**SOUTHEAST ASIA REGION**
**MEKONG RIVER COMMISSION(MRC)**

# THE STUDY ON DATA COLLECTION SURVEY ON THE BASIN MANAGEMENT AND ENVIRONMENTAL CONSERVATION IN MEKONG RIVER BASIN

## FINAL REPORT

**September 2019**

**JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)**

**CTI ENGINEERING INTERNATIONAL CO., LTD.**
**PASCO CORPORATION**
**JAPAN OVERSEAS FORESTRY CONSULTANTS ASSOCIATION**

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**Location Map**


**Location Map (Overlaying with LANDSAT Scene)**

**Location Map**

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## ABBREVIATIONS

Organizations, Programs and Projects

| | | |
|---|---|---|
| AAN | : | Alternative Agricultural Network *Thailand's NGO |
| ADPC | : | Asian Disaster Preparedness Center |
| ADB | : | Asian Development Bank |
| CDP | : | Carbon Disclosure Project * international NGO |
| CTII | : | CTI Engineering International Co., Ltd. |
| EU | : | European Union |
| FAO | : | Food and Agriculture Organization |
| FSC | : | Forest Stewardship Council |
| ICHARM | : | International Centre for Water Hazard and Risk Management |
| IPCC | : | Intergovernmental Panel on Climate Change |
| JICA | : | Japan International Cooperation Agency |
| JOFCA | : | Japan Overseas Forestry Consultants Association |
| JST | : | JICA Study Team |
| MRC | : | Mekong River Commission |
| NMC | : | National Mekong Committee |
| PASCO | : | PASCO CORPORATION |
| WB | : | World Bank |

Technical Terms

| | | |
|---|---|---|
| AE | : | Accredited Entities |
| AR-CDM | : | Afforestation/Reforestation Clean Development Mechanism |
| CBET | : | Community-Based Eco-Tourism |
| CDM | : | Clean Development Mechanism |
| CoC | : | Chain of Custody |
| COD | : | Chemical Oxygen Demand |
| EIA | : | Environmental Impact Assessment |
| Eco-DRR | : | Ecosystem-Based Disaster Risk Reduction |
| ELC | : | Economic Land Concession |
| ESG | : | Environmental, Social and Governance |
| FRL | : | Forest Reference Level |
| GCM | : | Global Climate Model |

| | | |
|---|---|---|
| GDP | : | Gross Domestic Product |
| GHG | : | Green House Gases |
| IQQM | : | Water Quantity and Quality Simulation Model |
| NFMS | : | National Forest Monitoring System |
| NRS | : | National REDD+ Strategy |
| NTFPs | : | Non-Timber Forest Products |
| PES | : | Payment for Ecosystem Services |
| PFES | : | Payment for Forest Environmental Services |
| PPP | : | Public Private Partnership |
| RCP | : | Representative Concentration Pathways |
| RRI | : | Rainfall Runoff Inundation |
| SIS | : | Safeguard Information System |
| SWAT | : | Soil and Water Assessment Tool |
| TOTP | : | Total Phosphorus *T-P |
| TSS | : | Total Suspended Solid |

Others

| | | |
|---|---|---|
| AR5 | : | Fifth Assessment Report |
| BAU | : | Business As Usual |
| C/P | : | Counterpart |
| D/FR | : | Draft Final Report |
| FR | : | Final Report |
| GCF | : | Green Climate Fund |
| GIS | : | Geographical Information System |
| LANDSAT | : | Land Satellite |
| LMB | : | Lower Mekong Basin |
| NGO | : | Non-governmental Organization |
| ODA | : | Official Development Assistance |
| REDD+ | : | Reduction of Emission from Deforestation and forest Degradation |
| R-PP | : | Readiness Preparation Proposal |
| SDGs | : | Sustainable Development Goals |
| UMB | : | Upper Mekong Basin |
| UNDP | : | United Nations Development Programme |
| UNFCCC | : | United Nations Framework Convention on Climate Change |

# EXECUTIVE SUMMARY

## 1. OUTLINE OF THE STUDY

### 1.1 Background

The Mekong River is one of the major international rivers with a catchment area of some 795,000 $km^2$ and its basin lies over six countries. The river originates in Tibet Plateau, flowing south in the mountainous areas in China's Yunnan Province, then formulates a national border of Republic of the Union of Myanmar (Myanmar) and the Lao People's Democratic Republic (Lao PDR). It flows down south in the territory of Lao PDR then formulates a national border of Lao PDR and Kingdom of Thailand (Thailand). The river further flows down in the southern areas of Lao PDR and through the territory of the Kingdom of Cambodia (Cambodia), then formulates Mekong delta in the territory of Socialist Republic of Viet Nam (Viet Nam) and flows into the South China Sea. The Mekong River Basin is indispensable natural resource for the livelihood of the area's people in the aspect of food, water and transportation, and at the same time, it is one of the world's highest biodiversity areas.

The Eighth Mekong-Japan Summit Meeting was held in Vientiane, Lao PDR on September 7, 2016. Mr. Shinzo ABE, Prime Minister of Japan expressed his intention to start a study to contribute to environmental conservation, and particularly protection of forest resources, in the Mekong River Basin. The intention was positioned as one of the Japan Mekong Connectivity Initiative Projects (JMCI Projects) and Japan International Cooperation Agency (JICA) accordingly decided the implementation of the present Study.

### 1.2 Objectives

The purposes of this Study are to focus on the basin management of the Mekong River by changing the basin environment and forest resources due to climate change, organize the basic information, grasp the current state of forest conservation for the management of the Mekong River Basin, identify issues and organize future countermeasures.

### 1.3 Information on Study Implementation

#### (1) Study Target Countries

The Study targets five countries in the Mekong River Basin, including Cambodia, Lao PDR., Thailand, Viet Nam, and Myanmar.

#### (2) Study Period

The study period is from December 15, 2017 to September 30, 2019.

#### (3) Counterparts

- MRC: Mekong River Commission
- National Mekong Committees (NMC): Cambodia, Lao PDR, Thailand and Viet Nam
- MRC Dialogue Country: Myanmar (Forest Department (FD) of Ministry of Environmental Conservation and Forestry (MOECF))
- Relevant ministries / departments, research institutes, etc. in each country of the Mekong region
- Related aid organizations (Asian Development Bank, UNDP, etc.)
- Private sector (including private companies and NGOs)

#### (4) Work Procedure

In this Study, a hot spot which is defined as potential vulnerable area by deforestation and/or climate change shall be clarified. In addition, social/ natural drivers which have induced deforestation in the LMB are to be examined through interview and site surveys and actual activities for mitigation of deforestation by government, private companies and NGO, etc. will be examined. The Study has prepared two types of hot spots as follows:

**(1) Hot Spot-1:** A deforestation area is identified from historical land cover maps, and a certain area which can be affected environmentally and socio-economically by deforestation is clarified as Hot spot 1.

**(2) Hot Spot-2:** The flow regime of Mekong River can be changed by deforestation and/ or climate changes, which might cause increases in vulnerable areas against flooding, drought and salt injury. Those areas are defined as Hot Spot-2, and will be estimated by basin management model.

After the Study Team clarifies 1) hot spots, 2) drivers of deforestation and 3) activities against deforestation, the Study will propose policy recommendations including creations of new projects to the MRC and agencies/organizations relevant to forest management in target countries in the LMB.

## 2. UNDERSTANDING OF CURRENT SITUATION

### 2.1 Watershed Management Model

To assess the environmental impacts of deforestation and climate change in the LMB, hydrological models available for watershed management are needed. MRC has developed an integrated MRC Toolbox that integrates analysis models with data management tool and analysis tool. The Modelling/ Software tool is used for watershed management as Decision Support Framework (DSF). The hydrological and hydraulic analysis models of DSF include 1) SWAT model, 2) IQQM model and 3) ISIS model. The outline of each model is shown in Table 2.1.

**Table 2.1 Outline of each model**

| No. | Model | Summary |
|---|---|---|
| 1 | SWAT | The SWAT model developed by the Department of Agriculture in U.S. is a model for estimating runoff in each watershed from rainfall and climate data. This result becomes time series input data of hydraulic analysis model. Scenarios such as land use and climate change can be assessed by using this model. |
| 2 | IQQM | The Integrated Quantity and Quality Model (IQQM) is a watershed simulation model which is originally developed for the Murray-Darling basin in Australia. IQQM simulates river systems using runoff from sub-watersheds of the SWAT model as input data, and it can take into account water use such as dams, irrigations and drinking/industrial water use. |
| 3 | ISIS | ISIS is a watershed management model. This model, developed by HR Wallingford and Halcrow, is used to simulate downstream river networks, including Tonle Sap and the Mekong Delta. The model takes into account the effects of the tide, the backflow of Lake Tonle Sap, the inflow from several tributaries, and the overflow of rivers during the flood season. |

Source: JICA Study Team

In this Study, adoption of the existing DSF analysis model was proposed, and an agreement was reached with MRC at the kick-off seminar held in June 2018.

### 2.2 Collection of Meteorological and Hydrological Data

The following 11 observation items can be downloaded from MRC Data Service & Download.

Weather: wind speed (m/sec), wind direction (degrees), solar radiation (w/m$^2$), solar radiation time (hrs.), relative humidity (%), evaporation (mm), atmospheric temperature (°C), atmospheric pressure (hPa)

Hydrological: water level (m), discharge (m$^3$/s), sediment concentration (ppm)

When data from individual station were downloaded, data from many stations existed only until 2009, and data from 2009 onward could not be downloaded. This may be related to the baseline period of 1985 to 2008 in the discussion of the Council Study hydrological simulation described later. Because the data from 2009 onward have not been consolidated, the possibility that the Council Study used data up to 2008 cannot be ruled out.

### 2.3 Review of Council Study

The latest watershed management of the Mekong River Basin was under consideration in the 2017 Mekong River Committee Council Study (released in April 2018). The MRC Council Study assessed the socio-economic and hydrological impacts (both positive and negative) across the Lower Mekong Basin (LMB) brought by various scenarios of the future water resources developments and climate changes. This Study is a work to investigate sustainable watershed management in the Mekong River Basin from forest conservation approach. The Study reviewed the Council Study, and organized issues in a wide range of fields including themes other than forest conservation.

### 2.4 Preparation of Forest Cover Map

This Study has confirmed the current situation for preparing the forest cover maps in the five countries of the Lower Mekong River Basin. The forest cover maps in each country were prepared not only by several donors including JICA but also by themselves. Meanwhile, it was urgent to grasp the changes in forest cover, especially changes in the forest cover over the period from 2000 to 2015. The Study team agreed to utilize the Time Series Land Cover data from Asian Disaster Preparedness Center (ADPC). In this Study, these data were used to create tree cover data from 1987 to 2018.

## 3. STUDY ON PRESENT CONDITION AND ISSUES

### 3.1 Forest Cover Map

Using the time series land cover data by pixel-based classification, the Study Team analyzed forest cover change from 1987 to 2018 for the purpose of grasping the forest cover change situation. In addition, for the purpose of grasping the drivers of forest cover change trends, especially the relationship between deforestation and increase in agricultural areas, the classification items of land cover data was aggregated to forest-related area i.e. tree cover and agricultural-related area. After grouping, the area was tabulated by prefecture.

### 3.2 Extraction of Hot Spot-1

For the extraction of Hot Spot-1, the calculation of each indicator was utilized such as correlation coefficient in individual province. The following condition of indicators was utilized for extraction of hot spot-1.

