes each mitigation measure in detail including technical designs, equipment descriptions and operating procedures.

Of the Banks other safeguard policies Natural Habitats (OP/BP 4.04), Safety of Dams (OP/BP 4.37) and International Waterways (OP/BP 7.50) also have important implications for hydropower projects.

Regarding Natural Habitats it is stated that the *Bank does not support projects that, in the Bank's opinion, involve the significant conversion or degradation of critical natural habitats.*

The Safety of Dams Policy requires that experienced and competent professionals design and supervise construction, and that the dam safety measures are implemented throughout the project cycle.

The International waterways Policy seeks to ensure that all concerned and affected riparian countries on an international waterway are notified about hydropower development and other water-use projects are invited to express their views on the project.

4.3 International Finance Corporation (IFC)

IFC is one of the five organizations that forms the World Bank Group. While the World Bank (IBRD) provides loans and guarantees for governments and public sector projects IFC caters to private sector clients in developing countries.

IFC has developed a Sustainability Framework aimed at promoting sound environmental and social practices as well as transparency and accountability. IFC's Environmental and Social Performance Standards, that constitute a vital part of the Sustainability Framework, were first launched in 2006 while the latest revision was carried out in 2012. Today the IFC Performance standards have been recognized across the world as the benchmark for environmental and social risk management in the private sector.

There are eight separate Performance Standards dealing with the main sustainability aspects of a project. The first Performance Standard, *Assessment and Management of Environmental and Social Risks and Impacts*, requires borrowers to carry out an integrated assessment to identify the environmental and social impacts as well as risks, and opportunities related to their projects. The establishment of an environmental management system to manage environmental and social performance throughout the life of the project is also demanded.

The other Performance Standards set out objectives and requirements to avoid, minimize and compensate for impacts to workers, affected communities and the environment.

In the context of environmental impacts related to hydropower development Performance Standard 6, *Biodiversity Conservation and Sustainable Management of Living Natural Resources*, is one of the most important. Natural Habitats are here defined as intact geographical areas composed of plant and animal species of largely native origin. The main requirement is that a project shall not significantly convert or degrade natural habitats, unless no other viable alternatives exist or, where feasible, all impacts on the habitat will be mitigated so that no net loss of biodiversity occurs.

The Performance Standards are complemented by the separate Guidance Notes providing more details of the requirements under each Standard.

In addition to the Performance Standards IFC has developed Environmental Health and Safety (EHS) Guidelines which are technical reference documents with general and specific examples of Good International Industry Practices. They consist of the cross cutting General EHS guidelines applicable to all sectors plus eight industry specific guidelines whereof the power sector is one. However, so far guidelines have been made only for wind energy, geothermal power generation, thermal power plants and transmission lines while guidelines for hydropower are yet to be developed.

4.4 The world Commission of Dams

The World Commission on Dams issued their report, Dams and Development in 2000. Part I of the report reviews the worldwide experience with large dams with regard to a number of aspects, among them the environmental performance which is dealt with in Chapter 2 of the Report. Part II of the report proposes a framework for decision making related to water and energy resources development and puts forward a set of criteria and guidelines for planning, constructing and operating large dams.

Chapter 8 of the WCD report presents seven broad strategic priorities for guiding the decision making regarding large dams and hydropower projects, including public acceptance, alternative options assessment, sustaining rivers and livelihoods and entitlements and benefit sharing.

Chapter 9 presents a set of guidelines for good practices for each of the Strategic Priorities. The most relevant regarding environmental impacts of hydropower development are probably Strategic Priority no. 14, 15 and 16 presented under Strategic Priority 4: *Sustaining Rivers and Livelihoods*

Guideline no 14 – *Baseline Ecosystem Surveys* - states that surveys are necessary to establish the link between the hydrological regime of a river and its associated ecosystems and that relevant information on the following should be collected:

- the biology of important fish species (especially migratory species);
- habitats for threatened or endangered species;
- important areas for biodiversity; and
- important natural resources for downstream communities.

Guideline no 15 – *Environmental Flow Assessments* - recommends that an environmental flow should be released to sustain downstream ecosystems and livelihoods. Finally, Guideline no. 16 – *Maintaining Productive Fisheries* - recommends that proposed fish passes should be tested hydraulically and shown to be efficient mitigation tools for facilitating and enabling migration of the target species. Regarding reservoir fisheries its potential and productivity should be rigorously assessed, based on regional experience from similar reservoir fisheries. The guideline further recommends that reservoir fisheries to be properly managed to:

- prevent the loss of endangered and/or commercially important fish species;
- maintain the fish stock;
- ensure the long-term sustainability of the fish populations; and
- produce fish for local consumption and export.

Although various stakeholders have expressed their concerns about the implementation of the policy principles and detailed guidelines in the Report a number of international banks, including the World Bank, have adapted many of the recommendations of the World Commission of Dams in their safeguards.

4.5 International Hydropower Association (IHA)

After a comprehensive consultation and review process involving the World Commission on Dams recommendations, the Equator Principles, the World Bank Safe Guard Policies and the IFC Performance Standards, the international Hydropower Association published their last version of their Hydropower Sustainability Assessment Protocol in 2010. The Protocol is intended to be a tool that promotes and guides development of more sustainable hydropower through offering a sustainability assessment framework for development of hydropower projects and operation of hydropower plants. In order to reflect the different stages of hydropower development, the Protocol includes four standalone sections covering four phases, Early Stage (project identification), Preparation, Implementation and Operation. The sustainability of a project is assessed on the basis of objective evidence to establish a score which is compared to statements of basic good practice and proven best practice within each sustainability topic. There are five scoring levels with Level 3 and 5 providing benchmark performance levels against which the other scoring levels are calibrated. Level 3 describes basic good practise while Level 5 describes proven best practise.

Relevant sustainability topics for evaluating environmental performance of hydropower projects in the Implementation phase are:

- Biodiversity and Invasive Species (I-15);
- Erosion and Sedimentation (I-16);
- Water Quality (I-17);
- Waste, Noise and Air Quality (I-18)
- Reservoir Preparation and Filling (I-19);
- Downstream Flow Regimes (I-20)

For a project to score 3 and be judged to apply basic good practice it is required that impacts within the sustainability topics during project implementation are avoided, minimised and mitigated with no significant gaps. To score 5 it is in addition required that enhancements to pre-project conditions or contribution to addressing impacts beyond those caused by the project are achieved or are on track to be achieved.

The IHA Assessment Protocol does not go into detail and describe what constitutes basic good practise and proven best practise for mitigating impacts within the more than 20 sustainability topics that it covers.

4.6 Benefit Sharing (MRC, WB and ADB)

Benefit sharing is a promising concept in sustainably implementing hydropower and water infrastructure projects, and is emerging as a supplement to the standard requirements of compensation and mitigation. It has been championed by MRC, WB and ADB in various foras, initiatives and projects. For MRC it was implemented by Initiative for Sustaiable Hydropower. Benefit sharing is being driven by a societal responsibility to ensure that local communities end up with something better than pre-project economic conditions. For benefit sharing to work, certain core mechanisms must be in place: policies and the regulatory framework (government), corporate social responsibility policies (project proponent), and community acceptance of the project. Cooperation among these three parties enables tripartite partnerships (Lillehammer, Martin, and Dhillion 2011).

Mitigation measures are normally anchored in commitments related to the environmental impact assessment and licensing processes, either in international guidelines or more specifically in national legislation and regulatory processes. Benefit sharing goes beyond these commitments and focuses on enhancing community development related to opportunities created by the projects instead of only mitigating impacts (WB, ASTAE, 2014). Figure 4.1 illustrates the relationship and differences between traditional compensation and mitigation measures compared with benefit sharing. Note the relevance of conservation of watershed and biodiversity through either Payment for Ecosystem Services (PES) or Develoment Funds, for **this guideline**.

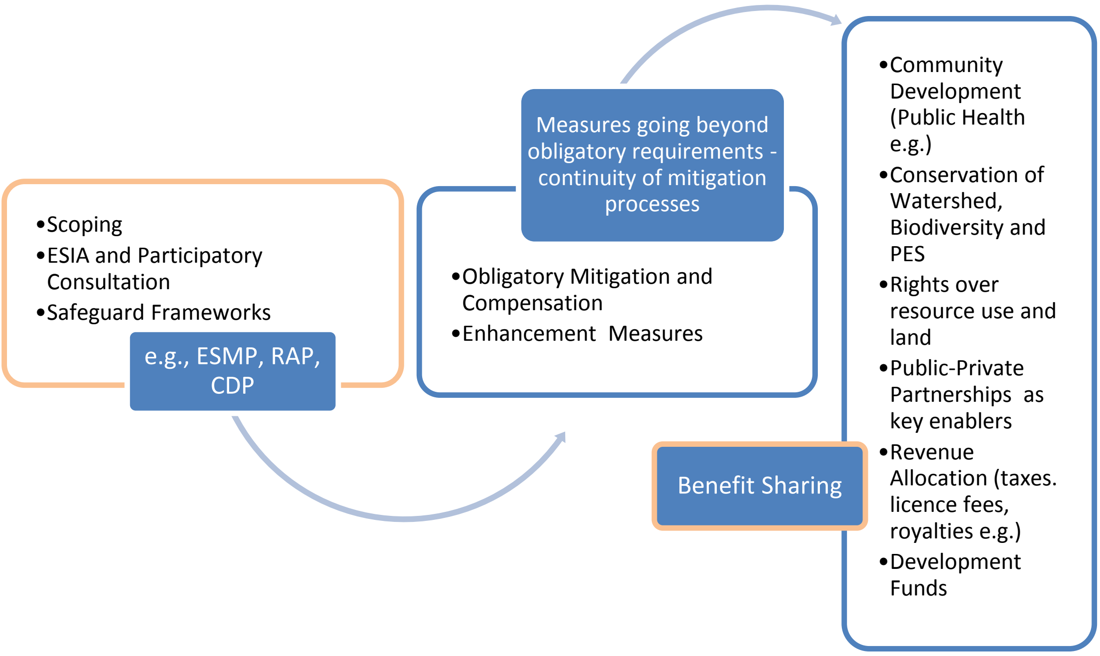

Figure 4.1. *Flow chart showing measures which go beyond their expected obligatory limits in quality and time (PES is Payment of Ecosystem Services, ESMP= Environmental and Social Management Plans, RAP=Ressetlement Action Plan and CDP=Communitu development Plan). Source: (Lillehammer, Martin and Dhillion, 2011).*

Vietnam has been developing and piloting benefit sharing for local communities affected by hydropower projects since 2006. The A'Vuong hydropower project was selected as a pilot study for benefit sharing in Vietnam, where the government of Vietnam and the Asian Development Bank were involved. As part of the technical assistance, a draft decree on benefit sharing was prepared in 2008, for pilot testing for the A'Vuong project. The pilot was completed in 2010 and implemented by the Electricity Regulatory Authority of Vietnam in close cooperation with the Provincial People's Committee of Quang Nam Province. The pilot included a wide range of actions such as direct involvement of communities and payments for ecological services.

5 Hydropower Risks and Impact Mitigation Guidelines and Recommendations

5.1 Overall Guiding Principles

The overall framework for the **Hydropower Risks and Impact Mitigation Guidelines and Recommendations** is portrayed in the figure 5.1. It constitutes (i) Overall Guiding Principles (Mekong 1995 Agreement supported by Strategic Planning Guides and PDG); (ii) General Principles (sustainable technical, social, economic and environmental considerations); as well as (iii) Guidelines and Recommendations with Mitigation Options for a) planning, design and construction of new hydropower and b) Guidelines and Recommendations for operation of existing and planned new hydropower.