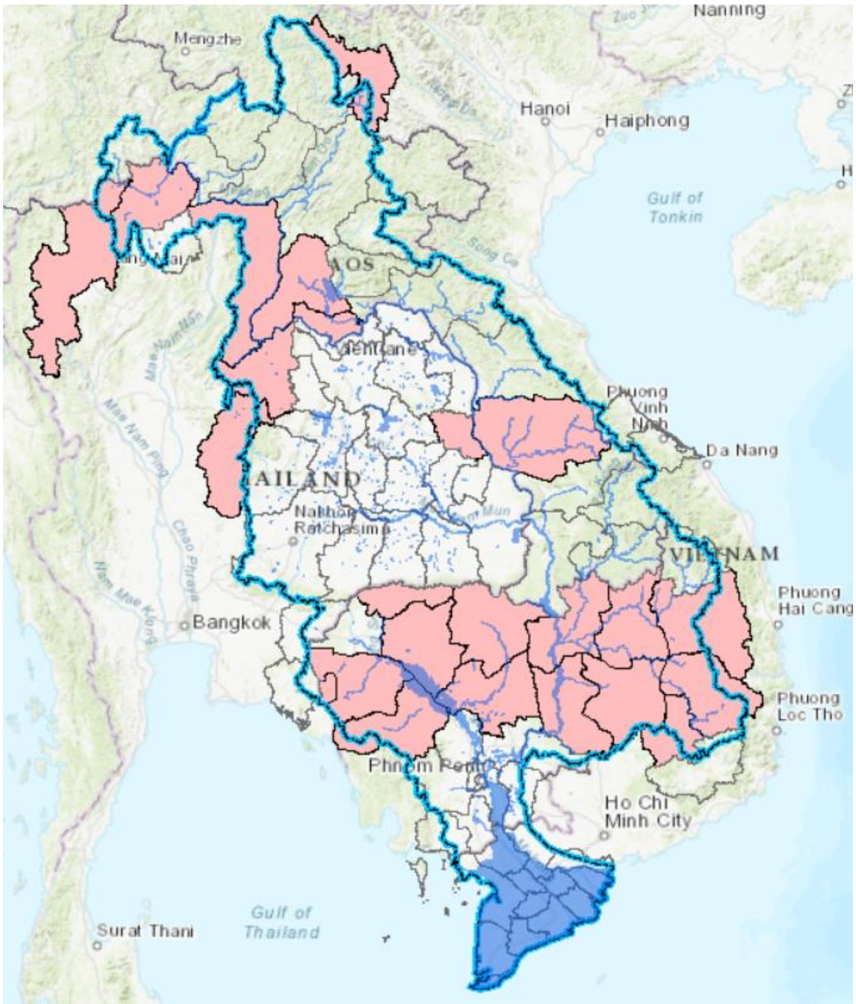
- Tree cover >= 50%
- Tree Cover Decreasing Rate <= 0.22% / Year
- Correlation Coefficient <= -0.7 for transition of tree cover area change and agricultural land area change

Based on the above criteria, for the deforestation hot spots, which is thought to be caused by the increase of agricultural land area, the hot spot provinces were extracted as shown in Figure 3.1

### 3.3 Factor Analysis Work on Deforestation and Forest Degradation

The Study summarized the circumstances of forests in the four LMB countries of Cambodia, Lao PDR, Thailand and Vietnam. This Study also organized the forest-related circumstances of the four countries into a two-tiered structure consisting of a “Summary Sheet” summarizing the information of each country and a “text” organizing the detailed information (refer to Table 3.1 as example). For Myanmar, The Study created a summary sheet without conducting detailed surveys.

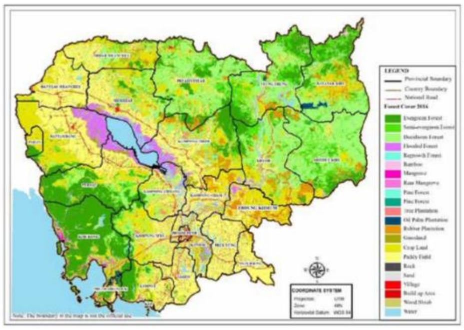
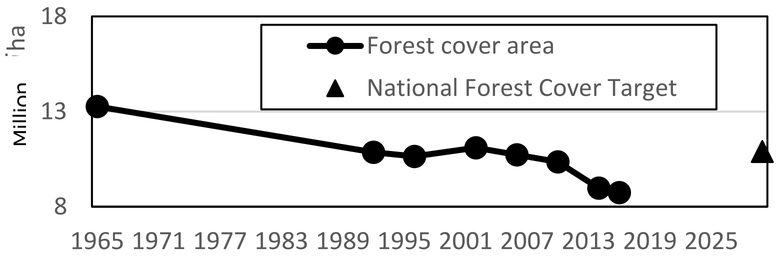
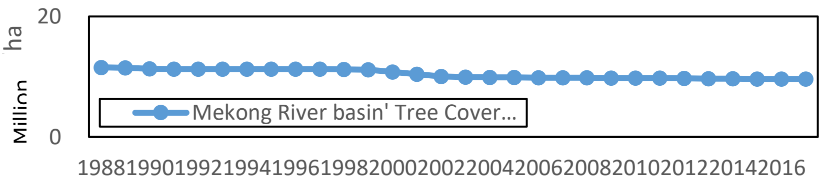
According to the survey in each country, the trend of the forest area in the Mekong region in recent years analyzed at the national level was increasing in Vietnam, almost constant in Thailand, and decreasing in Cambodia, Lao PDR and Myanmar. However, Vietnam, which has an increasing forest in the country as a whole, is a region where deforestation has been still progressing in the Central Plateau, the Mekong Basin. For this reason, forest resources in the entire Mekong Basin are still declining and deteriorating.




*Source: JICA Study Team*

**Figure 3.1 Study Area**

**Table 3.1 Example of Country Overview Sheet (Cambodia)**

<table>
<tr><td>National area</td><td>18,160,674 ha</td><td colspan="2">Forest cover in Cambodia (2016)</td></tr>
<tr><td>Population</td><td>16,246,000 (2017)</td><td colspan="2" rowspan="7"></td></tr>
<tr><td>Population growth rate</td><td>1.48% (2018)</td></tr>
<tr><td>GDP per capita</td><td>1,509 USD (2018)</td></tr>
<tr><td>Real GDP growth rate</td><td>7.25% (2018)</td></tr>
<tr><td>Forest area</td><td>8,742,401 ha (2016)</td></tr>
<tr><td>Forest area rate</td><td>48.14% (2016)</td></tr>
<tr><td>Forest targeted rate</td><td>60%（Including Natural Rubber and oil Palm）</td></tr>
<tr><td>Forest definition</td><td colspan="3">・Area: At least 0.5ha, Height: More than 5m, Canopy crown cover: More than 10%<br>・Included forest regrowth area and plantation area<br>・Rubber and oil palm plantation are classified as forest under the national forest definition, but are excluded under the REDD+ definition</td></tr>
<tr><td>Forest classification and jurisdiction</td><td colspan="3">・Permanent Forest Estate（PFE） : Forestry Administration, MAFF<br>・Inundated forest and mangrove outside of PAs : Fisheries Administration, MAFF<br>・Protected Area(PA) : General Department of Administration for Nature Conservation and Protection(GDANCP), MoE</td></tr>
<tr><td>Change of forest area in Cambodia</td><td colspan="3"></td></tr>
<tr><td>LMB area in Cambodia</td><td>16,457,410 ha</td><td colspan="2">LMB area in Cambodia</td></tr>
<tr><td>Provinces which is in LMB area</td><td>Banteay Meanchey, Takeo, Khmum, Battambang, Kampot, Kampong Cham, Kampong, Kratie, Chhnang, Kampong Speu, Tbong, Kampong Thom, Kandal, Krong Pailin, Mondul Kiri, Otdar Mean Chey, Phnom Penh, Pursat, Preah Vihear, Prey Veng, Stung Treng Ratanak Kiri, Siem Reap,</td><td colspan="2"></td></tr>
<tr><td>Tree cover area in the LMB area</td><td>8,384,248 ha(2017 年)<br>(JST data)</td><td>Tree cover rate in the LMB area</td><td>50.9 % (2017 年)<br>(JST data)</td></tr>
<tr><td>Chage of the tree cover in LMB are in Cambodia<br>(JSTdata)</td><td colspan="3"></td></tr>
</table>

Source: JICA Study Team

## 3.4 Understanding the Drivers of Deforestation and Summarizing the Results of Provincial Interviews

The Study Team visited 22 of Hot Spot-1 equivalent prefectures and conducted interviews on the forest conditions at the government agency responsible for local forest policy. The interview results in each prefecture are summarized in a format (refer to Table 3.2 as examples).

**Table 3.2 Example of Interview Format for Hot Spot-1 (Khammouane Province, Lao PDR)**

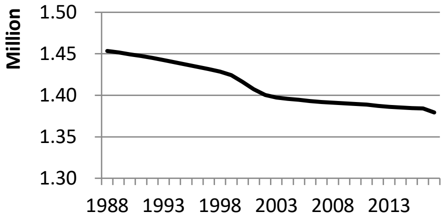
# Khammouane Province, Central Region, Lao PDR

**Agriculture** | **Develop ment** | Fire wood Charcoal | Forest fire | **Illegal Logging** | Increase | Other

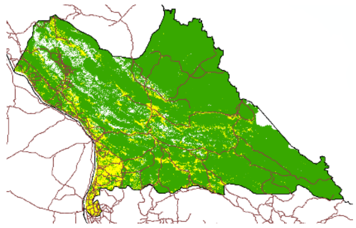
## Outline of the Province

- **Provincial Area:** 1,600,000 ha
- **Forest Type:** Dried Dipterocarpaceae Forest, Pine- Broad Leaved Tree Mixed Forest, Evergreen Broad-Leaved Forest
- **Forest Cover Area:** 1,058,000ha(Forest Cover Rate 65%) (2018)
- **Forest Category:** Protection Forest (19sites), Conservation Forest (10sites), Production Forest (3sites), Regeneration area (21,000ha), Reforestation (23,800ha), Other Protection Forest and Village Forest managed by villages
- **Targeted Forest Cover Rate:** No data
- **Tree Cover Area:**1,379,280ha(Tree Cover Rate 83.5%) (2017)
- **Population:** 414,000 (Population Density 25.9person/km$^2$)
- East part of the Province borders on Viet Nam, and West part of the Province borders on Thailand across Mekong River.

## Dynamics of Provincial Tree cover




## Provincial Tree Cover (2018)



## Status of Deforestation

- The biggest factor of the forest decrease is dam construction. A wide range of the forest sank in the dam lake while Hinboun dam was being constructed - its operation started since year 2000 and while Nam Theun dam 2 was being constructed - its operation started since year 2005.
- Mine development of Copper, Iron, Potassium, etc. has been carried out in Khammouane province and this is the second biggest factor of forest decrease.
- Slush and burn is little. In the province it was found in the district close to the Viet Nam border, but it has been decreasing because of progress of regulation.
- Strict control started by government ordinance 2015-2016, and illegal logging has decreased greatly. Current illegal logging is done by local people who fell logs by few numbers at the border area where inspector does not cover completely.
- In Khammoune province agriculture concession for sugar cane plantation is not provided. In case of the forest managed by the village decision making right is given by the village, so that conversion of the forest to plantation has been occurring.
- In the year 2017 out of the plantation area, 20.3 thousands ha, natural rubber occupies 7,350 ha and Eucalyptus (partially Acacia) occupies 15,000 ha, and Eucalyptus is mainly by companies while Acacia is mainly by the farmers. These plantations started recently (3 to 4 years before).

## Issue

- Classification of land is done but villages exist in areas classified as protected forest and agricultural activities are also conducted in some areas. It is necessary to rearrange land use classification to avoid such duplication in future.

## Cou nter mea

- In the past illegal logging in Khammuoune province was the problem. Due to strictly control has been conducted since 2015 illegal logging has decreased, then the situation is improved.

Area decreasing forests (forests→sugercane plantation)

Area decreasing forests (forests→mango plantation)

Source: JICA Study Team

### 3.5 Deforestation and Degradation in the Mekong River Basin

According to the survey in each country, the trend of the forest area in the Mekong region in recent years analyzed at the national level was increasing in Vietnam, almost constant in Thailand, and decreasing in Cambodia, Lao PDR and Myanmar. However, Vietnam, which has an increasing forest in the country as a whole, is a region where deforestation is still progressing in the Central Plateau, the Mekong basin. For this reason, forest resources in the entire Mekong basin are still declining and deteriorating. Deforestation / degradation drivers have been often analyzed from direct factors (conversion to farmland, timber export, etc.) and indirect factors. This study analyzed mainly direct factors, including the perspective of indirect factors.

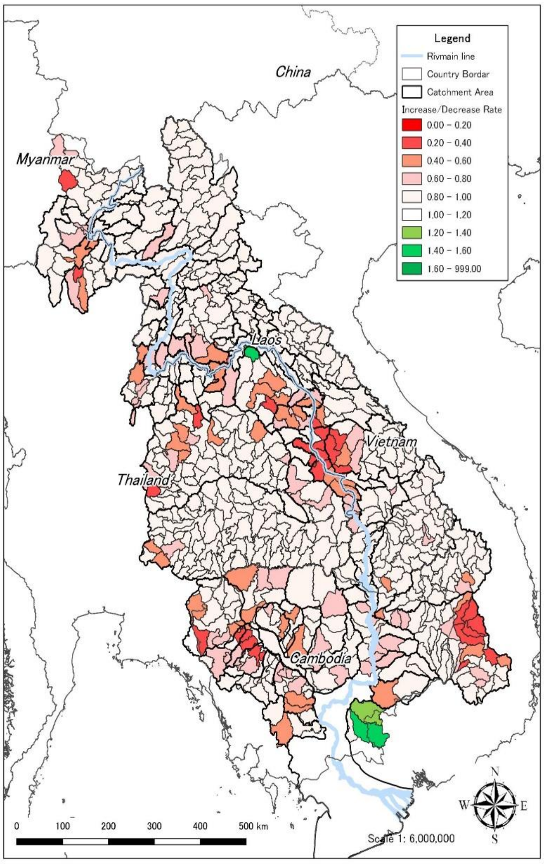
### 3.6 Deforestation Impact on the Mekong River

In this Study, two scenarios were set up to evaluate the impact of changes in forest area in the Mekong River Basin.

[Scenario 1: Deforestation case] Future forest changes in 2040 were predicted based on the secular change of forest cover. Many forest areas are expected to decline.

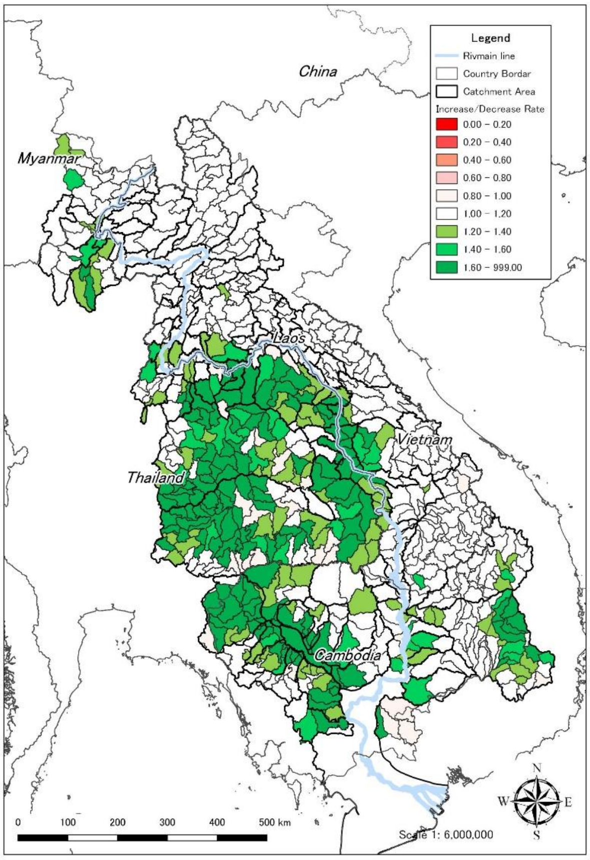
[Scenario 2: Forest recovery case] As an ideal forest conservation case, we assumed that the forest area recovered to the largest ever in 1987-2018.

The rate of changes in forest areas in Scenario 1 and Scenario 2 are shown in Figure 3.2 and Figure 3.3, respectively. In Scenario 1, the forest area of the Mekong River Basin is expected to decrease in 2040, except for some basins. Scenario 2 assumes a recovery to the largest forest area ever. The area of forest in Thailand has increased, suggesting that deforestation in the 1980s was particularly large.




Source: JICA Study Team

**Figure 3.2 Change in Forest Cover Areas in Scenario 1**




Source: JICA Study Team

**Figure 3.3 Change in Forest Cover Areas in Scenario 2**

### 3.7 Extraction of Hot Spot-2

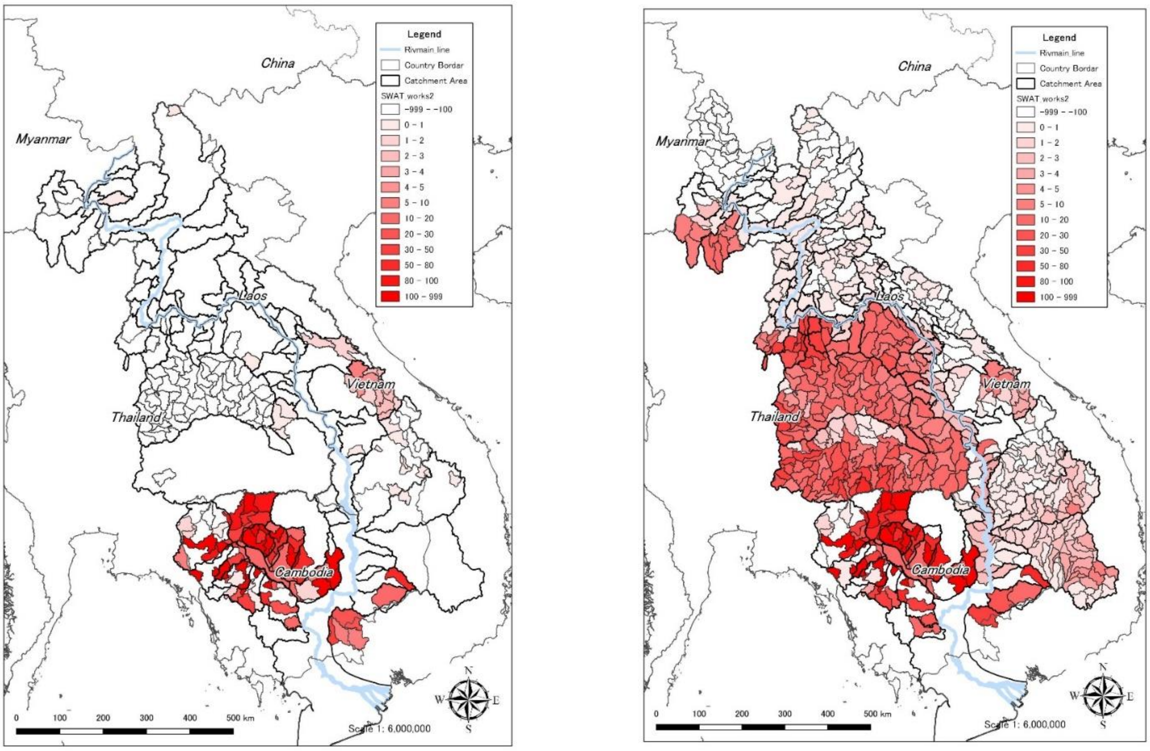
The Study Team defined regions that were vulnerable to floods and droughts due to deforestation as Hot Spots-2, and in order to extract those regions, the Study Team organized runoff volume and peak discharge from runoff calculation results from 1980 to 2007. Figure 3.4 shows the rate of change in annual outflow volume from the baseline 2007.

Through the sensitivity analysis on the Mekong River flow due to deforestation, it was confirmed that the Mekong River runoff mechanism is complex. It was confirmed that the restoration of the forest reduced the amount of surface runoff that caused flooding and sediment disasters, increased the infiltration amount, promoted groundwater recharge, and increased the amount of runoff into the Mekong River. The point where evaporation and evapotranspiration increased due to the increase in forest area needs to be examined in the future.

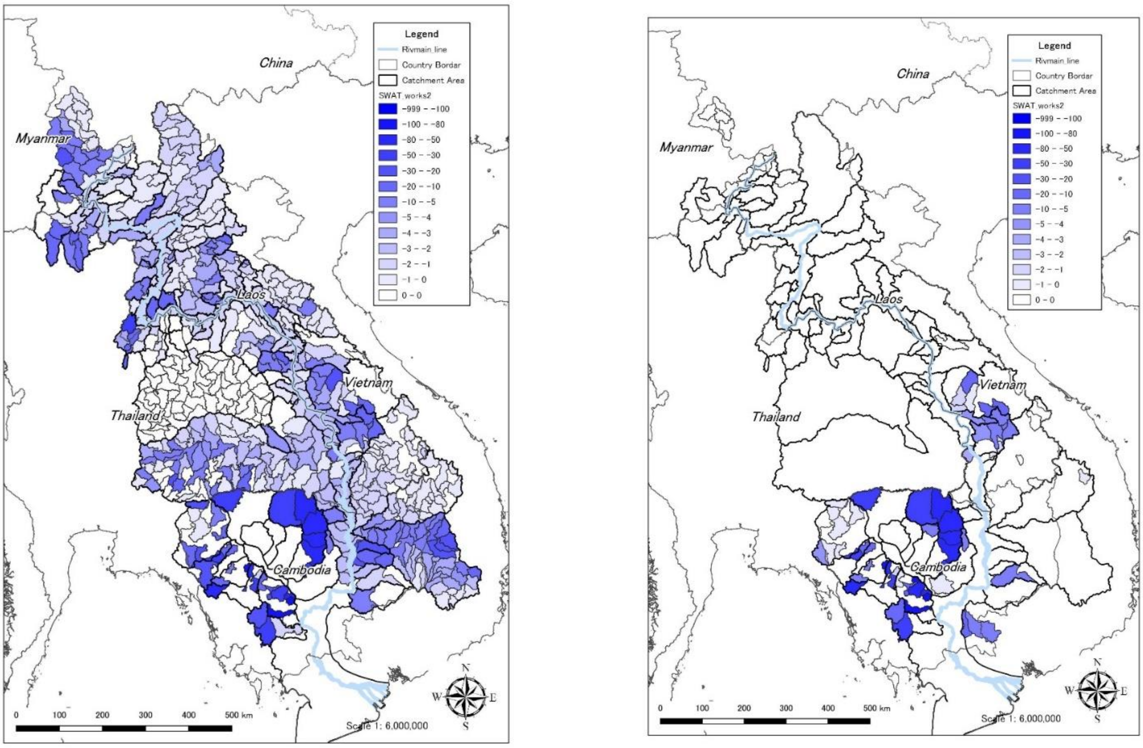
In addition, due to the confidentiality of the MRC, it was not possible to check all the input data in the MRC Tool box. If MRC will continue to use the toolbox as a tool for water resource management in the future, in addition to updating data (currently the base model is 2007), evaporation and evapotranspiration (change in evapotranspiration due to differences in forest age) )need to be considered.