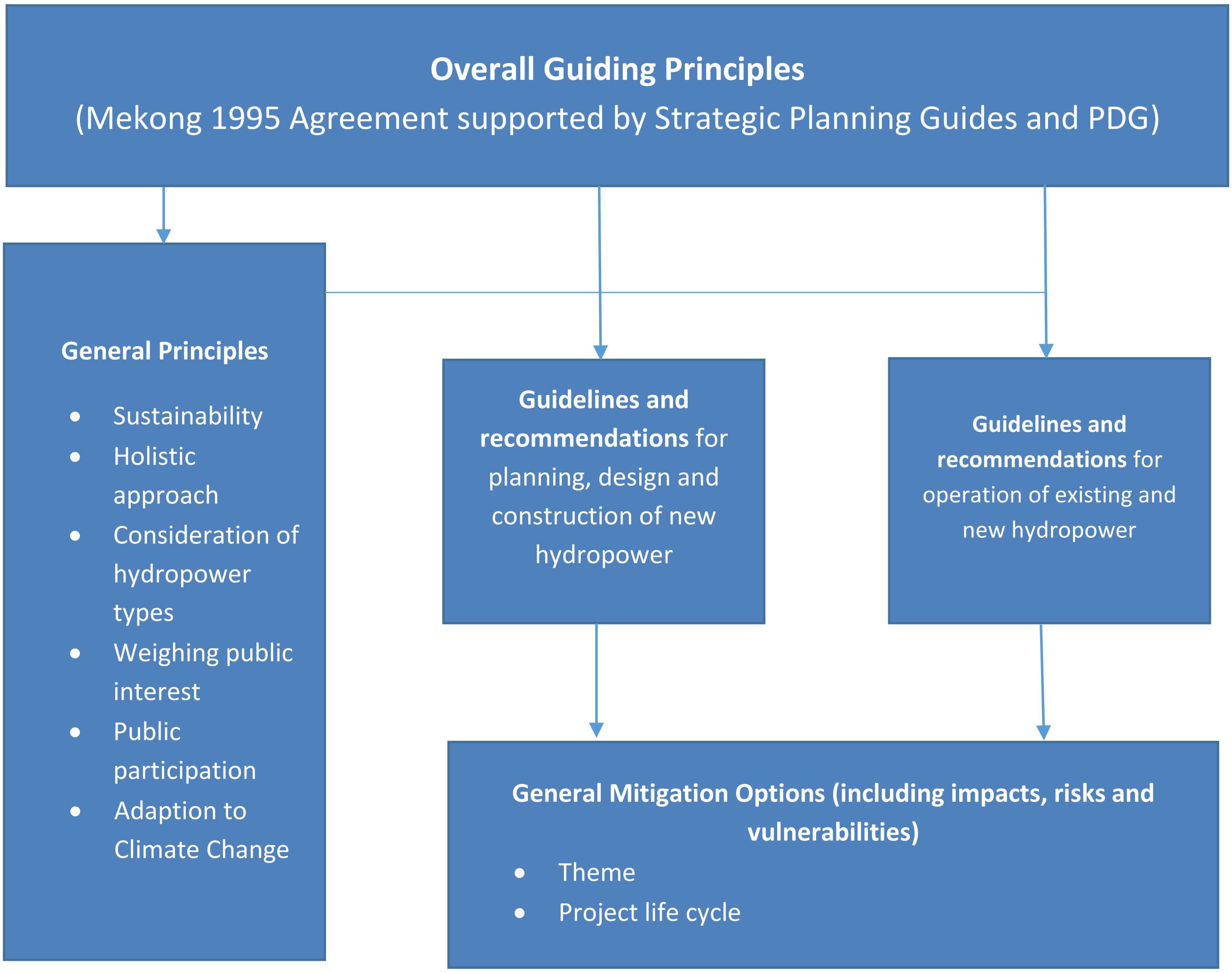

Figure 5.1. *Overall framework for the Hydropower Risks and Impact Mitigation Guidelines and Recommendations.*

The MRC cooperation is firmly based on the 1995 Agreement and during the last years the MRC has developed an applied its framework to address the issue of hydropower development in a holistic way. The following describes this framework to set the scene for the performance of the Guidelines and Recommendations.

5.1.1 The 1995 Mekong Agreement and the MRC Procedures

The Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin signed by Cambodia, Lao PDR, Thailand and Viet Nam on 5 April 1995 defines a set of principles and processes for pursuing a coherent strategy of integrated water resources management (IWRM) on the regional scale.

The 1995 Mekong Agreement encourages cooperation amongst the LMB countries to optimise the multiple use and mutual benefits of all riparian's while protecting the environmental and ecological balance in the basin.

The 1995 Agreement addresses different types of water use including proposed hydropower developments. In the latter respect, the following key chapters and articles are important guides to the Guidelines and Recommendations and the Manual:

- Chapter II: Definitions of Terms
- Article 1: Areas of cooperation
- Article 3: Protection of the Environment and Ecological Balance
- Article 4: Sovereign Equality and Territorial Integrity
- Article 5: Reasonable and Equitable Utilization
- Article 6: Maintenance of Flows on the mainstream
- Article 7: Prevention and Cessation of Damages of Harmful Effects
- Article 8: State Responsibility for Damages
- Article 26: Rules for Water Utilization and Inter-Basin Diversions
- Chapter V: Addressing Differences and Disputes

The Mekong River Commission (MRC) with its three bodies (Council, Joint Committee and Mekong River Commission Secretariat) serves as an international organization to ensure the implementation of the 1995 Mekong Agreement through its provisions and to adopt Procedures to facilitate and addressing such issues in a cooperative and amicable manner. The vision of the 1995 Mekong agreement is embedded within the following agreement between the member states; "..*to cooperate in a constructive and mutually beneficial manner for sustainable development, utilization, conservation and management of the Mekong River Basin water and related resources..*"

The five adopted Procedures for implementation within the MRC framework are the

(i) Procedures for Notification, Prior Consultation and Agreement (PNPCA; approved in 2003);
(ii) Procedures for Data and Information Exchange and Sharing (PDIES; approved in 2001);
(iii) Procedures for Water Use Monitoring (PWUM approved in 2003);
(iv) Procedures for Maintenance Flows on the Mainstream (PMFM approved in 2006);
(v) Procedures for Water Quality (PWQ approved in 2011).

According to the PNPCA, hydropower development on tributaries is subject to notification to the MRC Joint Committee and respective development on the mainstream requires prior consultation towards agreement between the countries.

The implementation of the PNPCA under the 1995 Mekong Agreement in case of a proposed hydropower dam, intends to benefit each MRC country and to facilitate the development of water and related resources in the LMB. Furthermore, the PNPCA commits the countries to notify their neighbours of proposed mainstream projects when they have sufficient information, then consult and reach agreement on whether or not to proceed, and if so, under what conditions.

The Mekong Agreement also requires the countries to "*make every effort to avoid, minimize and mitigate harmful effects*…", i.e. to adopt the mitigation hierarchy in the planning and implementation of hydropower and other infrastructure projects.

With relation to the mitigation hierarchy (Figure 5.2) avoidance is most regularly used at concept stage (master plans, pre-feasibility and feasibility studies) identifying alternative sites or technology to eliminate impacts. Minimisation is most often used prescribing actions during design, construction and operation stage to minimise or eliminate impacts. Compensation is used to offset residual impacts identified at different stages.

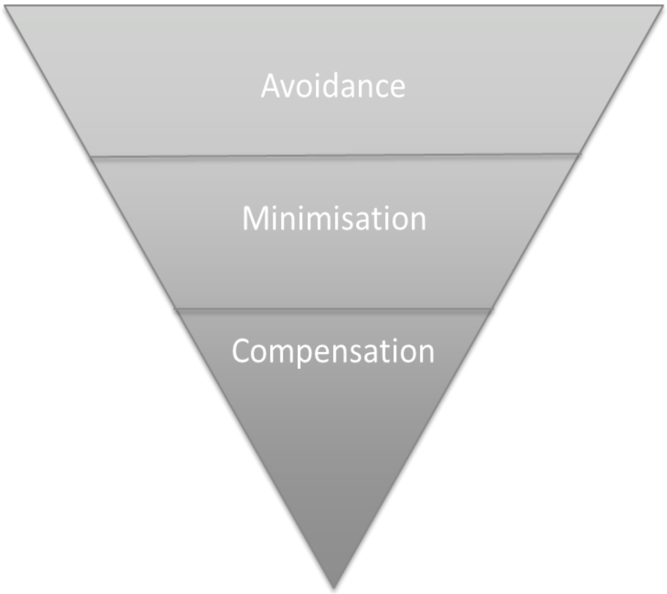

Figure 5.2. *The mitigation hierarchy (IEA, 2006).*

5.1.2 Basin Development Strategy, MRC Strategic Plan 2011-2015 and 2016-2020 update

The adoption of the MRC Strategic Plan (2011-15) and the IWRM-Based Basin Development Strategy (BDS) for the Lower Mekong Basin endorsed by the MRC Member Countries in January 2011 are important steps towards regional-level cooperation for sustainable basin-wide development, as envisaged in the 1995 Agreement. A draft update of the Strategic Plan has been made for the period 2016-2020.

Both strategies address the key role the hydropower sector will have on the MRC's IWRM strategic direction. The documents identify the need for further studies and guidance by the MRC Initiative for Sustainable Hydropower (ISH) regarding the sustainable development of hydropower in the LMB.

5.1.3 National Initiatives

The planned hydropower schemes on the LMB mainstream and tributaries are subject to national EIA procedures and decisions. All the LMB countries have developed regulations for EIAs at project level and partly also for SEAs and CIAs. For example, the SEA is required by law in Vietnam (Keskinen & Kummu 2010, Ke & Gao 2013). Additionally, Cambodia is drafting a new EIA law, the latest draft of which takes into account trans-boundary impacts (Ke & Gao 2013).

5.1.4 MRC Preliminary Design Guidance (PDG)

The most important safeguards for hydropower in the LMB are those in the Preliminary Design Guidance (PDG) for Mainstream Dams in the Lower Mekong Basin, which was issued by the MRC in 2009. The PDG outlines the expectations of, and an approach to, mitigation of the major risks for hydropower dams in the Mekong mainstream. For example, the PDG requires all mainstream dams to incorporate both upstream and downstream fish passage facilities, which should ensure "effective" passage (i.e. safe passage for 95% of the target species under all flow conditions). The PDG criteria have served as the compliance benchmarks in the technical reviews of the Xayaburi and the Don Sahong hydropower projects.

This Gudielines and Recommendations with the supporting Manual seeks to enhance and expand the PDG and to provide more effective and detailed documentation of the options and methods that may be used to cover the mitigation of hydropower risks in the Mekong mainstream as well as to expand the applicability of the PDG to the tributary developments.

The Preliminary Design Guidance (PDG) for the Proposed Mainstream Dams in the Lower Mekong Basin provide developers with an overview of issues that the MRC will consider during the prior consultation process under the 1995 Mekong Agreement. With regard to the Themes of this guideline the PDG provides recommendations as follows.

Environmental Flow and Aquatic Ecology

The PDG stipulates to incorporate instream flow (environmental flow) considerations appropriately at different project stages (design, implementation, operation and monitoring). The Design Guidance states that the developers should systematically assess the effect of combination of flow releases from the dam to address downstream impacts at different times of the year, also taking into account the position of the dam in possible cascade series of dams. This should be done by introducing appropriate Environmental Flow Assessment (EFA) methodologies at the EIA and feasibility study stage, appropriate to the scale and significance of the flow changes, and referring to good practice techniques and methodologies. The prescribed documentations to refer are: IUCN Publication- *'Flow: The Essentials of Environmental Flows' and World Bank Publication- 'Environment Flows: Concepts and Methodologies'*. MRC Environment Program (2011-2015) also highlights the requirement of further development of EFA approaches.

Sediment transport and geomorphology

The PDG provides an overview of potential sediment related impacts associated with the development of hydropower projects and approaches for mitigation and management. These impacts include reservoir deposition, changes to sediment transport from inflowing tributaries (both in the reservoir and downstream), downstream channel adjustments related to changes in hydrology and sediment loads and associated impacts on habitat distribution and quality. A summary of guiding principles for considering sediment related issues during the planning phase is provided for developers, which highlight the importance of:

- Understanding the relationships between hydraulics, river morphology and ecology;
- Assessing whether dam developments should be avoided in reaches susceptible to severe morphological change;
- Making dams transparent to sediment transport as much as possible;
- Considering sediment transport issues associated with tributary inputs.

The PDG discusses a range of sediment management options, including sediment routing, sediment bypass, sediment flushing, mechanical removal, sediment traps and sediment augmentation downstream of the reservoir. General guidance is provided with respect to site selection, modelling and monitoring of sediments into, within and downstream of the impoundment, and the inclusion of gates to enable sediment management options. Operational and ecological issues associated with the timing of sediment management are also highlighted, with an emphasis on continued monitoring over the life-cycle of the project to guide management strategies. Reactive measures, such as physical bank protection are indicated as a means of mitigating impacts which cannot be avoided through management of the project.

Water Quality

The PDG focuses on water quality risks associated with a series of low-head dams as proposed for the mainstream Mekong in the LMB, emphasizing that larger deeper storages may promote greater changes. The water quality risks identified by the PDG include changes to physical and chemical water quality parameters which can impact on the downstream ecosystem, and geomorphology (as related to sediment concentrations).

The water quality parameters that are important to consider in hydropower developments include temperature, pH, dissolved oxygen, Biological Oxygen Demand, total nitrogen, total phosphorus and coliform bacteria. These parameters can be altered during storage within a reservoir and especially under conditions where thermal stratification can lead to the development of stagnant water at depth.

Guidance for maintaining water quality includes the design and management of reservoirs which will achieve the water quality guidelines as set out in the MRC Technical Guidelines for Procedures on Water Quality. The PDG state the necessity of site – specific water quality monitoring, with the results to be interpreted within larger scale trends provided by the Water Quality Monitoring Network and Ecological Health Monitoring Network.

Fish passages on Mainstream Dams

The PDG gives an overview of the various fish guilds (10) on the Mekong and its tributaries and the likely impacts of mainstream dams. This is followed by guidance on fish passage design and operation. Important guiding principles are as follows:

- Fish passage facilities for both upstream and downstream passage must be incorporated into all dams.
- The developers should provide for effective fish passage bot upstream and downstream, defined as follows – "providing safe passage for 95% of the target species under all flow conditions"
- Where fish passage rates are unlikely to be adequate to maintain viable populations other mitigation options as part of compensation programs for lost fisheries resources must be developed.
- Fish passages and mitigation options should constitute multiple systems at each site to cater for the high number of species and high biomass.

The PDG details further biological, hydrological and hydraulic requirements for the fish passages during the various phases of the HPP project life cycle.

5.2 General Principles and Processes for Sustainable Hydropower Development

Hydropower's potential contribution to energy and water management goes beyond domestic and national electricity generation. As both power and water issues spill over national boundaries, as is the case of LMB, **hydropower offers potential benefits to regional development**. From the energy perspective it can help stabilize the regional electricity grid systems through unique services such as storage and regulating capacity and load following and reduce costs through coordination with thermal plants. Good practise in managing hydropower and water resources demands a river basin approach, regardless of national borders. Ensuring effective development and management of water infrastructure can help balance upstream and downstream interest and transform a potential source of conflict into a tool for regional cooperation and development (WB, 2009). As such MRC's initiatives in developing design and mitigation guidelines is an integral tool for this regional cooperation and development, given the vast plans for hydropower development on Mekong mainstream and the tributaries. Hydropower will also likely play a key role in **climate adaptation** as a renewable source of energy which can contribute to the reduction of GHG and to adaptation to changes from the foreseen increase in hydrological variability, e.g. help mitigate drought and floods. Furthermore, from the lessons learned of the past decade or so, hydropower is increasingly recognized as providing multiple opportunities to significantly enhance community, regional, national and transboundary development if planned, designed and implemented in a sustainable manner, including implementation of good industrial practise mitigation guidelines and options.