[Scenario 1(Deforestation)] [Scenario 2 (Reforestation)]

(1) Increase in annual runoff volume from the basin



(2) Decrease in annual runoff volume from the basin



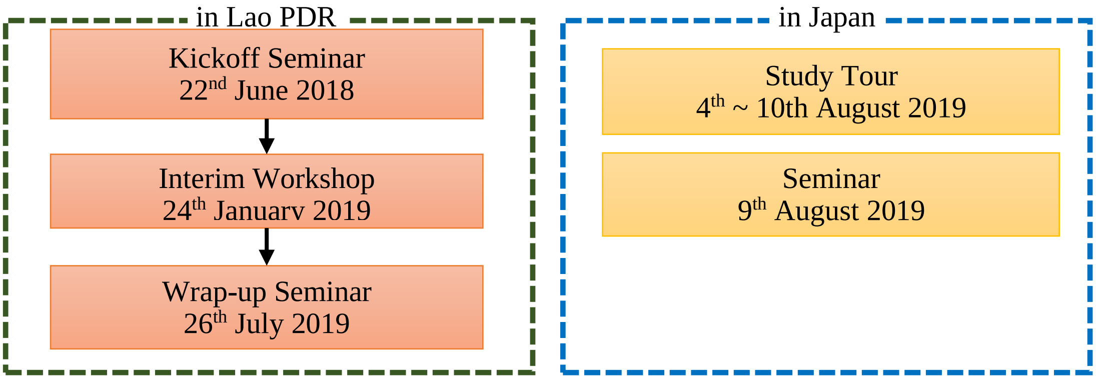

Source: JICA Study Team

**Figure 3.4 Change in Outflow Volume Relative to Baseline 2007**

# 4. SEMINARS

This Study held three local seminars and invitations to Japan as well as seminars and three domestic support committees*, with the main purpose of discussing and sharing work policies, work progress and deliverables (Refer to Figure 4.1).

* The 3rd domestic support committee was not suspended because the work process had been delayed from the initial plan, such as the delay in holding the seminar.




Source: JICA Study Team

**Figure 4.1 Schematic Diagram of Seminars/Commissions held by JICA Study**

# 5. APPROACH AGAINST ISSUES

## 5.1 Issues and Proposals on Forest Conservation

Table 5.1 summarizes issues on forest conservation.

**Table 5.1 Issues on Forest Conservation**

| **Deforestation and Degradation Drivers and Related Issues** |
|---|
| **1. Development other than agricultural development** |
| 1-1 (c) Illegal logging brings with it increased development activity (Lao PDR, Cambodia) |
| 1-2 (c) Reforestation obligations stipulated in development contracts are not implemented （Lao PDR） |
| 1-3 (c) Dam failures accompany deforestation and the forests that remain after dam failure damage will be converted into new settlements and agricultural land for the victims （Lao PDR） |
| 1-4 (a) Coordination between sectors is insufficient (Lao PDR) |
| 1-5 (a) Differences in recognition of forest value between sectors (Lao PDR)1-6 (c) Domestic migration of residents of development areas (Vietnam) |
| **2. Illegal logging** |
| 2-1 (a) Lack of human resources such as rangers (Cambodia, Lao PDR, Thailand, Vietnam) |
| 2-2 (a) Lack of equipment for patrol (Cambodia, Lao PDR, Thailand) |
| 2-3 (a) Forest boundaries are ambiguous (Cambodia, Lao PDR, Thailand, Vietnam) |
| 2-4 (b) Illegal logging takes place at night （Cambodia） |
| 2-5 (b) Illegal logging groups are armed and prepared to attack (Cambodia) |
| 2-6 (a) Lack of alternative livelihoods for the poor (Cambodia, Lao PDR, Thailand, Vietnam) |
| 2-7 (b) Illegal logging across borders (Lao PDR, Thailand) |
| 2-8 (b) Poor access to illegal logging sites (Lao PDR) |
| 2-9 (b) The subdivisions with jurisdiction have difficulty in managing total wood extraction, and loopholes exist in the laws (Lao PDR) |
| 2-10 (b) Illegal logging by foreigners (Thailand) |
| 2-11 (a) Increased demand for domestic timber (Cambodia, Lao PDR, Thailand, Vietnam) |
| 2-12 (a) The plantation trees are small in diameter and cannot be used as substitutes for the larger-diameter trees of natural forests (Vietnam) |
| **3. Collection of fuelwood** |
| 3-1 (a) Population growth in natural forests (Cambodia) |
| 3-2 (a) Collection of firewood material in natural forests (Cambodia) |
| 3-3 (a) Increased charcoal demand in the urban areas (Cambodia) |
| 3-4 (b) Funding shortfalls limit the implementation of plantation activities (Cambodia) |
| 3-5 (a) Increased Energy demand due to population growth (Lao PDR, Cambodia) |

**4. Collection of NTFPs**

4-1 (a) Burning for hunting wild animals (Cambodia, Thailand)
4-2 (a) Burning for the collection of honey (Cambodia)
4-3 (a) Burning to promote the growth of mushrooms (Thailand)
4-4 (b) Incorrect recognition of local residents for collecting NTFPs (Thailand)

**5. Forest fire**

5-1 (c) Worsening air pollution caused by forest fires (Thailand)
5-2 (a) Increased forest fires due to the prolonged dry season (Thailand)
5-3 (b) Financial support is needed due to difficulties in getting the local people to participate in forest fire prevention and extinction as volunteers (Thailand)

**6. Conversion to agricultural land**

6-1 (a) The economic poverty of local farmers is worsened by natural disasters such as increased floods, droughts, and locusts (Cambodia, Lao PDR, Vietnam)
6-2 (a) Agriculture development policy (Cambodia, Thailand)
6-3 (a) Lack of alternative livelihoods and lack of means of livelihood improvement (Cambodia, Lao PDR, Thailand, Vietnam)
6-4 (b) Existence of villages in protected areas (Cambodia, Lao PDR, Thailand)
6-5 (a) Lack of patrol and awareness-raising activities due to budget shortages (Cambodia, Lao PDR, Thailand, Vietnam)
6-6 (a) Traditional shifting cultivation in remote areas such as mountain areas (Lao PDR)
6-7 (a) Expansion of agricultural land by domestic migration (Lao PDR, Vietnam)
6-8 (a) Expansion of agricultural land accompanying the expanded development of the road network (Lao PDR, Thailand)
6-9 (a) Mechanization of agriculture (Thailand)
6-10 (a) Expansion of agricultural land by the development of factories (Lao PDR, Thailand)
6-11 (a) The falling prices of simple plantation products are impoverishing the farmers (Vietnam)
6-12 (a) Agricultural production brings in more income than forestry production (Vietnam)
6-13 (a) Increased drought (Cambodia, Lao PDR, Thailand, Vietnam)

**7. River bank erosion and coastal erosion**

7-1 (a) Insufficient supply of sediment downstream from the sediment deposits in the dams upstream (Vietnam)
7-2 (a) Changes in the periods and intensities of typhoons (Vietnam)
7-3 (a) Collapse of unbuilt riverbanks caused by bank protection work performed on only one side. (Lao PDR)

**Other Issues**

**8. Issues arising from deforestation and forest degradation**

8-1 Increased occurrence of mountain disasters (Lao PDR)
8-2 Progress of soil erosion (Lao PDR, Vietnam, Thailand)
8-3 Increased occurrence of floods (Lao PDR)
8-4 Implementation of compensation for people affected by mountain disasters and floods (Lao PDR)
8-5 Decreased wildlife (Lao PDR)

**9. Issues in tackling deforestation and forest degradation**

9-1 Technical difficulties of reforestation on steep slopes (Vietnam)
9-2 Lack of forest data for policymaking (Thailand)

**10. Issues in forestry**

10-1 Land ownership conflicts with local residents (Cambodia)
10-2 Small share of the GDP held by the forestry sector (Cambodia)
10-3 Inadequate understanding of other sectors prolongs the periods required to gain profits from the forestry sector (Cambodia)
10-4 Lack of management after planting (Cambodia, Lao PDR, Thailand)
10-5 Response to increasing demand for domestic timber (Cambodia, Lao PDR, Thailand, Vietnam)
10-6 Price competition with illegally harvested timber (Lao PDR)
10-7 Lack of data for developing a forestry strategy (Cambodia, Thailand)
10-8 High transportation costs (Cambodia, Lao PDR)
10-9 Immature wood processing technology (Lao PDR, Thailand, Vietnam)
10-10 Establishment of the Value Chain for Domestic Wood Products (Thailand)
10-11 Improved productivity and quality of plantation forests (Thailand, Vietnam)
10-12 The higher income brought in by agriculture versus forestry (Vietnam)
10-13 Deflated wood price due to the oversupply resulting from improved productivity (Vietnam)

Source: JICA Study Team

After reviewing the various initiatives aimed at forest conservation and sustainable use in each country, the field management issues identified through field surveys, and the activities related to forest conservation supported by Japan so far, the Study Team proposes new activities to further strengthen and promote sustainable forest management and conservation in Table 5.1.

**Table 5.1 New Activities to be Implemented for Forest Conservation**

| |
|---|
| A. Procurement of sustainable funds for forest management and conservation |
| B. Implementation of activities required for monitoring and management of forest dynamics in the LMB |
| C. Mobilization of the private sector to engage in sustainable forest management |
| D. Construction of a sustainable basin utilizing the diverse functions of the natural environment |
| E. Strengthening of forestry in the LMB |
| F. Sustainable energy use |

Source: JICA Study Team

## 5.2 Issues and Proposals on Basin Management

According to the Council Study, the valuation was made regarding the impacts of (1) hydropower development, (2) agricultural development, (3) domestic and industrial water, and (4) agricultural development on the Mekong River Basin as being significant. The Study Team had investigated the impact on the economy and the natural environment as well. Based on them, the Study Team summarized the main issues and proposals that should be implemented for future watershed management in Table 5.2.