Closely linked to the overall guiding principles in Chapter 5.1 are some **general principles** for sustainable development. Together with the policies and safegurads these provide the backbone for good industrial practise with regard to the **LMB Hydropower Risks and Impact Mitigation Guidelines and Recommendations** (see Figure 5.1), that are described in Chapter 5.3, and supported by details in the Manual (Volume 2). The general principles can be described as follows:

1. Hydropower development needs to respect the principles of sustainability, taking into account environmental, social and economic factors in an equally balanced way, throughout the project planning, construction and operation.
2. Renewable energy generation should be part of a holistic approach of energy policies. Untapped renewable energy potential, energy saving and increase of energy efficiency are important elements that should be considered in this approach.
3. In order to ensure a sustainable hydropower development and to weigh the different public interest in a balanced way national/regional hydropower strategies should be elaborated based on basinwide planning principles (As embedded in the Mekong Agreement and the MRC Strategic Plan). These strategies should consider the multifunctional use of hydropower infrastructure (e.g. flood control, irrigation, navigation, water supply etc.).
4. Weighing of the public interest on national/regional level has to be done in a transparent, structured and reproducible way based on criteria and relevant information, involving public participation in an early stage of development.
5. Hydropower has to take into account effects of climate change on the aquatic and riparian ecosystems as well as water resources (resilience of river habitats, quantity of flow, seasonal canges of flow, etc.)
6. The combination of technical upgrading with ecological restoration of hydropower instalations implies a win-win situation for energy production on the one side as well as for the improvement of environmental conditions.

5.3 Detailed Mitigation Guidelines, Recommendations and Options for the LMB

The tables in the following pages (Tables 5.1 – 5.5) constitutes a summary of the Mitigation Guidelines, Recommendations and Options for the LMB for this Version 1.0 of the - **Hydropower Risks and Impact**

Mitigation Guidelines and Recommendations. This will be further developed in the 2nd Interim and Final Phases following additional consultation with the MRC Member Countries. The mitigation options are presented in detail by thematic area (hydrology, geomorphology & sediment, water quality, fisheries) in Volume 2, the 'Manual'. Each thematic area in Volume 2 includes examples of good international and regional industrial practice, available criteria for evaluating the applicability of mitigation measures, technical guidance and information about monitoring and indicators

The mitigation options in TABLES 5.1 to 5.5 are structured according to the 5 key common overarching changes related to hydropower development, as identified in Chapter 3 of this volume. These are:

I. Annual / inter-annual changes to flow

II. Daily / short-time scale changes to flow and water level

III. Loss of river connectivity

IV. Impoundments

V. Diversion intra basin transfers

Within these identified major changes a set of major risks and impacts (left column in the Tables) for each thematic area has been identified. The identified mitigation options are then grouped into avoidance, mitigation (including minimization), compensation and adaption measures. The associated sub-sections define where in the project life cycle the various mitigation options are to be implemented. Cross-Referencing of the detailed description of the proposed mitigation options in the Manual will be included in the final version of this Volume 1. A succinct overview of how mitigation considerations should be incorporated into each stage of the hydropower life-cycle is presented following the Tables.

More details on the proposed mitigation measures can be found in Volume 2 as follows:

- Hydrology and water resources (Chapter 2.3)
- Geomorphology and sediments (Chapter 3.4)
- Water quality (Chapter 4.3)
- Fisheries and Aquatic Ecology (Chapter 5.3)
- Biodiversity and Natural Resources (Chapter 6.3)
- Engineering Response to Environmental Risks (Chapter 7)
- Ecosystem Services (Chapter 8.4)

Risks / Impacts	Table 5.1 (I) Annual/Inter Annual Changes to Flow			
	Planning / design / construction		Operation	
	Options	Indicators	Options	Indicators
Hydrology and downstream flows 1) Change of timing & duration of floods and low flows 2) Peaks in flood and low flow change, smoother hydrograph 3) Changes in Tonle Sap flows and salt intrusion in the delta **Geomorphology and Sediments** 1) Water logging & loss of vegetation leading to increased bank erosion Increased erosion due to increased scour 2) Winnowing of smaller sediment leading to bed armouring & reduction in	**(I.1) Avoidance**			
	(I.1.1) Dam siting in Master Plans to avoid risks and impacts in themes hotspot areas (MP) (I.1.2) Selection of sites with less hydrological and sediment impact (MP)	River length affected; contribution to LMB flow and sediment loads		
	(I.2.) Mitigation			
	(I.2.1) Development of flow rules (MP and F) (I.2.2) Develop joint operation rules for releases (F) (I.2.3) Design multiple large gated spillways/outlets at multiple levels, and low level sediment outlets (D) (I.2.4) Design bypass channels (F and D)	Minimum flow, dynamics, magnitude, duration, timing of wet and dry season flows	(I.2.5) Mimic 'natural' flow regime (artificial releases, environmental flows) (I.2.6) Maintain seasonal patterns through HP operations (I.2.7) Annual sediment sluicing to maintain seasonal pulse (I.2.8) Monitoring of impacts	Minimum flow; onset of wet season; magnitude, duration of wet/ dry season flows; changes to fish diversity/ biomass, sediment loads and timing of sediment delivery, extent and timing of salinity intrusion
	(I.3) Compensation			
	Plan for and implement; (II.3.1) Creation of offsets of residual impacted habitats and areas (F and D) (II.3.2) Floodplain and wetland rehabilitation (F and D)	Area of offsets and improved floodplain and wetland habitats	(I.3.3) Monitor offsets and floodplain and wetland rehabilitation	Changes to fish diversity/ biomass

downstream sediment supply 3) Channel narrowing through encroachment of vegetation 4) Decoupling of tributary & mainstream flows. Erosion and / or deposition due to tributary rejuvenation 5) Backwater sedimentation causing flood-level increase upstream **Water quality** 1) Changes / loss of seasonal temperature patterns downstream 2) Increased water clarity increasing water temperature and risk of algal growth **Fisheries and Aquatic Ecology** 1) Loss of migration/ spawning triggers; 2) reduced flood pulse and related productivity loss; habitat loss due to					
		(I.4) Adaptation			
		Implementation of operating rules Monitoring including stakeholder consultation to gauge effectiveness of mitigation actions Adaptive management guided by monitoring Catchment management activities to improve / maintain water quality, reduce sediment loads			
		MP = Master Plan F = Feasibility D = Detailed Design C= Construction			

morphological alterations 3) Habitat loss due to morphological alterations **Biodiversity, Natural Resources and Ecosystem Services** 1) Changes in wetland functions and dynamics due to shifts in timing of sediment and nutrient delivery 2) Loss of wetland/floodplain habitats					

Risks / Impacts	Table 5.2 (II) Short-term flow fluctuations / Hydro-peaking			
	Planning / design / construction		**Operation**	
	Options	**Indicators**	**Options**	**Indicators**
Hydrology and downstream flows 1) Short term flow fluctuations 2) Safety and navigability **Geomorphology and Sediments** 1) Rapid wetting and drying of banks 2) Increase in shear stress on river channel **Water quality** 1) Fluctuating temperature and water quality 2) Altered concentrations of downstream WQ parameters **Fisheries and Aquatic Ecology**	**(II.1) Avoidance**			
	(II.1.1) Dam siting in Master Plans to avoid risks and impacts in themes hotspot areas (MP) (II.1.2) Selection of sites where impacts are reduced by entering tributaries (MP)	River length affected		
	(II.2.) Mitigation			
	(II.2.1) Development of flow rules (F and D) (II.2.2) Design of re-regulation weir (D) (II.2.3) Coordination of multiple hydropeaking HPP (II.2.4) Design of aeration weir (II.2.5) Avoidance of flow fluctuations during construction (C) (II.2.6) Establish protected areas and evacuation paths for inundation zones (C) (II.2.7) Flexible mooring structures for ports (D and C) (II.2.8) River-bank stabilisation works (C)	Ramping frequency, amplitude, ramping rate, minimum flow temperature, dissolved oxygen, downstream damping of water-level fluctuations	(II.2.9) Re-regulation warning systems (II.2.10) Operating rules to minimise flow changes, management of re-regulation weir to provide appropriate downstream flow (II.2.11) Monitoring of impacts (II.2.12) Use of high/low level outlets to mimic seasonal temperature and manage dissolved oxygen	Ramping frequency, ramping amplitude, ramping rate, minimum flow, changes to fish diversity/ biomass. Bank / bed erosion rates Downstream temperature, D.O. downstream damping of water-level fluctuations
	(II.3) Compensation			
	Plan for and implement; (II.3.1) Habitat improvement (F and D) (II.3.2) Floodplain and wetland rehabilitation (D and C)	Area of improved floodplain and wetland habitats	(II.3.3) Monitor habitat improvement and rehabilitation	Changes to fish diversity/ biomass

1) Degradation of riparian and instream habitats 2) Thermopeaking 3) Increased fish/ macroinvertebrate drift and stranding 4) Offset of migration triggers **Biodiversity, Natural Resources and Ecosystem Services** 1) Degradation of function, dynamics and ecosystem services of wetland and riparian habitats		**(II.4) Adaptation**			
		Monitoring, adaptive management (based on monitoring data) Catchment management to maximise water quality in and discharged from impoundment			
		MP = Master Plan F = Feasibility D = Detailed Design C= Construction			

Risks / Impacts		Table 5.3 (III) Loss of river connectivity			
		Planning / design / construction		Operation	
		Options	Indicators	Options	Indicators
Hydrology and downstream flows **Geomorphology and Sediments** 1) Sediment availability not timed with periods of recession 2) Loss of sediment 'pulse' **Water quality** 1) Trapping of nutrients within impoundments (change in nutrient delivery downstream) **Fisheries and Aquatic Ecology** 1) Blocked spawning/ feeding migrations 2) Habitat/ population fragmentation		**(III.1) Avoidance**			
		(III.1.1) Dam siting in Master Plans to avoid risks and impacts in themes hotspot areas (MP) (III.1.2.) Assessment of requirements and distribution of migratory species (MP and F) (III.1.3) Assessment of sections sensible to river fragmentation and important habitats (no-go areas) (MP) (III.1.4) Assessment of alternative hydropower designs, operations (MP and F) (III.1.5) Assessment of sediment budgets (F)	River length disconnected; number of migratory species; Proportion of sediment load affected Downstream bank erosion		
		(III.2.) Mitigation			
		(III.2.1.) Consider alternative hydropower designs to minimize impacts on connectivity (MP and F) (II.2.2) Design multiple large gated spillways/outlets, and low level sediment outlets or bypass structures (D) (III.2.3) Design fish pass/ bypass channels (up- & downstream) (D) (III.2.4) Design measures for fish protection (D) (III.2.5) Ensure connectivity during construction (C)	Number and type of migratory species, migratory behaviour; FP requirements, biomass peaks Sediment loads and seasonality	(III.2.6) Annual sediment sluicing to maintain seasonal pulse (III.2.7) Monitoring of sediment (III.2.7) Monitoring of fish pass functionality (III.2.8) Monitoring of fish kills (spill flow/ turbines) (III.2.9) Assessment of population functionality (life cycle)	Timing and concentration of sediment pulses Number of successfully passing migratory species; biomass peaks; population status

3) Habitat loss due to morphological alterations 4) fish damage/ kills due to turbine/ spillflow passage **Biodiversity, Natural Resources and Ecosystem Services** 1) Changes in wetland functions, dynamics and ecosystem services, due to decrease in sediment and nutrient transfer		**(III.3) Compensation**			
		Plan for and implement; (II.3.1) Introduction of additional sediment downstream of impoundment (C) (III.3.1) Reconnecting floodplains, ensure connectivity during construction (C)			
		(III.4) Adaptation			
		Monitoring program to assess efficiency of measures , adaptive management Adaptation of sediment management guided by monitoring results Downstream bank protection works Adaptation of fish pass and fish protection on the basis of monitoring data			
		MP = Master Plan F = Feasibility D = Detailed Design C= Construction			

Risks / Impacts		Table 5.4 (IV) Impoundments			
		Planning / design / construction		Operation	
		Options	Indicators	Options	Indicators
Hydrology and downstream flows **Geomorphology and Sediments** 1) Reduction in sediment availability downstream of dam leading to increased erosion 2) Changes to the grain-size distribution of sediment downstream contributing to channel armouring and alteration of habitats 3) Lake bank erosion, increased risk of landslips 4) Loss of volume of active storage		**(IV.1) Avoidance**			
		(IV.1.1) Dam siting in Master Plans to avoid risks and impacts in themes hotspot areas (MP)	River length affected Retention time, depth of potential impoundments		
		(IV.2.) Mitigation			
		(IV.2.1) Avoid high retention time, plan and implement large bypass-systems (F,D,C) (IV.2.2) Assess and implement suitable turbidity thresholds with regard to natural floods for aquatic species (F,D) Design multiple large gated spillways/outlets, and low level sediment outlets as well as bypass channels (D) (IV.2.3) Minimise sediment runoff through design of access roads & seasonal work schedules (D and C) (IV.2.4) Implement site-specific water quality standards (e.g. TSS, oxygen, temperature) (F,D)	TSS, grain-size distribution, retention time, flow velocity, temperature, oxygen saturation, bathymetry	(IV.2.5) Implement habitat improvements in head of impoundment, (IV.2.6) Protection and armouring of downstream banks if required (IV.2.7) Catchment management to reduce sediment inputs (IV.2.8) Implement and apply suitable sediment management strategy (e.g. reservoir sluicing and/or occasional flushing) IV.2.9) Monitoring of abiotic parameters, species changes and passive drift rates (IV.2.10) Limit rate of water level drop to prevent slope and dam instability	TSS, retention time, flow velocity, temperature, oxygen saturation changes of fish community, biomass, fish drift, bathymetry