**Table 5.2 New Activities to be Implemented for Basin Management**

| Item | Outline |
|---|---|
| 1. Securing the ecosystem | Nine hydropower dams that are planned in the mainstream of Mekong River may hinder sediment movement and cause serious river erosion in the downstream area. Since the impacts expected from the development of hydropower dams are severe, the hydropower dams in the planning stage shall be suspended and two dams under construction (Xayaburi dam and Don Sahong dam) be monitored and the nine dams be reviewed until the allowable mitigation measures are clearly indicated. |
| 2. Ensuring food safety | Agricultural development enhances the economic value of the Mekong River Basin by exporting agricultural products, especially rice, and contributes to food security and livelihood of residents in the basin. However, there is a concern that unplanned agricultural development may adversely affect the basin or food supply. Countries in the Mekong River Basin need to review the agricultural sector expansion policy that fully considers ensuring food security within the basin. |
| 3. Ensuring good water environment | The average annual concentration of total phosphorus (TOTP) in the Mekong River was 0.058 mg / L in 2000, but rose significantly to 0.13 mg / L in 2004, exceeding the safety management standards. This suggests that the water quality of the Mekong River may have deteriorated due to household wastewater, industrial wastewater, agricultural chemicals, fertilizers, etc. Since many residents use the water from the Mekong River, comprehensive water quality management is indispensable to ensure water security for residents in the Mekong River Basin. |
| 4. Adaptation to climate change | Of the three climate change scenarios (M3CC, C2, and C3), the C3 scenario showing a drought trend, is expected to experience droughts that reduce precipitation and reduce crop production. The area is most vulnerable to drought and flooding include Tonle Sap Lake in Cambodia and the Mekong Delta in Vietnam. In the Mekong Delta, damages due to saltwater intrusion caused by rising sea level are also expected. Since the climate change affects the borders of the Mekong River Basin, mutual cooperation among MRC member countries shall be essential, and attention should be paid to The Mekong Adaptation and Strategy Plan (MASAP) developed by member countries. And These countries need to respond to climate change impacts in a coordinated manner at the national, regional and international levels. |
| 5. Comprehensive Sediment Management for Mekong River Basin | Of 11 planned dams, the two dams are already started construction in the mainstream of Mekong River. The Council Study reported that the construction of dams in the Mekong River “main stream” will drastically deplete the sediment transportation amount to the LMB in the future. The situation will incur the reduction of river bed/water level which normally adversely affect ecosystem of the river and lateral/across river structures such as bridges and embankments, and lead to development of river bank/coastal erosion and impediments to water intakes.<br><br>Therefore, a structuring of sedimentation transportation balance in the mainstream and sub-basins is essential to maintain appropriate conditions especially in terms of securing ecosystem, food |

| Item | Outline |
|---|---|
| | security and water security as well as disaster management in the watershed of Mekong River Basin. |
| 6. Others | (1) Risk Assessment Survey for Riverbank and Coastal Erosion<br><br>In order to clarify issues and effects caused by the construction of dams, the current/scenario basis dynamics of transportation and deposit of bed and suspended load should be scientifically/quantitatively analyzed in the mainstream of Mekong River. Based on the analyzed sediment dynamics, current potential risks and MRC-scenario basis risks regarding the erosions should be assessed with specific pictures in terms of locations and magnitudes along the river courses and coastal area. The specific pictures will contribute to the planning and implementation of countermeasures against the erosion.<br><br>(2) Survey for Water Quality Conservation and Enhancement of the Monitoring System<br><br>The current water quality monitoring system of the mainstream of Mekong River does not have enough function to timely evaluate effects of agricultural activities on the water quality from the viewpoints of increasing usage of agricultural chemicals and fertilizers effects. Therefore, implementation of surveys is recommended to MRC in order to elucidate contamination sources and pollution materials for the following purposes: (1) setting proper monitoring indicators/parameters with their standard values and (2) installation of additional water quality monitoring stations to detect location contamination sources. The improved water quality monitoring system will contribute to examination and implementation of water purification measures in the Mekong River.<br><br>(3) Improvement of Data Collection System and Update/Verification of SWAT and IQQM Models<br><br>The hydrological analysis in the Council Study (2018) was carried out utilizing the hydrological simulation model (SAWT and IQQM) which was completed in 2007. The model should be updated with recent hydrological data observed from 2008 in order to verify the model parameters in recent periods. In fact, JST could not collect the recent data as of April 2019. In addition, the establishment of systematic procedure or structure for data collection and storage in MRC is also recommended in order to smoothly make decisions on the watershed management in reference to issues facing the Mekong River Basin.<br><br>(4) Enhancement of Hydrological Observation Network<br><br>Although the prehension for meteorological conditions including the impact of climate change is important for the watershed management of Mekong River, currently the density of hydro-met monitoring stations is relatively not enough in comparison with the vast area of the basin. In addition to the contribution to improvement of the model, the enhancement of hydro-met monitoring station network is recommended to secure the accuracy of hydro-met analysis and regional climate change projections in the basin.<br><br>For areas where installing the stations is inapplicable, the radar rainfall and satellite observation rainfall might be covered instead of ground observation rainfall. For reference, in areas where flash floods and sediment disasters occurred frequently due to the short-term concentrated rainfall, appropriate type of rain gauges to measure short duration rainfalls and telemetry systems may be necessary for the purpose of flood control planning, flood warning and forecasting, early evacuation system etc. As pointed out above, the monitoring stations/system should be introduced and developed in consideration of characteristics and restrictions of/in target river basins. |

Source: JICA Study Team

# CHAPTER 1 OUTLINE OF THE STUDY

## 1.1 Background

The Mekong River is one of the major international rivers with a catchment area of some 795,000 $km^2$ and its basin lies over six countries. The river originates in Tibet Plateau, flowing south in the mountainous areas in China's Yunnan Province, then formulates a national border of Republic of the Union of Myanmar (Myanmar) and the Lao People's Democratic Republic (Lao PDR). It flows down south in the territory of Lao PDR then formulates a national border of Lao PDR and Kingdom of Thailand (Thailand). The river further flows down in the southern areas of Lao PDR and through the territory of the Kingdom of Cambodia (Cambodia), then formulates Mekong delta in the territory of Socialist Republic of Viet Nam (Viet Nam) and flows into the South China Sea. The Mekong River Basin offers indispensable natural resources for the livelihood of the area's people in the aspect of food, water and transportation, and at the same time, it is one of the world's highest biodiversity areas.

In recent years, the scale of extremely heavy rainfall, prolonged draughts and flood disasters presumably resulting from climate change has been expanding in the Mekong River Basin. The expansion of the disasters gives a great influence on the local economy. Areal decrease and deterioration of tropical forests cause biodiversity loss and exhaustion of water resources in the area, as well as accelerating climate change on a worldwide scale through the emission of carbon dioxide accumulated in trees and soil. Deforestation for agricultural area expansion, decrease in forest resources due to development through population increase, and striking biodiversity loss necessitate collaborated implementation of early efforts for sustainable maintenance and management of biological function of the forests, e.g., disaster prevention and reduction, recharging function of water resources by the basin's countries.

The Eighth Mekong-Japan Summit Meeting was held in Vientiane, Lao PDR on September 7, 2016. Mr. Shinzo ABE, Prime Minister of Japan expressed his intention to start a study to contribute to environmental conservation, and particularly protection of forest resources, in the Mekong River Basin. The intention was positioned as one of the Japan Mekong Connectivity Initiative Projects (JMCI Projects) and Japan International Cooperation Agency (JICA) accordingly decided the implementation of the present Study.

## 1.2 Study Objectives

The purposes of this Study are to: focus on the basin management of the Mekong River by changing the basin environment and forest resources due to climate change, organize the basic information, grasp the current state of forest conservation for the management of the Mekong River Basin, identify issues and organize future countermeasures.

The Study results include the results of project formation and policy best practices / recommendations for the basin management. In addition, this Study was conducted in consideration of the following matters.

(1) Collection of basic information of forest management;

(2) Environmental impacts by climate changes; and,

(3) Historical changes of forest resources.

## 1.3 Study Target Countries

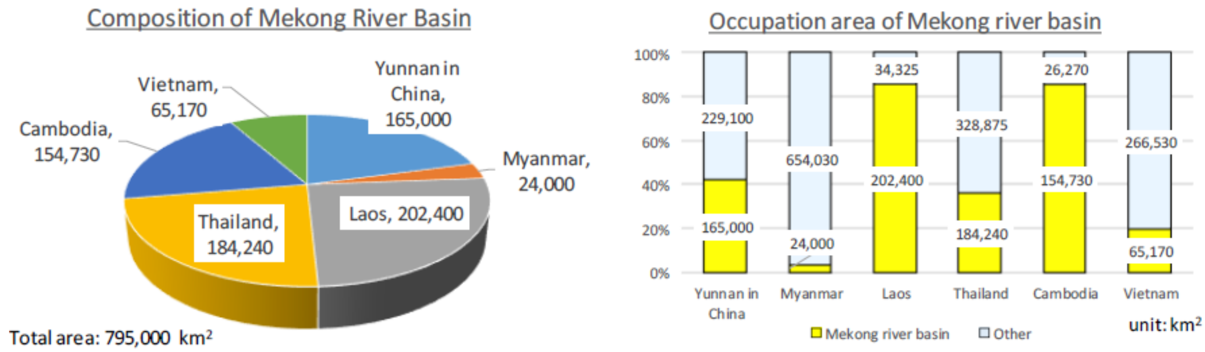
The Study targets five countries in the Mekong River Basin, including Cambodia, Lao PDR., Thailand, Viet Nam, and Myanmar.

## 1.4 Study Period and Area

The study period is from December 15, 2017 to September 30, 2019. The study area is five countries in Mekong River Basin: Cambodia, Lao PDR., Thailand, Viet Nam and Myanmar. The Mekong River Basin, excluding China, is called the Lower Mekong River Basin (LMB). Figure 1.1 and Figure 1.2 show the Study area and the occupied area of each country in the LMB, respectively.


*Source: JICA Study Team*

**Figure 1.1　Study Area**




*Source: JICA Study Team*

**Figure 1.2　Area occupied by Each Country in the LMB**

Table 1.1 shows the implementation structure (Study Team) on the Japanese side.

**Table 1.1 Implementation Structure (Study Team) on the Japanese Side**

| No. | Position | Expert Name | Affiliation | Note |
|---|---|---|---|---|
| 1 | Team Leader (TL)/ Watershed Management 1 | Keiji SASABE | CTII*1 | December 2017 to January 2019 |
| 1-1 | Team Leader (TL) | Takayuki HATANO | CTII | January to September 2019 |
| 1-2 | Watershed Management 1 | Toshihiro GOTO | CTII | January to September 2019 |
| 2 | Deputy TL/ Watershed Management 2/ Climate Change/ Hydrological Analysis | Kazuhiro NAKAMURA | CTII | |
| 3 | Forest Cover Map Development | Kei SATO | PASCO*2 | |
| 4 | Private Sector Promotion / Business Collaboration | Daisaku KIYOTA | CTII | |
| 5 | Sustainable Forest Management (Mitigation / REDD +) | Sahori FUJIMURA | JOFCA*3 | |
| 6 | Support for Seminars etc. | Shumpei ICHIKAWA | CTII | |

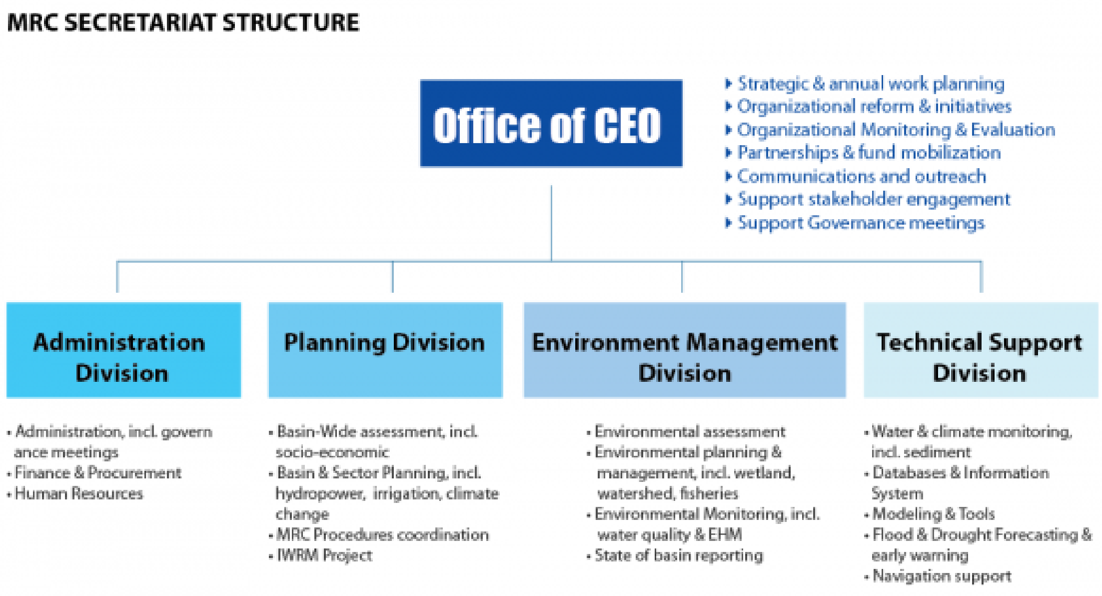
*1CTI Engineering International Co., Ltd., *2PASCO Corporation, *3 Japan and Overseas Forestry Consultants Associate

## 1.5 Counterparts

Major counterpart organizations are as follow:

- MRC: Mekong River Commission

| | |
|---|---|
| Location | Vientiane, Lao PDR |
| Section in-charge | Environmental Management Division |
| Main Persons in-charge | Mr. Tran Minh Khoi (Director), Dr. So Nam (Chef Environmental Management Officer), Dr. Prayooth Yaowakhan (Ecosystem and Wetland Specialist) etc. |
| Organization | Refer to Figure 1.3 |




*Source: MRC Website*

• National Mekong Committees (NMC): Cambodia, Lao PDR, Thailand and Viet Nam

**Figure 1.3 MRC Organization Structure**

Table 1.2 shows the committee names, positions and persons in charge in each country.

**Table 1.2 Summary of National Mekong Committees in each Country**

| Country | Name | Position | Person in charge |
|---|---|---|---|
| Cambodia | Cambodia National Mekong Committee Secretariat | Permanent Vice-Chairman | Mr. Te Navuth |
| Lao PDR | Lao National Mekong Committee Secretariat | Secretariat General | Mr. Chanthanet Boualapha |
| Thailand | Thai National Mekong Committee Secretariat | Secretariat General | Dr. Somkiat Prajamwong |
| Viet Nam | Viet Nam National Mekong Committee Secretariat | Director General | Dr. Le Duc Trung |

Source: Data from MRC modified by JICA Study Team

- MRC Dialogue Country: Myanmar (Forest Department (FD) of Ministry of Environmental Conservation and Forestry (MOECF))
- Relevant ministries / departments, research institutes, etc. in each country of the Mekong region
- Related aid organizations (Asian Development Bank, UNDP, etc.)
- Private sector (including private companies and NGOs)

## 1.6 Work Procedure and Implementation Schedule

Table 1.3 shows main work procedure of this Study. In this Study, a hotspot which is defined as potential vulnerable area by deforestation and/or climate change shall be clarified. In addition, social/ natural drivers which have induced deforestation in the LMB are to be examined through interview and site surveys, and actual activities for mitigation of deforestation by government, private companies and NGO, etc. will be examined.

**Table 1.3 Main Work Procedure**

| |
|---|
| **Step 1: Preparation** |
| ➢ Collect satellite image data<br>➢ Create forest cover map in LMB<br>➢ Predict change in forest area (1986-1999, 2016 and 2019)<br>➢ Identify deforested areas on map (Hot spot 1)<br>➢ Estimate the future forest coverage<br>➢ Prepare input (land use data considering future deforestation)<br>➢ Set future scenarios regarding forest area forecasting and climate change based on the latest research outputs (e.g. sea level rise) |
| **Step 2: Sensitivity Analysis** |
| ➢ Develop a basin model to quantitatively assess the impacts by deforestation and climate change<br>⇒ Utilization of MRC toolbox<br>➢ Run basin simulations in future scenarios<br>➢ Analyze simulation results<br>➢ Identify potentially-vulnerable areas (floods, droughts, saltwater intrusions) due to deforestation and climate change (Hot spot 2) |
| **Step 3: Grasp of Present Conditions and Issues and their Arrangement** |
| **Step 3-1: Forest Conservation** |
| ➢ Identify deforestation areas and their drivers (thru field reconnaissance, interviews, literature surveys etc.)<br>➢ Verify the relationship between the drivers and Hot spot 1<br>➢ Search for activities contributing to deforestation measures (interviews, literature survey etc.)<br>➢ Evaluate the practical or potential effects of the activities<br>➢ List up effective measures against deforestation |
| **Step 3-2: Watershed Management** |
| ➢ Analyze potential vulnerable areas (Hot spot 2) from the viewpoint of water resources management<br>➢ Analyze detailed negative impacts by deforestation (if necessary)<br>➢ List up effective measures |
| **Step 4: Countermeasures and Policy Recommendations** |
| ➢ Countermeasures and policy recommendations based on the results of Step 3<br>・Forest conservation (collaboration with external organizations, activities contributing to ESG / SDGs, monitoring, organizations, etc.)<br>・Watershed management (intensified monitoring, sediment management, basin management function build-up, etc.) |

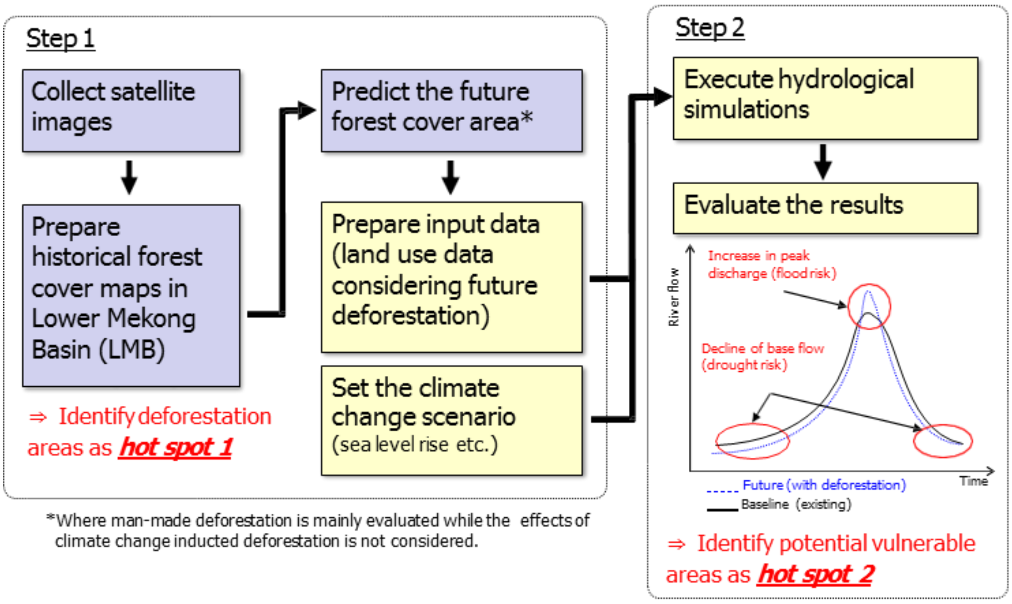
Source: JICA Study Team

The Study has prepared two types of hotspots as follows:

**(1) Hot spot 1:** A deforestation area is identified from historical land cover maps, and a certain area which can be affected environmentally and socio-economically by deforestation is clarified as Hot spot 1.

**(2) Hot spot 2:** The flow regime of Mekong River can be changed by deforestation and/ or climate changes, which might cause increases in vulnerable areas against flooding, drought and salt injury. Those areas are defined as Hot spot 2, and will be estimated by basin management model.

Figure 1.4 shows the procedure of identification of Hot spot 1 and 2. Hot spot 1 is clarified by analysis of historical forest cover maps. On the other hand, Hot spot 2 will be identified by hydrological and hydraulic analysis.

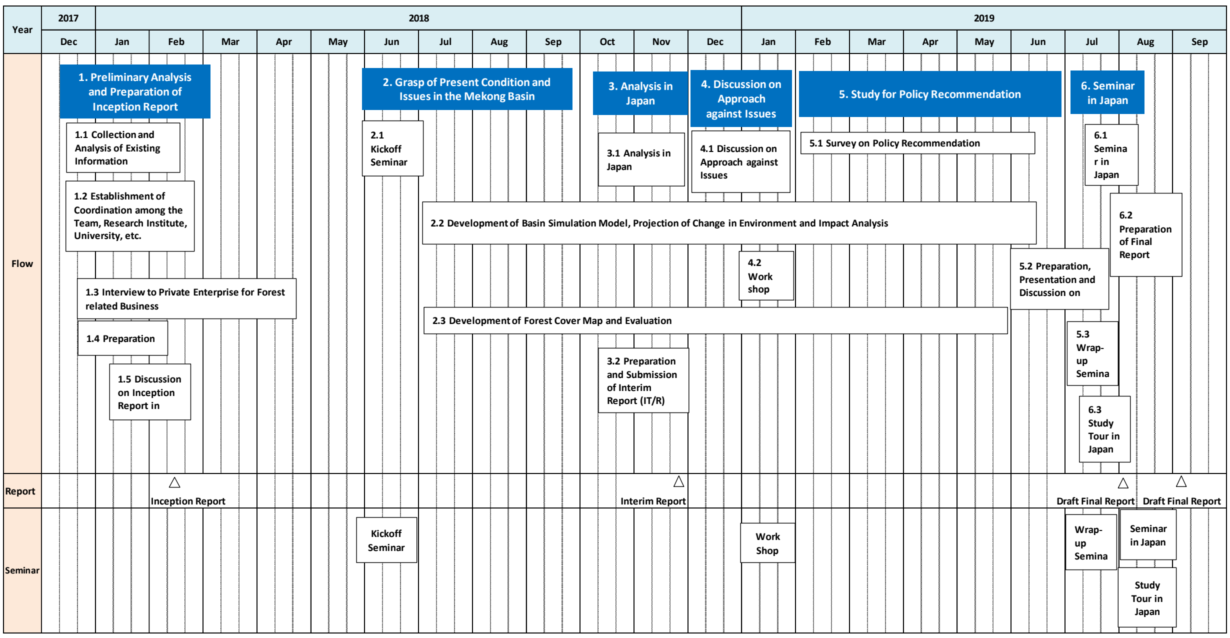



Source: JICA Study Team

**Figure 1.4 How to Identify Hot Spot 1 and 2**

After the Study Team clarifies 1) hot spots, 2) drivers of deforestation and 3) activities against deforestation, the Study will propose policy recommendations including creation of new projects to the MRC and agencies/organizations relevant to forest management in target countries in the LMB.

The activities of this Study have been carried out according to the schedule shown in Figure 1.5. At the beginning, the Study was projected to be completed by March 2019. However, the Study period has been extended until September 2019 due to some causes such as delay of holding the kick off seminar with difficulty of signing the MoU between MRC and Japanese side.