<table>
<tr><td rowspan="5">Water quality
1) Lake stratification
2) Increased water clarity
3) Temperature change in lake and discharge
4) Low DO or high gas supersaturation
5) Changes in nutrient loads

Fisheries and Aquatic Ecology
1) Changes from fluvial to lake habitats (habitat & species loss)
2) Habitat loss due to sedimentation (upstream) and sediment deficit (downstream)
3) Deposition/ delay of drifting eggs/ larvae
4) loss of orientation
5) stranding due to water level fluctuations
2) Reservoir flushing leading to fish damage and kills and alteration of habitats</td><td></td><td colspan="4">(IV.3) Compensation</td></tr>
<tr><td></td><td>Plan for and implement;
(IV.3.1) Plan and provision for regeneration of vegetation and offset areas (D and C)
(II.3.2) Catchment management to reduce sediment inputs and sustain ecosystem functions and services (F and D)</td><td></td><td>(IV.3.3) Maintain and monitor offset areas.
(IV.3.4) Regulation of operation to maintain health of “new” riparian areas</td><td></td></tr>
<tr><td></td><td colspan="4">(IV.4) Adaptation</td></tr>
<tr><td colspan="5">Monitoring program to assess efficiency of measures , adaptive management
Lake level fluctuation limits to manage lake bank erosion</td></tr>
<tr><td></td><td>MP = Master Plan
F = Feasibility
D = Detailed Design
C= Construction</td><td></td><td></td><td></td></tr>
</table>

Biodiversity, Natural Resources and Ecosystem Services 1) Change to / loss of riparian-ecosystems, habitats and biodiversity					

Risks / Impacts		Table 5.5 (V) Diversions or Intra-basin Transfers			
		Planning / design / construction		Operation	
		Options	Indicators	Options	Indicators
Hydrology and downstream flows 1) Change of magnitude & dynamics of flows **Geomorphology and Sediments** 1) Channel narrowing due to vegetation encroachment 2) Armouring of beds and bars 3) Increased bank erosion and bed incision **Water quality** 1) Change in nutrient and other water quality parameters in both donor and receiving catchments		**(V.1) Avoidance**			
			River length affected, number of catchments affected, degree of flow alteration		
		(V.2.) Mitigation			
		(V.2.1) Minimise degree of transfer to minimise impacts in both catchments (F, D) (V.2.2) Development of environmental flow rules. i.e. minimum flow and dynamic flow (F and D)	Minimum flow, flow dynamics, seasonality of flow, flood frequency	(V.2.3) Application of environmental flows; monitoring of compliance and impacts; adaptive management (V.2.4) Operating rules to maintain geomorphic processes in both catchments (V.2.5) Protection and armouring of downstream banks in receiving catchment if required (V.2.6) Monitoring of flows and biological response	Flowrates, sediment loads and seasonality Downstream channel changes (erosion or constriction) fish diversity, fish biomass/ density
		(V.3) Compensation			
		(V.3.1) Periodic flood releases to 'donor' river to maintain channel capacity (F and D)		(V.3.2) Maintain and monitor restored river/channel/floodplain areas.	Same as under mitigation

Fisheries and Aquatic Ecology 1) Reduced productivity due to reduced river dimension (flow, depth, width) and flow dynamics 2) Reduced connectivity 3) Stress due to water quality changes 4) Habitat loss due to morphological alterations 5) Possible loss of large species **Biodiversity, Natural Resources and Ecosystem Services** 1) Flow changes to wetland and floodplain areas (decrease or increase) leading to changes in ecosystem-functions, dynamics and services as well as biodiversity		(V.3.1) Restoration of impacted diversion stretch/channel (D and C)			
		(V.4) Adaptation			
		Monitoring program to assess efficiency of measures , adaptive management Adaptation of environmental flow on the basis of monitoring data			
		MP = Master Plan F = Feasibility D = Detailed Design C= Construction			

5.4 Summary of Mitigation Options and Engineering Response for the Different Project Phases

5.4.1 Approach of the guidelines

As demonstrated in Tables 5.1-5.5, the mitigation of hydropower risks and impacts requires a life-cycle approach to hydropower development and operation. The following sections provide a brief overview of the issues and approaches that should be considered during each phase of a hydropower project. These topics are discussed in detail by each thematic area in Volume 2, which should be consulted for more detailed information. Figure 5.3 below transfer the general principles from the mitigation hierarchy (Figure 5.2) into the HP project life cycle and can be seen as an overarching generic practical process for risk and impact mitigation in LMB.

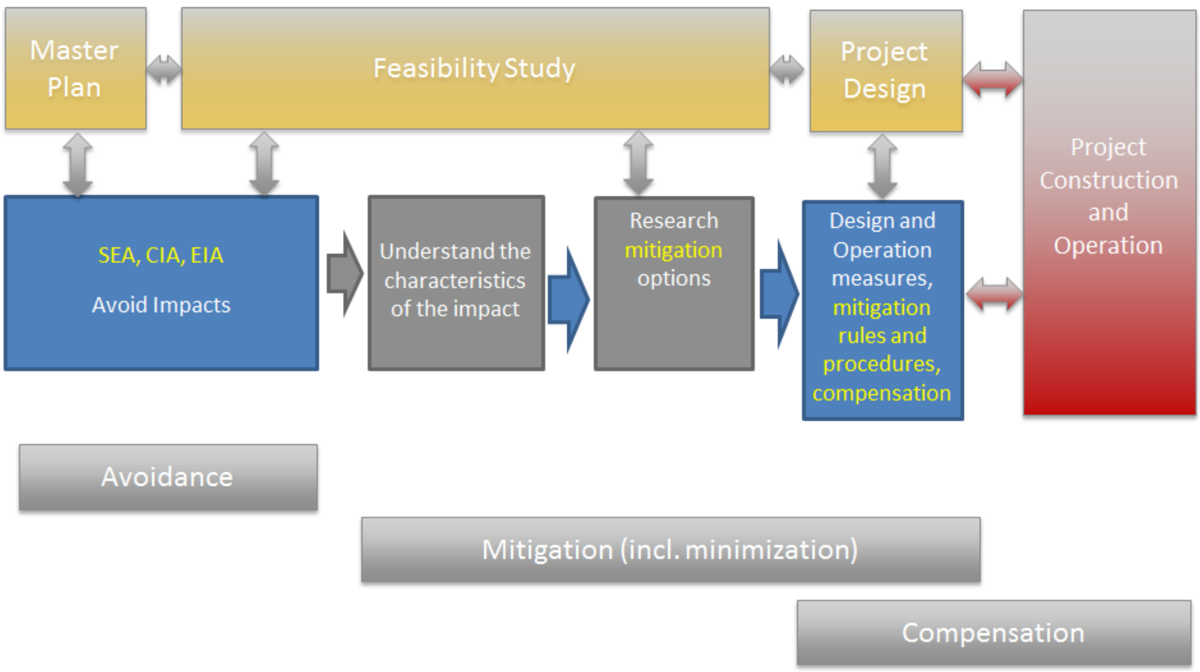

Figure 5.3. *MRC adjusted Generic Practical Process for Risk and Impact Mitigation - Project Life Cycle.*

5.4.2 Master Plans

The development of Basin Master Plans is critical to the development of sustainable hydropower. Master Plans need to be based on a sound knowledge of the conditions within the catchment (flow regimes, sediment budgets, fisheries and aquatic ecological systems) and how hydropower development could potentially alter these systems. Hence, Master Plans typically should include a SEA and/or CIA (see Chapter 1.2.3). The identification and feasibility of potential mitigation measures should be an integral part of Master Planning and included at the earliest stages of planning. The siting and scale of hydropower projects are critical factors in determining the long-term impacts of developments, and environmental factors as well as power production potential need to be considered and evaluated during the development of Master Plans. Attributes of hydropower projects that need to be considered at the Master Planning phase include:

- Location of project relative to upstream and downstream tributaries: Typically, the having large volume unregulated tributaries entering downstream can assist with the mitigation of impacts by providing seasonally appropriate flow and sediment input, and maintaining catchment connectivity for migratory species;

- Height of dam and size of impoundment. Generally lower dams and smaller developments have lower levels of downstream impact;
- Relationship to other hydropower or water resource developments.

Master planning should consider the impact of individual hydropower developments, as well as the cumulative development of hydropower (and other water resource developments) within and between catchments. Master Planning provides the opportunity to develop integrated and complementary hydropower projects that can be operationally coordinated to meet power demands whilst limiting environmental and social impacts to accectable levels.

Master Planning also provides the opportunity to establish basin and catchment specific requirements and targets for hydropower developments. These types of overarching criteria might include *inter alia*:

- Environmental flow requirements (minimum flows, seasonal releases, irrigation releases, etc.)
- Limits on ramping rates
- Water quality targets, such as dissolved oxygen levels and seasonal temperature ranges
- Sediment concentration limits or targets associated with sediment flushing operations
- Limits to lake level operating ranges (e.g. to facilitate other water uses)
- Identification and protection of ecosystem, biodiversity and wetland hotspots
- Identification of potential intact river-routes for fish migration and other water uses

5.4.3 Feasibility

The key objective of the feasibility stage is to optimise the installed capacity and layout of a project withyin the constraints imposed by the associated ESIA. Furthermore, during the feasibility stage of a development, a more detailed understanding of the environmental conditions within the catchment is required to guide the general project layout and preliminary design, including the identification of appropriate mitigation measures. Detailed investigations into the physical and ecological characteristics of the catchment should be initiated during this phase, and continue through the design phase, providing as long a record as practical to guide project development. The final siting and design specifications of a project needs to be decided taking into account power generation and environmental mitigation issues.

At this stage, mitigation measures to address known issues, such as the provision of an acceptable downstream flow regime and / or fish passage should be incorporated into the project, but mitigation strategies that provide for unforeseen future changes also need to be considered. Future changes might be associated with future water resource of other developments upstream or downstream of the project that could impose operating constraints on the HP operation, or changes associated with the energy market or societal expectations. The feasibility study provides the basis on which investment decisions are made, so all issues need to be identified and catered for in the proposed design and operation, including flexibility for any future changes. This includes the identification, selection and costing of appropriate infrastructure, operating rules, and potential offsets. The development and implementation of site-specific monitoring regimes that can provide additional information for the design, construction and long-term operation of the project should also be developed and implemented during the feasibility stage.

The feasibility stage should also be guided by the results of site-specific investigations and detailed modelling at the project and catchment scale to arrive at the best environmental outcome in the most cost effective manner, too also back up the drafting of the CA and the PPA.

Stakeholder consultation during this phase is essential for refining the understanding of potential environmental issues and impacts identified in the Master Plan, and to guide the direction of the feasibility study.

5.4.4 Detailed Design

The detailed design phase of Hydropower developments progresses and refines, and developes in detail, the mitigation concepts and approaches identified during the feasibility phase to arrive at the final design of the project. This includes the detailing of mitigation infrastructure, which might include:

- High and low level outlets to facilitate the discharge of water from different levels within the impoundment and the potential to pass sediments through the dam;
- Re-regulations weirs to dampen downstream water level fluctuations
- Aeration weirs to increase oxygen levels in the tail water;
- Fish passage addressing both upstream and downstream migration;
- Sediment bypass channels or tunnels, or infrastructure to promote the deposition of sediment at the upstream end of reservoirs where it can be periodically harvested;

The detailed design phase also typically involves the drafting of an Environmental Monitoring and Management Plan (EMMP), to be implemented during the Construction and Operation phases.

5.4.5 Construction

Environmental mitigation measures should be incorporated into the construction process by analysing the potential impacts of access, working areas, sources of materials, equipment and materials management and construction methodologies and defining actions to eliminate or mitigate these impacts. To this end, it is standard good industrial practice to require the contractor to finalize, submit and implement the Environmental Monitoring and Management Plan (EMMP) drafted during the detailed design phase. This plan should be required to include specific sub-plans which would typically include the following:

- Erosion and Sediment Control Plan
- Spoil Disposal Plan
- Quarry Management Plan
- Water Quality Monitoring Plan
- Chemical Waste/Spillage Management Plan
- Emergency Plan for Hazardous Materials
- Emissions and Dust Control Plan
- Noise Control Plan
- Physical Cultural Resources
- Landscaping and Revegetation Plan
- Vegetation Clearing Plan
- Waste Management Plan
- Reservoir Impoundment Management Plan
- Environmental Training for Construction Workers Plan
- On-site Traffic and Access Management Plan
- Explosive Ordnance Survey and Disposal Plan
- Constructions Work Camps and Spontaneous Settlement Areas Plan

In addition, a Manual of Best Practice in Site Management of Environmental Matters and a Project Staff Health Program should be drafted and reviewed by an independent expert. To achieve a consistent approach such standards should be imposed by Government through the Concession Agreement.

5.4.6 Operations

The operational phase of a hydropower project is the longest period of the project life-cycle, and can last from decades to centuries. Operations should be based on the principle of adaptive management, underpinned by appropriate monitoring. Operating rules need to be continually evaluated and modified as warranted. The range of potential mitigation responses and measures incorporated during the feasibility and design stages (and as part of the EMMP) will determine the range of responses available during the operational phase of a project.