Source: JICA Study Team

**Figure 1.5 Work Schedule**

# CHAPTER 2 UNDERSTANDING OF CURRENT SITUATION

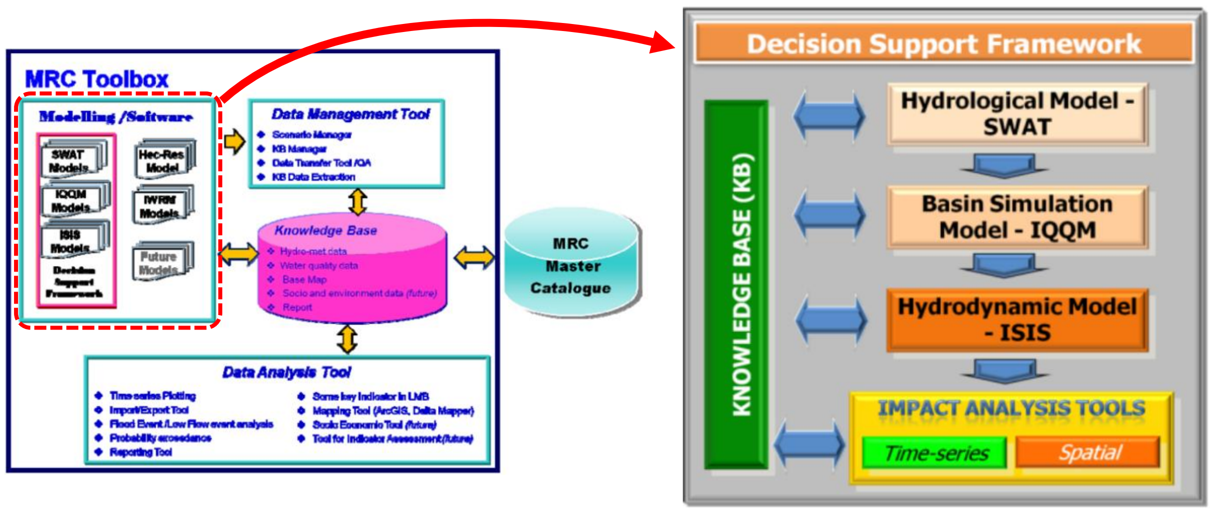
This chapter provides information on the current status of the MRC, which serves as the basis for surveys on watershed management and forest conservation.

## 2.1 Watershed Management Model for Study of Watershed Management

### 2.1.1 Decision Support Framework (DSF)

To assess the environmental impacts of deforestation and climate change in the LMB, hydrological models available for watershed management are needed. MRC has developed an integrated MRC Toolbox that integrates analysis models with data management tool and analysis tool. The Modelling/Software tool is used for watershed management as Decision Support Framework (DSF).

Figure 2.1 shows the MRC Toolbox and DSF. The hydrological and hydraulic model of DSF consists of three models: SWAT model, IQQM model, and ISIS model.




*Source: MRC websitehttp://portal.mrcmekong.org/mrctoolbox*

**Figure 2.1 Constitution of the MRC Toolbox and Decision Support Framework (DSF)**

The applicable watersheds of each model are shown in Figure 2.2. The DSF considers the region upstream from Kratie in Cambodia as an outflow region and the region downstream as a downstream region. The SWAT model and the IQQM model are adopted in the region upstream from Kratie, while the ISIS model, which is a hydraulic analysis model, is adopted in the downstream region.

Outflows from each catchment are calculated by using the SWAT model, and the results are used as input data to the IQQM model in order to simulate river networks. Flow calculations at Kratie are carried over to the ISIS model for the Tonle Sap and the Mekong Delta downstream region from the Kratie in Cambodia. Therefore, the output of the Kratie point of the IQQM model becomes the upstream end as boundary condition of the ISIS model.

Mekong River Basin
*(in 5 Countries: Thailand, Cambodia, Laos, Vietnam, and Myanmar)*


**Figure 2.2 Hydrological/Hydraulic Model for analysis of LMB**

The outline of each model is shown in Table 2.1.

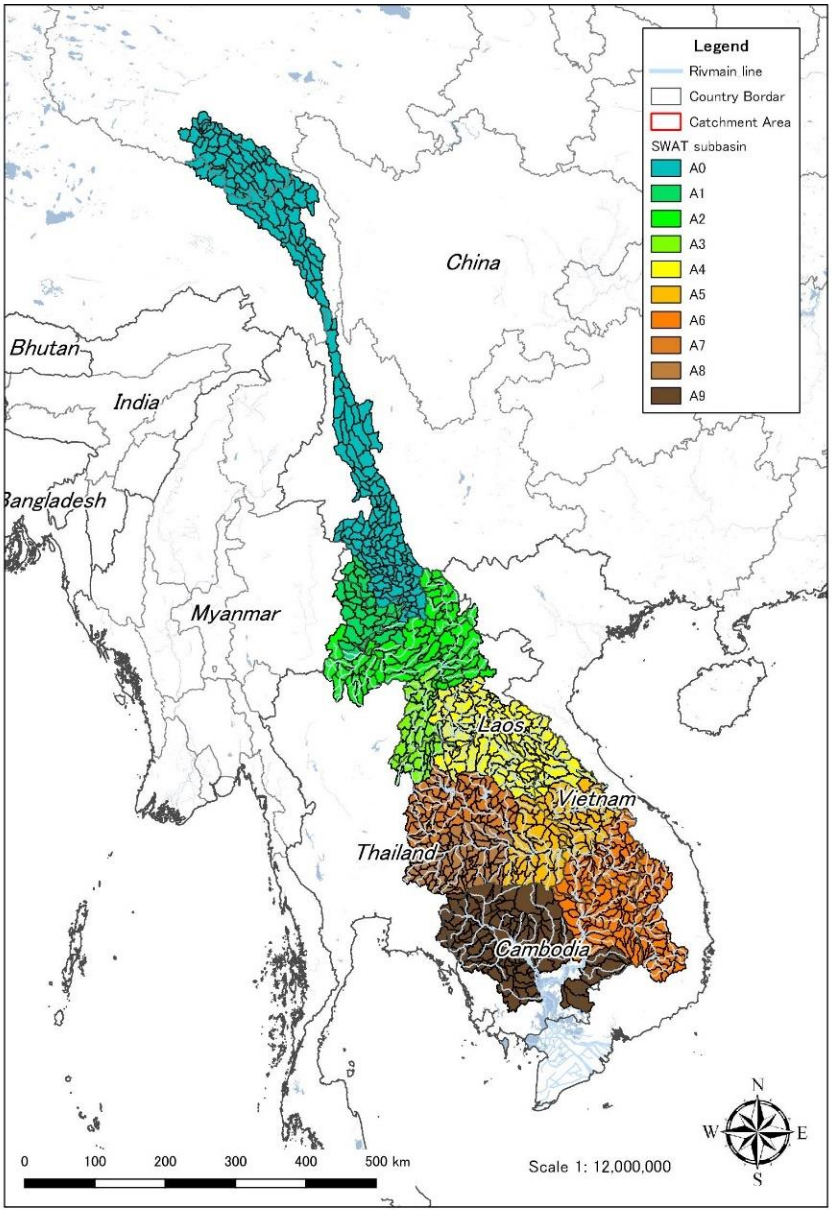
**Table 2.1 Outline of each model**

| No. | Model | Summary |
|---|---|---|
| 1 | SWAT | The SWAT model developed by the Department of Agriculture in U.S. is a model for estimating runoff in each watershed from rainfall and climate data. This result becomes time series input data of hydraulic analysis model. Scenarios such as land use and climate change can be assessed by using this model. |
| 2 | IQQM | The Integrated Quantity and Quality Model (IQQM) is a watershed simulation model which is originally developed for the Murray-Darling basin in Australia. IQQM simulates river systems using runoff from sub-watersheds of the SWAT model as input data, and it can take into account water use such as dams, irrigations and drinking/industrial water use. |
| 3 | ISIS | ISIS is a watershed management model. This model, developed by HR Wallingford and Halcrow, is used to simulate downstream river networks, including Tonle Sap and the Mekong Delta. The model takes into account the effects of the tide, the backflow of Lake Tonle Sap, the inflow from several tributaries, and the overflow of rivers during the flood season. |

In the next section, model information obtained from past technical reports released by MRC and interviews with MRC members are summarized.

### 2.1.2 SWAT Model

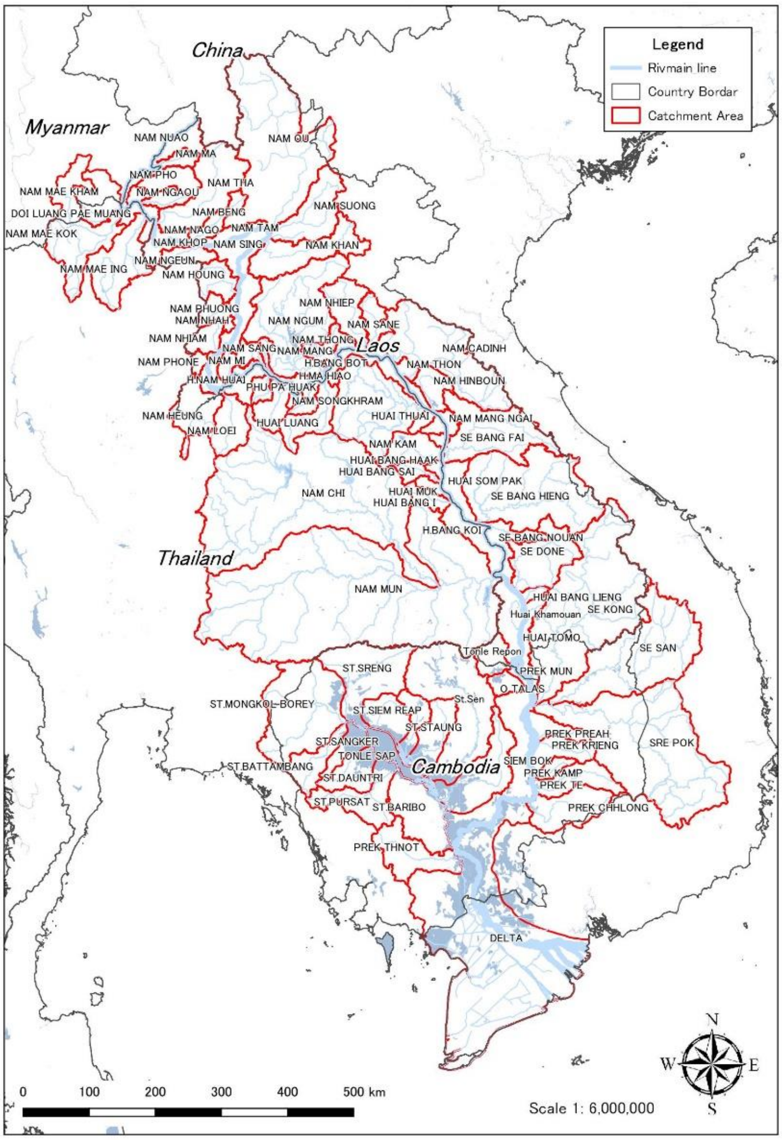
The SWAT model divides the Mekong River Basin, including China, into 10 large basins, and each large basin has sub-basins, for a total of 870. The downstream from Kratie in Cambodia is not modeled with SWAT model. The watershed division map is shown in Figure 2.3. SWAT model is incorporated in each sub-basin and runoff is calculated from rainfall data. The A0 basin is the Mekong River basin in China. So, it seems to be difficult to obtain information on detail hydrological condition from China, but according to the MRC, the hydrological information (Water level and discharge) at the downstream end of the A0 basin is provided by China. So, it is used as a calculation boundary condition and given at the upstream end of A1.




*Source: Data provided by MRC, prepared by the research team*

**Figure 2.3 Watershed division map (SWAT model)**

Figure 2.4 shows the major tributaries in the LMB. It is divided into 104 river basins in the LMB.