During operations, the hydropower operator needs to be actively involved in catchment management activities. Catchment management goals should include the minimisation of upstream or downstream changes that might affect HP operations. The operator needs to be aware of risks associated with new developments that might be linked to the creation of the impoundment, such as water quality risks associated with increased runoff from agricultural or industrial discharges or *in situ* activities such as aquaculture. Catchment management also needs to include the development and maintenance of communication systems to alert communities regarding the potential for extreme flows or other unusual events (e.g. sediment flushing).

Over the decades, operations will need to adapt to changing conditions associated with climate change, and changes to electrical transmission systems or energy markets. The development of upstream, downstream or tributary hydropower projects can also lead to the need for altering operations. These future ‘unknowns’ highlight the need for ongoing monitoring flexibility with respect to environmental mitigation measures.

The longevity of hydropower operations provides unique challenges to the hydropower sector, and successional planning and inter-generational information management is required for sustainable operations. Monitoring and reporting should be based on a systems approach to ensure that information and knowledge is efficiently stored and available for future generations.

5.5 Indicators and Monitoring

The ISH11 project (Improved Environmental and Socio-Economic Baseline Information for Hydropower Planning) identified information needs for hydropower projects over the project-life-cycle. Table 5.6 contains a summary of the range of indicators from the ISH11 projects that also is relevant for the ISH0306. When considering indicators and monitoring requirements for the various themes in this guideline, it is important to implement monitoring regimes that will provide adequate information at the required scales. For example, short term sediment transport information is required to understand the timing, seasonality and variability of sediment inputs, whilst the same information over years and decades is needed to assess how long-term sediment yields respond to upstream flow alterations, catchment land use changes or climate change. Similar considerations are also relevant for the other issues. Indicators and monitoring for ISH0306 is dealt with in detail for each theme in Volume 2, the Manual, and will be further developed and tailored to the Guidelines and Recommendations in the 2nd Interim and Final Phases.

Table. 5.6. *Indicators relevant to Hydropower developed by ISH11 (in grey of relevance for ISH0306).*

Discipline Area	Type of Parameter or Indicator	Parameter and Indicator Examples
Hydrology	Rainfall	Level, variability, extreme events
	Water level	fluctuations, attenuation
	Discharge	Patterns (frequency, magnitude, rate of change), seasonality
	Tidal flow dynamics	Current directions, velocities, timing
Water Quality	Physical	temperature, pH, electrical conductivity, dissolved oxygen, turbidity, total suspended solids (TSS)
	Chemical	ions, metals, nutrients, chemical oxygen demand
	Biological	Chlorophyll-a, Faecal coliforms
Sediments and Geomorph-ology	Sediment loads	Suspended sediment load, bedload
	Sediment characteristics	Grain size, organic content, nutrient content
	Morphology	Cross-section profiles, longitudinal channel profiles, planform features (e.g. channel sinuosity or braiding), changes in rate of channel migration, bank stability
	Habitat quantity & quality	e.g. coefficient in variability of depth; heterogeneity of current velocities; presence of large woody debris; land cover
	Tidal sediment dynamics	Rates of change and locations for transport, deposition, erosion
Aquatic Ecology	Macroinvertebrates	Abundance, richness, biomass, proportions, diversity of species or groups
	Selected taxa	e.g. mayflies, snails, bivalves, flagship species – abundance, condition
Fisheries	Fish and OOAs populations & biology	Species diversity, composition, abundance, biomass, size, condition
	Fishing activities	Number of fishers, boats, gear; catches as CPUE or consumption (kg/hh/yr)
Socio-economic	Economic development	Population growth rate; national income/expenses from/to hydropower; GDP; income level and distribution (including poverty); taxes and subsidies (related to hydropower); employment statistics; number and types of industries; electricity demand; urbanisation -

Discipline Area	Type of Parameter or Indicator	Parameter and Indicator Examples
		migration/urban growth; extent and production of irrigated areas; tourism; income mix.
	Livelihoods	Full-time and part-time fishers; access to riverbank gardens; number of HHs resettled; scale of river transport; scale of sand mining.
	Dependency on water-resources	% people fishing in river and connected wetlands; % of fish and OAA/P based diet
	Vulnerability and resilience	Poverty incidence; mobility (migration); education level; household size, dependency rate (household age structure); percent of households with non-aquatic sources of income.
	Community living conditions	Access to affordable electricity; access to services (health, education, water supply); employment; road types and density; investment levels; resettlements; culturally sensitive areas affected.
	Food security	Level of food security, including nutrition; freshwater/aquaculture/ marine fish and OAA/Ps in diet; CPUE.
	Benefit sharing	Access to and price of electricity for communities affected by hydropower; existence and levels of cash transfers to those.
	Capacity building	Reservoir stocking; cage aquaculture; resettlement; reservoir leisure and tourism activities.
	Climate change	National CO_2 emissions from power production; level of CDM funding of hydropower
	Hydropower plants	Numbers, location, size of hydropower plants of different types

5.6 Multicriteria Evaluation of Mitigation Recommendations

The multicriteria evaluation of mitigation guidelines, recommendations and options should be based on a combined economic and financial analysis together with an assessment of non-monetized environmental benefits, shortly described below and to be developed further during 2nd Interim and Final Phases. For the ISH0306 study, this will be rigourously tested in the Case Study during the 2nd Interim Phase, for selected mitigation options and scenarios. The **economic** assessment of alternative designs and operations, due to recommended mitigation options, should be through a comparison of indicators (net present value – NPV, economic internal rate of return – EIRR, benefit-cost ratio – B/C, etc.) calculated on the basis of net benefits (benefits minus costs valued in economic terms (alternative value)) over a time period of say 25 years of operation. This calculation will be net of all taxes, duties and subsidies. The **financial** assessment of alternative designs and operations, due to recommended mitigation guidelines, should be through a comparison of indicators (net present value – NPV, financial internal rate of return – FIRR, levelised power tariff, etc.) calculated on the basis of net cash flow (revenues minus costs) over a time period.

The economic and financial indicators above should then be weighted against a ranking of selected monetized and non-monetized environmental benefits and risks. Assessment of environmental benefits from proposed mitigation options (as described in Chapter 5.3) can be undertaken by use of some selected indicators described. All indicators can be ranked according to a scale from 0 (no positive impact) via 1 (small positive), 2 (medium positive), 3 (high positive) to 4 (very high positive) impacts of implementing the mitigation options. The indicators can them be pooled to come up with and overall ranking of monetized and non-monetized environmental benefits from the proposed mitigation measures.

Lastly the ranking of the non-monetized benefits can be weighted against the economic and financial assessment to come up with a final pooled multicriteria evaluation of the mitigation recommendations. This approach is also embedded in the Portifolio Planning Concept of ISH02 as portrayed below.

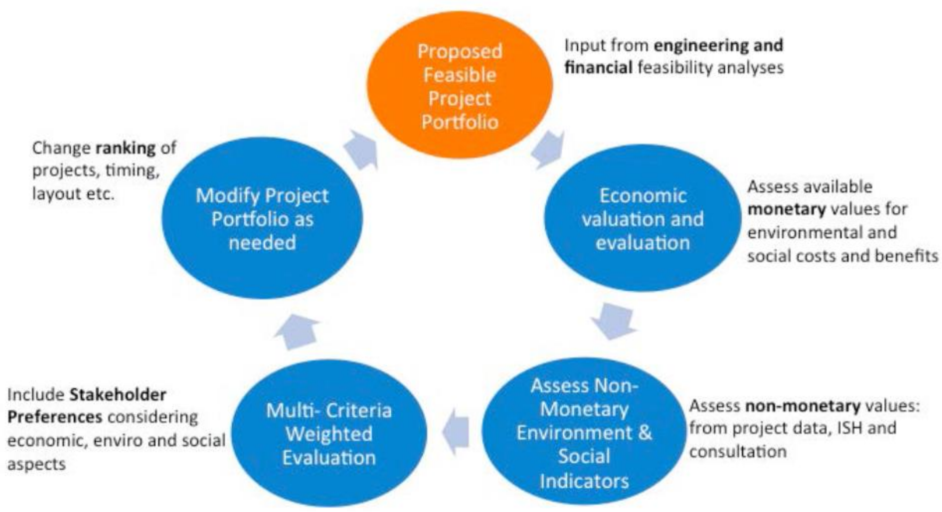

Figure 5.4. *The Portifolio Planning Concept for evaluation of hydropower and multipurpose planning portifolios (Source: MRC, 2015).*

6 Dam Safety Guidelines and Recommendations

The **Dam Safety Guidelines and Recommendations** is a stand alone delivery, and not so closely related to the **Hydropower Risks and Impact Mitigation Guidelines and Recommendations** in the previous chapters, albeit a clear deliverable in the ToR. Therefore it is in a separate Chapter with the recommendations outlined below.

General Considerations

Dam safety is a subject of paramount importance in hydropower development, and as such all risk areas that may affect safety during design, construction and operation should be taken into account. It is generally desirable to avoid a risk altogether rather than manage the consequences. Standard procedures around the world (e.g. The Construction (Design and Management) Regulations, UK Government, 2015) require designers to demonstrate that they have identified potential risks during construction, operation and de-commissioning and have taken steps to either remove the risk from their project layout, mitigate the risk by revised design outlines or provided effective warning and safety measures for residual risks. Where risks are unavoidable, suitable levels of risk for each project component should be defined. If defined levels cannot be achieved, then implementation should not proceed.

A consistent design approach is required following approved standards and guidelines, utilising safety factors that are sufficiently high and providing system redundancies. Seismic studies should be project-specific, based on conditions of the local area. Regional studies should not be accepted for final design. The selection of design floods standards, although varying widely around the world, should be undertaken using a common approach for all projects in the same river basin and should be in line with national legislation.

The design of hydropower projects should be undertaken bearing in mind future operation and maintenance of the schemes. As an example, isolating facilities should be considered in power tunnels and spillway bays for inspection and repairs, and provisions should be made for instrumentation for dam monitoring purposes (e.g. leakages and movements). At the Nam Ou 6 Hydropower Project, in the Luang Prabang province of Lao PDR, a geo-membrane rock fill dam has been adopted which is considered to be one of the highest in the world of this type. In order that the upstream face may be inspected and repaired in the future a drawdown tunnel has been provided in order to lower the water levels in the reservoir during the dry season. In addition there is no back fill or protection on the upstream face so that it will remain accessible. The upstream face of the dam prior to impounding is shown in Figure 6.1.

Figure 6.1. *Upstream face of the Nam Ou 6 dam, Lao PDR (Source: Multiconsult).*

Consideration should always be given to alternative design solutions to reduce or eliminate safety risks during operation by simply changing the layout of the project elements, eliminating high risk elements or introducing new project elements.

Gated Spillways

In general, gated spillways should be avoided; thus eliminating the risk of gate failure and operator error. Where gated spillways are unavoidable, it is essential to provide multiple redundancies of power supplies and related systems, and ensure that adequate opening and closing rates can be achieved.

It is unlikely that there will be any alternative to the adoption of gated spillways on the mainstream Mekong projects. A specific issue that requires consideration on these projects will be performance following a full load rejection by the generating units. For example, the Xayaburi project has a design generation discharge of 5,140 m^3/s and this discharge must be immediately transferred to the spillway in the event of a station trip, otherwise there would be an unacceptable impact on discharge and tail water level downstream.

At the Bujagali Hydropower Project, on the Victoria Nile, the service spillway is an air regulated siphon with a capacity equal to the full station load. If a station load rejection occurs there is very little time to open the bottom outlet gates and the siphon replaces the discharge of the power station with minimal reservoir surcharge. This arrangement is passive and intrinsically safe. A general view of the Bujagali Project is shown in Figure 6.2.

Figure 6.2. *General view of the Bujagali Hydropower Project, Uganda (Source: Multiconsult).*

Safety Plans

It is essential that a Hydro Safety Plan, an Emergency Preparedness Plan and a Flood Instruction Plan are all in place prior to reservoir impoundment.

A Hydro Safety Plan is required to protect operating staff and members of the public. Typically this plan includes measures such as safety fencing, security lighting, floating booms near the entrances of power intakes, spillways and other water releasing structures, warning signs near bodies of water that may be subject to changes in level, manned guardhouses and procedures to restrict access to authorised personnel only and audible warnings where flows are discharged. The plan should also require the engagement of the local community with the implementation of awareness programmes to inform major operational events (e.g. impoundment), safety incidents and project risks to be avoided.

An Emergency Preparedness Plan should identify issues during normal operation and maintenance that may lead to an emergency and require a specific response. Flow charts should be developed to determine the responsibilities and actions to be taken as the problems develop, whether they can be resolved or not. These actions may include monitoring at more frequent intervals, internal communications, modifying the operational parameters, repair works and notification to the public at risk. The plan should be developed in accordance with recognised international guidelines such as the Federal Guidelines for Dam Safety - Emergency Action Planning for Dam Owners, published by the Federal Emergency Management Agency, US Department of Homeland Security. Sections within the plan should include as a minimum:

Emergency identification and evaluation
Preventative Actions
Notification Procedures and Flowcharts
Responsibilities under the Plan
Preparedness
Downstream Impacts

The appendices to the plan should typically include:

Project Details
Operators Instructions
Reservoir Water Level Charts
Inundation Maps and Predicted Water Levels
Response during darkness and adverse weather
Communication systems
Emergency Supplies and Equipment Sources
Emergency Power Supplies
Access to Project Land and Structures
Training

A Flood Instruction Plan defines the procedures and responses required for the operation of gated spillways and outlets, ensuring that the safety of the dam and appurtenant structures is maintained at all times. The operational rules under normal conditions and during flood events should produce acceptable downstream releases for the community and the environment, avoiding releases larger than those prior to the construction of the project, sudden increases in water levels and out of bank discharges, where possible. In addition, procedures should be defined for the notification of downstream population centres and dam owners when large releases are expected.

Operation & maintenance manuals should be drafted to provide guidance for the safe operation of the project, instruct monitoring procedures and prevent the deterioration of the project elements, so that the project may fulfil its life cycle.

Expert Review

Design, construction and operational approaches and procedures should be reviewed by external experts from an early stage. It is frequently the case that external review is only commenced after Financial Close has been achieved. This always is too late since key design decisions will have been made by this stage that are contractually difficult to change.

The World Bank's Operational Policy 4.37 requires an independent panel, consisting of three or more experts, to review and advise on matters relative to dam safety and other critical aspects of the dam, its appurtenant structures, the catchment area, the area surrounding the reservoir and downstream areas. It is desirable to extend the terms of reference to cover other areas such as project layout, technical design, construction procedures and other project elements such as power facilities, river diversion during construction, navigation bypasses and fish passage arrangements. Alternatively, it may be preferable to appoint a consulting engineering company instead of an expert panel, as this could provide access to a broader range of expertise. In either case, it is essential that the recommendations given by the external party are taken into consideration.

REFERENCES

The full set of references for Volume 1 and Volume 2 of the 1st Interim Report with the supporting ISH0306 Knowledge Base is provided at the end of Volume 2 and not duplicated in this Volume 1.

ANNEXES

Annex 1: National and Regional Consultations and Workshop Proceedings

National Consultations and Workshop Proceedings – 1st Interim Phase

Workshops and Consultations Schedule

The National Consultations and Workshops of the 1st Interim Phase were held between 10 – 21st August 2015 in Cambodia, Lao PDR, Thailand and Vietnam. The schedule was as follows:

1) 10 – 11th August – National Consultation and Workshop, Cambodia. Venue: Angkor Paradise Hotel, Siem Reap.
2) 13 – 14th August – National Consultation and Workshop, Lao PDR. Venue: Thavonesouk Hotel, Van Vieng.
3) 17 – 18th August – National Consultation and Workshop, Thailand. Venue: Sofitel Sukhumvit Hotel, Bangkok.
4) 20 – 21st August - National Consultation and Workshop, Vietnam. Venue: Hoi An Hotel, Do Son.

Workshop agendas are outlined in the following:

National Workshop Objectives

- Consult on LMB priority hydropower risks, impacts and vulnerabilities
- Consult on good practice mitigation options for LMB and areas of mitigation improvements
- Consult on architecture, contents and details of preliminary Mitigation Guidelines and Recommendations Framework
- Consult on final Case Study modelling information needs

Agenda - Cambodia 10 – 11th August

Time	Topic	Responsible
Day 1 Session 1	**Theme: Priority Hydropower Risks, Impacts and Vulnerabilities**	
0830 – 0900	Registration	MRCS/ISH
0900 – 0910	Opening Address	NMC - Chair
0910 – 0930	The ISH Initiative and Background of ISH0306	ISH
0930 – 1000	The ISH0306 Study – *Reporting back main issues from the Inception Phase + Study Scoping and Planning*	Leif Lillehammer
1000 – 1010	Comments and discussions	Chair
1110 – 1020	Coffee/Tea break	
1020 – 1050	Priority hydropower risks, impacts and vulnerabilities – *Hydrology and downstream flows*	Ron Passchier
1050 – 1100	Comments and discussions	Chair
1100 – 1140	Priority hydropower risks, impacts and vulnerabilities – *Erosion, sediments, geomorphology and water quality*	Lois Koenhken
1140 – 1150	Comments and discussions	Chair
1150 – 1240	Luncheon	

Time	Topic	Responsible
1240 – 1320	Priority hydropower risks, impacts and vulnerabilities – *Aquatic Ecology and Fisheries*	Carina Mielach and Stefan Schmutz – presented by Leif Lillehammer
1320 – 1330	Comments and discussions	Chair
1330 – 1400	Priority hydropower risks, impacts and vulnerabilities – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer
1400 – 1410	Comments and discussions	Chair
1410 – 1430	*Case Study modelling*	Ron Passchier
1430 – 1440	Coffee/Tea break	
Session 2	**Theme: General Mitigation Options and Guidelines**	
1440 – 1520	General Project Mitigation Options – *Alternative schemes layout and dam safety risks assessment*	Chris Grant
1520 – 1530	Comments and discussions	Chair
1530 – 1600	General Project Mitigation Options – *Alternation of operation rules and joint operation. Technical possibilities and economic considerations*	Chris Grant
1600 – 1610	Comments and discussions	Chair
1610 – 1700	Comments and discussions/summing up day 1	Chair
Day 2		
0830 – 0840	Opening day 2	Chair
0840 – 0920	General Project Mitigation Options – *Erosion, sediments, geomorphology and water quality*	Lois Koehnken
0920 – 0930	Comments and discussions	Chair
0930 – 1010	General Project Mitigation Options – *Aquatic Ecology and Fisheries*	Carina Mielach and Stefan Schmutz – presented by Leif Lillehammer
1010 – 1020	Comments and discussions	Chair
1020 – 1030	Coffee/Tea break	
1030 – 1050	General Project Mitigation Options – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer
1050 – 1100	Comments and discussions	Chair
1100 – 1110	Plenary information about **Mitigation Guidelines and Recommendation Framework**	Leif Lillehammer
1100 - 1200	Group discussion about **Mitigation Guidelines and Recommendation Framework**	Facilitated by ISH and Consultant
1200 - 1230	Reporting back to plenary about **Mitigation Guidelines and Recommendation Framework**	Stakeholders facilitated by Chair
1230 – 1300	Closing remarks and summing up of workshop	ISH/Chair
1300	Luncheon	

Agenda - Lao PDR 13 – 14th August

Time	Topic	Responsible
Day 1		
0830 – 0900	Registration	MRCS/ISH
0900 – 0910	Opening Address	NMC - Chair
0910 – 0920	The ISH Initiative and Background of ISH0306	ISH
0920 – 0950	The ISH0306 Study – *Reporting back main issues from the Inception Phase + Study Scoping and Planning*	Leif Lillehammer
0950 – 1000	Comments and discussions	Chair
1000 – 1010	Coffee/Tea break	
1010 – 1040	Priority hydropower risks, impacts and vulnerabilities – *Hydrology and downstream flows*	Ron Passchier
1040 – 1050	Comments and discussions	Chair
1050 – 1120	Priority hydropower risks, impacts and vulnerabilities – *Erosion, sediments, geomorphology and water quality*	Lois Koehnken
1120 – 1130	Comments and discussions	Chair
1130 – 1220	General Project Mitigation Options – *Erosion, sediments, geomorphology and water quality*	Lois Koehnken
1220 – 1230	Comments and discussions	Chair
1230 – 1320	Luncheon	
1320 – 1350	Priority hydropower risks, impacts and vulnerabilities – *Aquatic Ecology and Fisheries*	Carina Seliger
1350 – 1400	Comments and discussions	Chair
1400 – 1440	General Project Mitigation Options – *Aquatic Ecology and Fisheries*	Carina Seliger
1440 – 1450	Comments and discussions	Chair
1450 – 1500	Coffee/Tea break	
1500 – 1520	Priority hydropower risks, impacts and vulnerabilities – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer
1520 – 1530	Comments and discussions	Chair
1530 – 1550	General Project Mitigation Options – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer
1550 – 1600	Comments and discussions	Chair
1600 – 1640	General Project Mitigation Options – *Alternative schemes layout and dam safety risks assessment*	Chris Grant
1640 – 1650	Comments and discussions	Chair
1650 – 1720	General Project Mitigation Options – *Alternation of operation rules and joint operation. Technical possibilities and economic considerations*	Chris Grant
1720 – 1730	Comments and discussions/summing up day 1	Chair
Day 2		
0830 – 0840	Opening day 2	Chair
0840 – 0910	*Case Study modelling*	Ron Passchier
0910 - 0930	Comments and discussions	Chair
0930 – 0950	Plenary information about **Mitigation Guidelines and Recommendation Framework**	Leif Lillehammer
0950 - 1130	Group discussion about **Mitigation Guidelines and Recommendation Framework**	Facilitated by ISH and Consultant
1130 - 1200	Reporting back to plenary about **Mitigation Guidelines and Recommendation Framework**	Stakeholders facilitated by Chair

Time	Topic	Responsible
1200 – 1230	Closing remarks and summing up of workshop	ISH/Chair
1230	Luncheon	

Agenda - Thailand 17 – 18th August

Time	Topic	Responsible
Day 1		
0830 – 0900	Registration	MRCS/ISH
0900 – 0910	Opening Address	NMC - Chair
0910 – 0920	The ISH Initiative and Background of ISH0306	ISH
0920 – 0950	The ISH0306 Study – *Reporting back main issues from the Inception Phase + Study Scoping and Planning*	Leif Lillehammer
0950 – 1010	Comments and discussions	Chair
1010 – 1020	Coffee/Tea break	
1020 – 1050	Priority hydropower risks, impacts and vulnerabilities – *Hydrology and downstream flows*	Ron Passchier
1050 – 1110	Comments and discussions	Chair
1110 – 1140	Priority hydropower risks, impacts and vulnerabilities –*Geomorphology, sediments and water quality*	Lois Koehnken
1140 – 1200	Comments and discussions	Chair
1200 - 1300	Luncheon	
1300 – 1340	General Project Mitigation Options –*Geomorphology, sediments and water quality*	Lois Koehnken
1340 – 1400	Comments and discussions	Chair
1400 – 1430	Priority hydropower risks, impacts and vulnerabilities – *Aquatic Ecology and Fisheries*	Carina Seliger
1430 – 1450	Comments and discussions	Chair
1450 – 1530	General Project Mitigation Options – *Aquatic Ecology and Fisheries*	Carina Seliger
1530 – 1550	Comments and discussions	Chair
1550 – 1600	Coffee/Tea break	
1600 – 1620	Priority hydropower risks, impacts and vulnerabilities – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer
1620 – 1630	Comments and discussions	Chair
1630 – 1650	General Project Mitigation Options – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer
1650 – 1710	Comments and discussions/summing up day 1	Chair
Day 2		
0830 – 0840	Opening day 2	
0840 – 0920	General Project Mitigation Options – *Alternative schemes layout and dam safety risks assessment*	Chris Grant
0920 – 0940	Comments and discussions	Chair
0940 – 1020	General Project Mitigation Options – *Alternation of operation rules and joint operation. Technical possibilities and economic considerations*	Chris Grant
1020 – 1040	Comments and discussions	Chair
1040 – 1110	*Case Study modelling*	Ron Passchier
1110 – 1130	Comments and discussions	Chair

Time	Topic	Responsible
1130 – 1300	Luncheon	
1300 – 1530	Plenary discussion about **Mitigation Guidelines and Recommendation Framework**	Facilitated by Chair – Information by Consultant
1530 – 1600	Closing remarks and summing up of workshop	ISH/Chair

Agenda - Vietnam 20 – 21st August

Time	Topic	Responsible
Day 1		
0830 – 0900	Registration	MRCS/ISH
0900 – 0910	Opening Address	NMC - Chair
0910 – 0920	The ISH Initiative and Background of ISH0306	ISH
0920 – 0950	The ISH0306 Study – *Reporting back main issues from the Inception Phase + Study Scoping and Planning and Overview Mitigation Guidelines*	Leif Lillehammer
0950 – 1010	Comments and discussions	Chair
1010 – 1020	Coffee/Tea break	
1020 – 1050	Priority hydropower risks, impacts and vulnerabilities – *Hydrology and downstream flows*	Ron Passchier
1050 – 1110	Comments and discussions	Chair
1110 – 1140	Priority hydropower risks, impacts and vulnerabilities –*Geomorphology, sediments and water quality*	Lois Koehnken
1140 – 1200	Comments and discussions	Chair
1200 - 1300	Luncheon	
1300 – 1340	General Project Mitigation Options –*Geomorphology, sediments and water quality*	Lois Koehnken
1340 – 1400	Comments and discussions	Chair
1400 – 1430	Priority hydropower risks, impacts and vulnerabilities – *Aquatic Ecology and Fisheries*	Carina Seliger
1430 – 1450	Comments and discussions	Chair
1450 – 1530	General Project Mitigation Options – *Aquatic Ecology and Fisheries*	Carina Seliger
1530 – 1550	Comments and discussions	Chair
1550 – 1600	Coffee/Tea break	
1600 – 1620	Priority hydropower risks, impacts and vulnerabilities – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer
1620 – 1630	Comments and discussions	Chair
1630 – 1650	General Project Mitigation Options – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer
1650 – 1710	Comments and discussions/summing up day 1	Chair
Day 2		
0830 – 0840	Opening day 2	
0840 – 0920	General Project Mitigation Options – *Alternative schemes layout and dam safety risks assessment*	Chris Grant
0920 – 0940	Comments and discussions	Chair

Time	Topic	Responsible
0940 – 1020	General Project Mitigation Options – *Alternation of operation rules and joint operation. Technical possibilities and economic considerations*	Chris Grant
1020 – 1040	Comments and discussions	Chair
1040 – 1110	*Case Study modelling*	Ron Passchier
1110 – 1130	Comments and discussions	Chair
1130 – 1300	Luncheon	
1300 – 1500	Plenary discussion about **Mitigation Guidelines and Recommendation Framework**	Facilitated by Chair – Consultant informed
1530 – 1600	Closing remarks and summing up of workshop	ISH/Chair

Consultations and Discussions – Main Issues

General

- Presentation and communication of the technical outputs of the project will be critical to its success.
- Chapters should be consistent in their layout and treatment of risks and mitigation, including the treatment of mainstream and tributaries and "eco-regions" clearly defined in the document structure.
    - Tables of Pressures/risks/impacts should be presented in each section in a consistent way.
    - Mitigation options should then also be presented.
    - Consideration should be given to the modification of the diagrams representing the study "workflow" and the modelling approach.
    - Connections to the Council Study inputs and outputs should also be clear (diagrammatically).
    - Clear sources should be provided in all sections/figures.
- Early attention should be given to options for web based publication of the Guidelines (with the ISH).
- The relationships between the PDG and the ISH0306 Guidelines should be clear. An example framework also to build on is the Danube Sustainable Hydropower Development Guidelines Framework (ICPDR, 2013).
- A concept paper on the "Case Study" will be prepared for inclusion in the Interim Report #1.
    - Scenarios: There was some discussion on the appropriateness of 2040 Scenario. ISH will clarify this in due course.
    - A number of sub-scenarios were agreed – these will be described and presented in September 2015.
    - There is need to ensure credibility of inputs and data by referring to DSF and MRC Council Study sources wherever possible (Thailand).
- "Dam Safety GL for ISH" was raised by Vietnam. ISH will confirm what is meant by this.
- It was agreed that wider "ideas" of possible technologies may be presented but clear reference should be made to the "most appropriate" method.

- Research concept notes should be more defined and specific where possible i.e. they should allow consideration by funding agencies and research organisations.
- Mitigation Framework:
    - Less project phases (columns) will be considered to make it easier to read and interpret.
    - Should be presented separately in each thematic section (separate pressures/impacts table then mitigations table) in the 1st Interim Report.
    - There is a need to enhance the conceptual explanation.
- Terms used need to be clearly defined (e.g. restoration, compensation etc.)
- There is need to consider how and whether ISH0306 deals to the larger issue of mitigation of "China Dams". Refer to the Council Study.

By Country

Cambodia

- Explain possible flow changes along LMB more in detail, including looking at runoff per unit area, and looking at the timing of the onset of the flood season.
- 3S contribution of 23% of the flow. Question was raised about the basis of the calculation behind this.
- On sediments and water quality stakeholders asked the consultant to include assessment of mercury related to hydropower development as well as the same for algal blooms.
- The Cambodian delegation raised concern about using Xayaburi as an example of good practise (fisheries, sediment flushing e.g.) as there has been no consensus from the countries, and some countries have not yet reviewed the project
- On the Mitigation Guidelines the main comment was that Cambodia does not have the resources to complete Master Plan and Pre-Feasibility Level studies so need to rely on the developer's investigations. .
- The Mekong Dolphin should be given consideration in the biodiversity context as there are very low numbers of this species remaining.
- There was concern about which species are used as example species for each of the fish guilds with respect to fish passage.
- There was interest in the issues of offset compensation and benefit sharing, although it was discussed that this is outside of the scope of this project, but being looked at in another ISH project.

Lao PDR

- SEA and TdEIA are not considered in Lao PDR. Suggestions to take it out from the Mitigation Guidelines. This refers also to the next bullet-point.
- On the Mitigation Guidelines the main comment was that Lao PDR does not see the need or undertake this at Master Plan and Pre-Feasibility Level.
- Be more balanced related to both positive and negative impacts, e.g. also include benefits from hydropower development (such as flood mitigation). Should also be included in the Mitigation Guidelines, e.g. for example through Benefit Sharing mechanisms.

- Participants noted that the transpboundary EdEIA process has not been approved by all countries
- Participants also commented that this type of study should include impacts from irrigation, industrial exploitation etc. and not linking impacts only to hydropower development as this might become quite biased.
- The cascade might only consist of 5 HPP's and not 6. Should be clarified.
- On the issue of adaptive management (presented by Lois) suggestions was that the Consultants need to use proven technology or methodology.
- On sediments, the Consultant should include assessment of nutrients and sediment grain size changes.
- Number of total fish species varies from different sources. Should be looked into. Update of fish data should be through the MRC fisheries program.
- Questions were raised about the applicability for Mekong on the proposed aquatic ecology and fisheries mitigation measures. The consultant has prepared summary tables for this which will be further studied and exemplified in detail.
- Efficiency of the fish friendly (or less fish harmful) turbines should be looked into.
- Participants also commented that most examples given come from Europe, and not from the region or from tropical rivers like the Mekong.
- The ecological health monitoring tool from the MRC should be looked into, as Lao participants suggested it would be a good input to the study.
- Participants commented that the impacts about areas (the forest for example) with higher biodiversity than wetlands should be included in the study. This will be looked into, but forestry impacts is more local in nature and not so much related to mainstream/transboundary impacts.
- Participants proposed that the study team covers all data and all species in the next phases rather than only the wetland and only the fish.
- Consultant should compare standards on mitigation between the 4 countries.
- Include Climate Change in the assessment.
- An open source model should be used for the HP modelling, e.g. HecResSim instead of Mike 11.
- The impacts and mitigation assessment should distinguish those between tributaries and mainstream.

<u>Thailand</u>

- Separate the impacts and mitigation assessment related to basin sub-sections (all thematic areas).
- There is also large impacts from major irrigation developments, studied by the WUP-FIN Team amongst others.
- Tonle Sap system is also impacted by local development.
- Consultant should document the source of their results more clearly, and also clearly distinguish between their own results and other sources.
- Consultant should find means to get information on flow etc. from the Lancang part of Mekong.
- Reservoir stratification not so much an issue for the mainstream dams but Lancang dams stratifies, and some tributary dams stratify seasonally.
- Consultant should utilize MRC WQ monitoring program.

- As for Lao PDR, questions were raised according to the applicability of example fish passes for the Mekong.
- Related to monitoring of the success of fish passages a question was raised related to what will be the timeframe (length) of the monitoring. This will vary from project to project.
- Stakeholders questioned the functionality of the Xayaburi fish passage.
- Consultant should seek more information on fish larvae and eggs through MRC Fisheries Program.
- Consultants should update status of protected areas assessed.
- On the proposed Mitigation Guidelines framework Thailand stated that they will have more detailed internal discussions about it with line agencies in September 2015.

Vietnam

- Consultant should describe more in detail the methodology of the development of the Mitigation Guidelines, and also include risks.
- Consultant should learn from previous international lessons on Mitigation Guidelines.
- Consultant should include impacts and mitigation options for livelihood in their assessment.
- Consultant should clearly describe method of identifying flow change in various impact zones. Then use this to assess impacts on sectors.
- Stakeholders informed that an increase in dry season flows and a decrease in wet season flows is currently observed in the Delta with impacts on salt-water intrusion and irrigation.
- Consultants should try to get info on flows from the Lancang cascade.
- Risks need to be prioritised and biodiversity should focus on specific issues.
- Impacts and guidelines should also include geographical focus.
- Consultant should interact with the Delta Study, and also study saline intrusion in the delta.
- Consultant should utilize the Vietnam experience in developing Joint Operation Rules for cascade development.
- On sediments and geomorphology from Kratie to Delta, the Consultants should look into their findings on risks and impacts as they do not totally match with other reports (e.g. consider findings from the Delta Study).
- The Mitigation Guidelines should also include those of siting of dams, ways to manage the reservoirs and risk assessment management.
- Consultant should be more balanced on costs and impacts versus benefits.
- The Mitigation Guidelines should be realistic and pragmatic for LMB.
- Related to the Case Study the year of baseline should align with that of the Delta Study.
- Stakeholders expressed doubts about using the 2040 scenario related to its applicability.
- Consultant should more clearly define the concept of ecosystem services.
- The Mitigation Guidelines should be detailed as much as possible but should also be a little open for adaptions.
- The 1st Interim Report should also include a list of indicators used in the assessment.
- The study team should consult on already existing guidelines.
- The study should enhance information sharing on a timely basis and keep contact with the NMC's regularly.

List of Stakeholder Participants at the Workshops

Siem Reap, Cambodia, 10-11 August

No.	Name & Surname	Position	Organisation
1	H.E. Mr. Te Navuth	Secretary General	CNMC
2	H.E. Mr. Kol Vathana	D. Secretary General	CNMC
3	H.E. Mr. Long Saravuth	D. Secretary General	CNMC
4	Mr. Heng Sovannara	Deputy Director	OFE/FIA
5	Mr. Dok Doma	Deputy Director	MRD
6	Chheang Hong	Director of IKM Dept.	CNMC
7	Hak Socheat	Nat FMM Coordinator	CNMC
8	Phin Rady	Deputy Director	MoE
9	Tong Seng	Chief of Office	MOWRAM
10	Chea Leng	Director Division	MoE
11	Thach Sovanna	Deputy Director	MOWRAM
12	Sok Khom	FP Coordinator	CNMC
13	Thay Piseth	Nat. EP Coordinator	CNMC
14	Chy Chanrasmey	Deputy Director	MME
15	Chheng Phen	Deputy Director	IFReDI
16	Tai Pallay	Environment Program Manager	NGO Forum
17	Heng Sokchay	National Consultant	CNMC
18	So Sokha	Deputy Director	CNMC
19	Kim Lay		CNMC
20	Kong Lamielpsey	ISH Assistant	CNMC
21	Uoy Suthy	Translator	
22	Leif Lillehammer	Team Leader	Multiconsult
23	Ron Passchier	Hydrologist and Water Resources Modeller	Deltares
24	Carina Seliger	Fisheries & Aquatic Ecol.	BOKU University
25	Chris Grant	Hydropower Design and Operations	Multiconsult UK
26	Lois Koehnken	MRC Sediment Expert	Private consultant
27	Simon Krohn	ITA	MRC
28	Chea Piseth	Program Officer	MRC

Van Vieng, Laos, 13-14 August 2015

No.	Name & Surname	Position	Organisation
1	Dr. Daovong Phonekeo	Director General	Department of Policy and Ennergy Planning
2	Mr. Somphanh Phanouvith	Deputy Director of section	LARReL
3	Mr. Aliyasack Tounalom	Deputy Centre of Energy	DESIA.MONRE
4	Mr. Bounthanom Chamsing	Deputy chief of Fisheries Section	DLF

No.	Name & Surname	Position	Organisation
5	Mr. Prasith Dimanivong		DMH
6	Mr. Khonsavanh Louangraj	Director of Division	DEQP-MONRE
7	Mr. Soukkaseum Chanthapanya	Deputy of Division	DID,LNMCS
8	Mr. Sengduangdeuan Phouthanoxay	Deputy of Unit	DMH
9	Dr. Bounsavane Douangboubpha	Lecturer	Faculty of Environmental Sciences, NOUL
10	Mr. Somphone	Technical	NRW, Vangvieng
11	Lois Koehnken	MRC Sediment Expert	Private Consultant
12	Simon Krohn	ITA	MRC
13	Thipsathiane Khamvongsa	National Consultant	LNMCS,MONRE
14	Leif Lillehammer	Team Leader	Multiconsult
15	Ron Passchier	Hydrologist and Water Resources Modeller	Deltares
16	Carina Seliger	Fisheries & Aquatic Ecol.	BOKU University
17	Chris Grant	Hydropower Design and Operations	Multiconsult UK
18	Ms. Nongnout Phanphongsa	Technical staff	Natural Resources and Environment Institute
19	Ms.Daovinh Souphonphacdy	Technical staff	EP, LNMCS
20	Mr. Vilaboun Chitthanousone	Deputy chief of Division	DEIB,MEM
21	Mr. Lamphone Dimanivong	Deputy chief of Division	DEPP, MEM
22	Dr. Phoukhong Sengvilay	Deputy chief of Division	DEM/MEM
23	Mr. Bouavone Biakomebrou	Deputy chief of Division	LNMCS
24	Mr. Souksakhone Chanthavong	Technical staff	DWR
25	Mr. Oudone Khounsavanh	Deputy chief of Division	DLF
26	Mr. Thongthip Chandalasane	National ISH Coordinator	LNMCS
27	Mr. Keomany Louanglith	Chief of Division	LNMCS
28	Mr. Khamsone Philavong	Deputy chief of Division	LNMCS
29	Ms. Thepphachanh Xaobootdavong	Technical staff	LNMCS
30	Mr. Phetsamone Keovongvichith	Acting Director of Intergovernmental Organisation Division	MOFA
31	Ms. Dalaphone	Translator	
32	Ms. Somsangvane Keovilay	Technical staff	DEPP, MEM
33	Mr. Thongsay	Technical staff	Department of Inspection
34	Ms. Pany Khamtachanhome	Technical officer	BDPD, LNMCS
35	Ms. Tiw Phimthong	Technical officer	DDMCC, MONRE
36	Mr. samko Sorinxay	Technical officer	ASOEN, LNMCS

Bangkok, Thailand, 17 – 18 August 2015

No.	Name & Surname	Position	Organisation
1	Mr. Nirut Koonphol	Director, Bureau of International Cooperation, Bureau of Mekong	Department of Water Resources
2	Ms. Nuanlaor Wongpinitwarodom	Policy and Plan Analyst, Senior Professional Level	Department of Water Resources
3	Assoc. Prof. Chayiuth Sukhsri	TNMC Advisor/Hydrologist Expert	Department of Water Resources
4	Mr. Nirat Puriphanphinyo	Civil Engineer, Senior Professional Level	Department of Water Resources
5	Mrs. Ruampom Ngamboriruk	Policy and Plan Analyst, Professional Level	Department of Water Resources
6	Mr. Winai Wangpimool	Civil Engineer, Professional Level	Department of Water Resources
7	Mrs. Kareema Wongsin	Policy and Plan Analyst, Professional Level	Department of Water Resources
8	Ms. Thitima Phuavong	Assistant to National EP Coordinator	Department of Water Resources
9	Ms. Saranpat Piriyaprasit	Assistant to National ISH Coordinator	Department of Water Resources
10	Dr. Apichart Termwitchakom	Senior Expert Fisheries	
11	Mr. Cherid Kalayanamitr	Chief of Social and Health Impact Department	EGAT
12	Mr. Sakpinit Padungkij	Senior Expert – Environmental Impacts	Office of Project Management, Royal Irrigation Department
13	Mrs. Intanin Incchayanuth	Environmentalist, Senior Professional Level	Environmental Impact Evaluation Bureau
14	Mr. Chavalit Jiravichailit	Civil Engineer, Senior Professional Level	Department of Alternative Energy Development and Efficiency
15	Mr. Direct Kongpare	Soil Survey, Senior Professional Level	Department of Land Development
16	Mr. Prayuth Graiprab	Civil Engineer, Senior Professional Level	Department of Water Resources
17	Mrs. Wandee Pattanasatianpong	Scientist, Senior Professional Level	Bureau of Research, Development and Hydrology
18	Ms. Chanikam Chotima	Fishery Biologist, Professional Level	Department of Fisheries
19	Ms. Sirisuda Jamnongsog	Lecturer at Faculty of Fisheries	Kasetsart University
20	Dr. Piyatida Ruangrassamee	Lecturer	Faculty of Engineering, Chulalongkom University
21	Mr. Nipon Munmueangsaen		
22	Mr. Gun Wongarch		
23	Mr. Panaboon Ritthidej	Harbour Master	Marine Department
24	Mr. Abdulkoffa Leeyao	Environmentalist, Practitioner Level	Pollution Control Department, MONRE
25	Ms. Aim-on Pruksuriya	Policy and Plan Analyst	Office of the National Economic and Social Development Board

No.	Name & Surname	Position	Organisation
26	Mr. Pavisorn Chuenchum	MA Student	Faculty of Engineering, Chulalonkorn University
27	Mr. Voradeth Phonekeo	ISH Consultant	MRCS
28	Mr. Simon Krohn	ITA	MRCS
29	Mr. Leif Lillehammer	Team Leader	Multiconsult
30	Mr. Chris Grant	Hydropower Design and Operation Expert	Multiconsult UK
31	Mr. Ron Passchier	Hydrologist and Water Resources Modeller	Deltares
32	Dr. Lois Koehnken	Sediment and Water Quality Expert	Private Consultant
33	Mrs. Carina Seliger	Fishery and Aquatic Ecology Expert	BOKU

Do Son, Hai Phong City, Vietnam, 20-21 August 2015

No.	Name & Surname	Position	Organisation
	From Hanoi		
1	Dr. Le Duc Trung	Director General	Viet Nam National Mekong Committee (VNMC)
2	Mr. Tran Duc Cuong	Deputy DG	Viet Nam National Mekong Committee (VNMC)
3	Mr. Nguyen Van Bang	Senior staff	ISH National Coordinator, VNMC
4	Mr. Thai Minh Quang	Senior staff	Viet Nam National Mekong Committee (VNMC)
5	Mr. Nguyen Hai Thanh	Senior staff	Viet Nam National Mekong Committee (VNMC)
6	Dr. Nguyen Quang Trung	National Consultant	Institute of Water Resources and Environment
7	Ms. Le Thi Viet Hoa	Head of Division	Department of Water Resource Management, MONRE
8	Dr. Nguyen Tien Giang	Deputy Director	National University of Science and Nature
9	Dr. Ngo Le Long	Head of Division	Hanoi University of Water Resources
10	Mr. Tran Quoc Lap	Senior staff	Electricity of Viet Nam
11	Mr. Nguyen Quang Luan	Researcher	Institute for Hydropower and Renewable Energy
12	Mr. Tran Xuan Thai	Hydrology Expert	Association of Large Dam and Water Resources Development
13	Mr. Tran Ngoc Duong	Senior staff	Research Center for Hydrology and Water Resources
14	Mr. Doan Manh Cuong	Interpreter	
15	Mr. Ly Quoc Trung	Interpreter	
	From HCM, Can Tho and Central Highland		
16	Mr. Tran Minh Khoi	Senior staff	EP National Coordinator, VNMC
17	Mr. Pham Khac Thuan	Senior staff	Southern Institute of Water Resources Research

No.	Name & Surname	Position	Organisation
18	Mr. Tran Tuan Hoang	Senior staff	Sub-institute of Meteorology, Hydrology and Environment
19	Mr. Tran Quang Tho	Deputy Division Head	Southern Institute of Water Resources Planning
20	Mr. Nguyen Van Ninh	Senior staff	Division for Water Resources Planning and Investigation for the South of Viet Nam
21	Mr. Le Khac Hieu	Researcher	Southern Institute for Fisheries Planning
22	Mr. Tran Van Thin	Lecturer	University of Water Resources, HCM
23	Mr. Pham Quoc Hung	Senior staff	Research Institute for Aquaculture
24	Mr. Ha Phuoc Hung	Division Head	Can Tho University
25	Mr. Nguyen Minh Chien	Researcher	Can Tho University
26	Mr. Pham Van Tinh	Senior staff	DARD, Dak Lak province
27	Mr. Nguyen Nhat Quang	Senior staff	DARD, Gia Lai province
	From MRC and ISH0306		
28	Mr. Simon Krohn	ITA	MRCS
29	Mr. Leif Lillehammer	Team Leader	Multiconsult
30	Mr. Chris Grant	Hydropower Design and Operation Expert	Multiconsult UK
31	Mr. Ron Passchier	Hydrologist and Water Resources Modeller	Deltares
32	Dr. Lois Koehnken	Sediment and Water Quality Expert	Private Consultant
33	Mrs. Carina Seliger	Fishery and Aquatic Ecology Expert	BOKU

Regional Consultation and Workshop, 1st Interim Phase - Phnomh Penh, Cambodia, 18-19 November 2015

Objectives

- Consult on LMB priority hydropower risks, impacts and vulnerabilities
- Consult on good practice mitigation options for LMB and areas of mitigation improvements
- Consult on Preliminary Mitigation Guidelines and Recommendations
- Consult on Case Study approach and scenarios
-

Agenda

Time	Topic	Responsible
Day 1		
0830 – 0900	Registration	MRCS/ISH
0900 – 0910	Opening Address	Chair
0910 – 0920	The ISH Initiative and Background of ISH0306	ISH
0920 – 0940	The ISH0306 Study – Project Overview and *Mitigation Guidelines and Recommendations Framework*	Leif Lillehammer
0940 – 1030	Themes Input – *Key Hydropower Risks, Impacts and Vulnerabilities*	IC Expert Team (Kees, Lois, Stefan, Leif, Chris)
1030 – 1040	Coffee/Tea break	
1040 – 1200	Plenary Discussion - *Mitigation Guidelines and Recommendations Framework and Key Risks*	Chair
1200 - 1300	Luncheon	
1300 – 1330	Hydropower risks, impacts and vulnerabilities: *Hydrology and downstream flows - Main issues and research needs*	Kees Sloff
1330 – 1350	Comments and discussions	Chair
1350 – 1430	Hydropower risks, impacts, vulnerabilities and mitigation options: *Geomorphology, sediments and water quality – Priority cases and research needs*	Lois Koehnken
1430 – 1450	Comments and discussions	Chair
1450 - 1500	Coffee/Tea Break	
1500 – 1540	Hydropower risks, impacts, vulnerabilities and mitigation options: *Aquatic Ecology and Fisheries – Priority cases and research needs*	Stefan Schmutz
1540 – 1600	Comments and discussions	Chair
1600 – 1630	Hydropower risks, impacts, vulnerabilities and mitigation options – *Biodiversity, natural resources and ecosystem services*	Leif Lillehammer and Sophal Chhun
1630 – 1650	Comments and discussions	Chair
1650 – 1700	Summing up day 1	Chair
Day 2		
0830 – 0840	Opening day 2	
0840 – 0930	General Project Mitigation Options: *Alternative schemes layout, dam safety risks assessment, operation and economic considerations – Priorities,*	Chris Grant

Time	Topic	Responsible
	needs and challenges for Mekong mainstream and tributaries	
0930 – 1000	Comments and discussions	Chair
1000 – 1010	Coffee/Tea Break	
1010 – 1050	Planning for Second Interim Phase: *Case Study approach and scenarios – Activity 5*	Kees Sloff/Chris Grant supported by IC Expert Team
1050 – 1200	Comments and discussions	Chair
1200 – 1210	Closing remarks and summing up of workshop	ISH/Chair

List of Stakeholder Participants at the Workshop

List of participants

No	Name and Surname	Position/Organization
	Cambodia	
1	Mr. Sia Samnang	Director of Personnel and HRD Dept. and National DMP Coordinator, CNMC
2	Mr. Hean Veasna	Chief of Office, MME
3	Mr. Thong Sokvongsa	Chief of Office Dept. of water quality management, MOE
4	Dr Sopphal Chhun	National Coordination for ISH0306
5	Miss Kong Lamielpisey	Assistant for ISH, CNMC
	Lao PDR	
6	Mr. Khanmany Khounphonh	Deputy Director General, Department of Metrology and Hydrology
7	Mr. Sanya Somvichit	Director of Electricity General Planning, Department of policy and planning Energy
8	Mr. Lamphone Dimanivong	Deputy Director of Division, Department of Energy policy and planning
9	Mrs. Thipsathiane Khamvongsa	National Consultant LNMCS
10	Mr. Udone Khonsavanh	The Living Aquatic Resources Research Centre (LARReC)
11	Mrs. Lackdavone Valangkoun	Technical officer, LNMCS
12	Ms. Thepphachanh Xaoboutdavong	Technical, LNMCS
	Thailand	
13	Mr. Chaiyuth Sukhsri	TNMC member committee
14	Mr. Nirat Phuriphanhphinyo	Civil Engineer, Senior Professional Level
15	Dr. Apichart Termwitchakorn	Senior Expert on Fisheries
16	Mrs.Intanin Inchayanunth	Environmenalist, Senior Professional Level, ONEP
17	Mrs. Wandee Pattanasatianpong	Scientist, Senior Professional Level, Department of Water Resources, MONRE
18	Ms.Chanikarn Chotima	Department of Fisheries
19	Miss Oranuch Ratana	Policy and Plan Analyst, ONESD
20	Mrs. Sutara Yindeerod	Policy and Plan Analysis, Department of Land Management

Viet Nam		
21	Mr. Nguyen Van Bang	Senior VNMC staff, ISH National Coordinator
22	Mr. Thai Minh Quang	VNMC staff (from Hanoi)
23	Ms. Tran Thi Kim Hue	VNMC staff (from HCM)
24	Mr. Le Xuan Cau	Institute of Hydrometeorology and Climate Change (from Hanoi)
25	Ms. Vu Nguyen Hoang Giang	Southern Institute of Water Resources Research (from HCM city)
26	Mr. Truong Cong Truong	Divison for Water Resources Planning and Investigation for the Sourth of Viet Nam (from HCM city)
27	Mr. Tran Tuan Hoang	Sub-Institute of Hydrometeorology and Climate Change (from HCM city)
ISH MRCS		
28	Director Naruepon Sukumasavin	OIC, ISH and Director PLD
29	Mr. Voradeth Phonekeo	ISH Advisor
30	Mr. Simon Krohn	ITA, ISH
31	Ms. Praivan Limpanboon	PO/ISH MRC
32	Ms. Chanchouly Athanaphone	Programme Assistant, ISH
33	Dr So nam	MRC/FP
34	Mr. Vanna	CCAI
35	Mr. Henry Mangarra	CS/TCN
Speaker		
36	Mr. Leif Lillehammer	Multiconsult
37	Mr. Chris Grant	Multiconsult
38	Dr. Kees Sloff	Deltares
39	Dr Lois Koehnken	Consultant
40	Stefan Schmutz	Consultant

Main Comments and Agreements from the Workshop

General

- National matrix (risks and mitigation) inputs to be included in the draft Guidelines and shared with other member countries.
- Comments on the layout of the Guidelines well received; additional comments and suggestions by email.
- Previous studies (e.g. WUP) to be reviewed.
- Lessons learned from use of PDG to be included.
- Dissemination very important.

Consult on LMB priority hydropower risks, impacts and vulnerabilities

- Comments will be included in the revised version 1.0
- Format to clearly set out the process.
- Separate out causal factors (e.g. China and tributary dams).

- General consensus that key risks are covered in Version 1.0 (check with the National Matrices)

Consult on Mitigation Guidelines and Recommendations Framework

- Three volumes sent to NMC for review
- Additional comments from NMC to be sent by email.
- Framework generally agreed:
  - Guidelines – general based on MA95 and PDG
  - Manual – specific details of the technical methods, design parameters etc
  - Knowledge base – format to be refined.
- Table (2.1) /Matrix to be reviewed based on revised layout and sent back to MC for comment.
- Table needs to be specific and clear on the risks and mitigations.
- Link Table 2.1 to the more detailed description of the risks, impacts and mitigation options in Manual.

Consult on Case Study approach, scenarios and modelling

- Update Volume 3 the scoping of the case studies and have it sent to MCs
- MCs send any further comments to MRC/ISH.