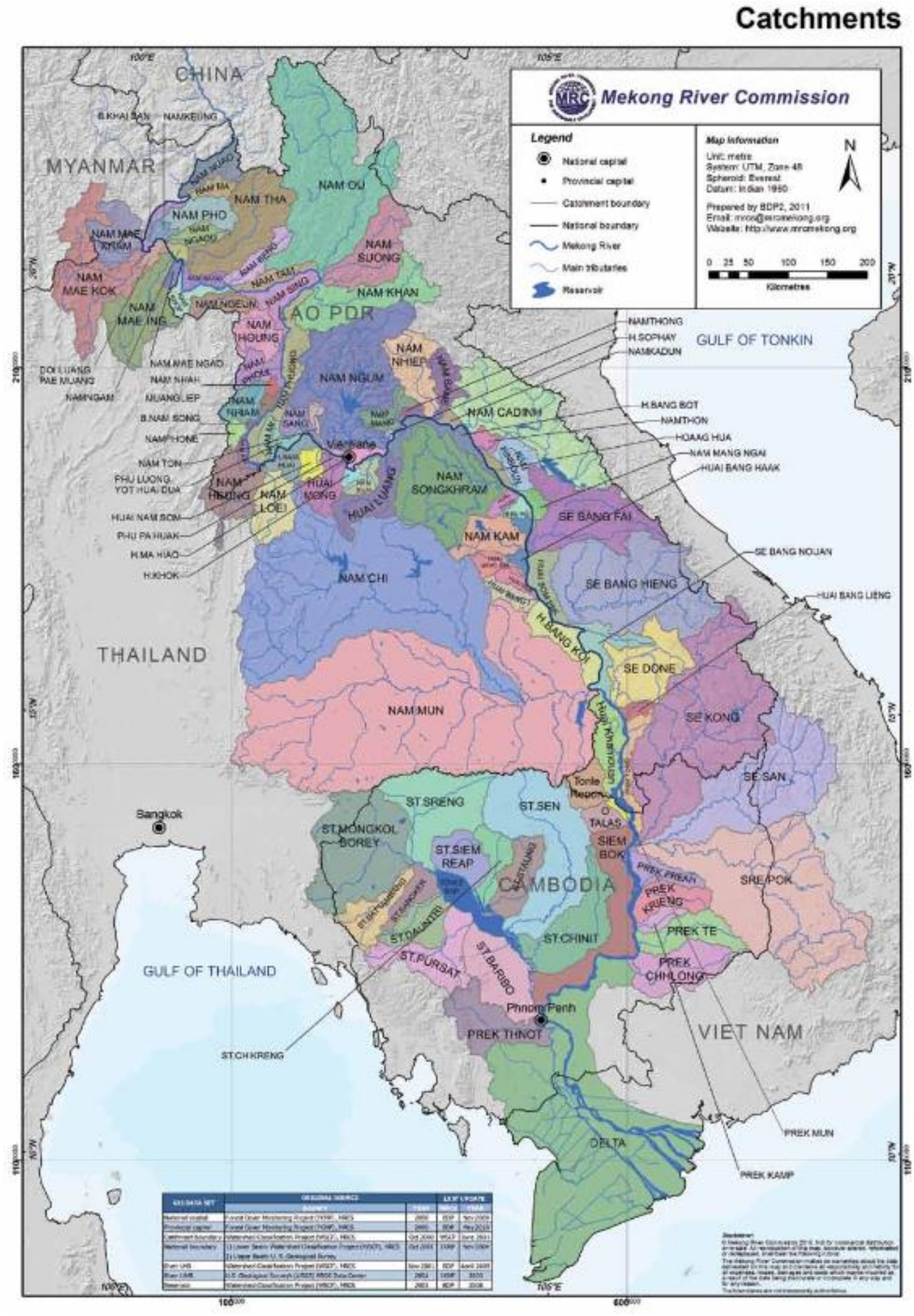

*Source: Data provided by MRC prepared by the research team*

**Figure 2.4 Major river basins of the LMB**

### 2.1.3 IQQM Model

According to interviews with MRC headquarters, the river network of the Mekong River and its tributaries has been modeled by IQQM. Cross-sectional data which were surveyed before 2003 was employed, and the data were not updated when the Council Study was published in 2018. MRC stated that the approval of each country's NMC is required when updating the cross-sectional data and other modifications. The model update is not easy due to internal procedure of MRC and NMCs, and it is expected to take a much time. So, updating cross-sectional data including improving the NMC approval system (shortening) is a major challenge going forward.

The hydrograph output by IQQM has 65 points in the LMB (shown in Figure 2.5).




*Drawing from: MRC*

**Figure 2.5 output point of IQQM**

### 2.1.4 ISIS Model

Detailed information on the ISIS model was not available due to information security of MRC. In addition, through discussions at the kick-off meeting held in June 2018, an interim seminar held in January 2019 and other technical meetings with MRC, it was decided that the analysis of the ISIS model would not be carried out in the Project because of the heavy burden on MRC staff.

As of January 2019, the MRC Headquarters had 1 modeler, and 1 support from the NMC in Vietnam, and it was confirmed that a total of 2 modelers were engaged in analysis work. Increasing of MRC personnel is to be also a big issue.

### 2.1.5 Hydraulic Analysis Model Adopted in This Project

For the following reasons, it was proposed that the hydrological and hydraulic analysis model used in this project should be based on the existing DSF analysis model, and an agreement was reached with the MRC at the kick-off seminar held in June 2018.

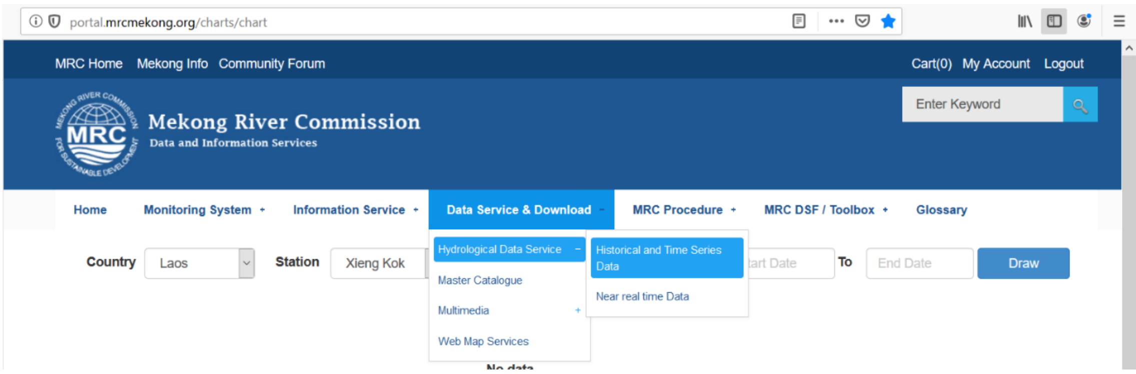
- ➢ The model is already utilized past MRC researches/studies, i.e. Council Study (2018.) and Climate Change and Adaptation Initiative (CCAI)
- ➢ The approval of each NMCs is necessary for the modification and improvement of the model. MRC staff said it would take several years to update the model, so we decided it would be efficient to use the existing model.

## 2.2 Collection of Meteorological and Hydrological Data

This section mainly describes the situation of data related to watershed management.

### 2.2.1 MRC Date Service

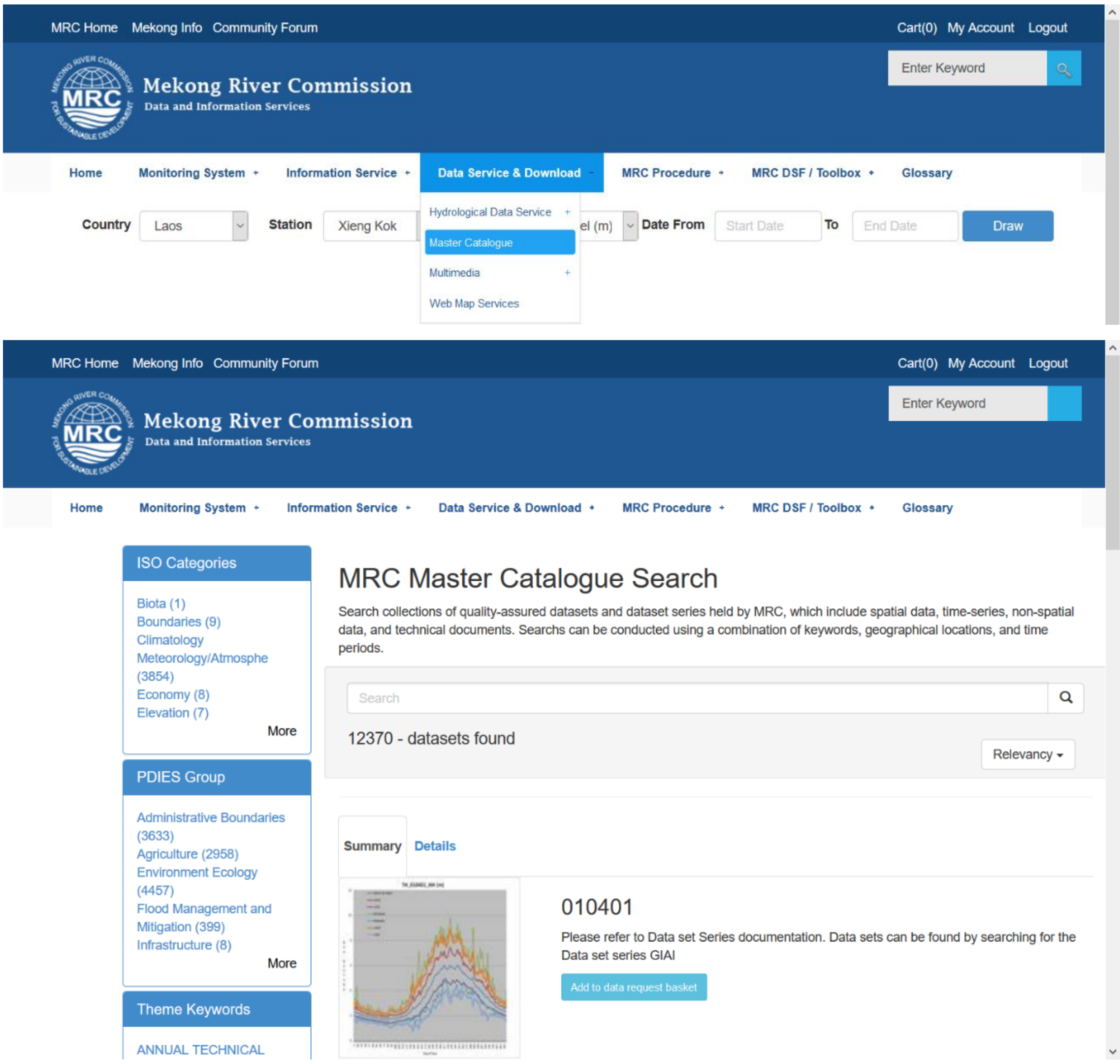
The library of the Mekong River Commission (in Vientiane City, Lao PDR) has been holding meteorological hydrological observations in the LMB since the late 1950s as the Year Book. In the late 1990s, the library published a CD-ROM version of the Year Book. It is now possible to download data on the website. Data acquisition is subject to a fee, but data can be downloaded free of charge under the MOU for this project.




*Source: http://portal.mrcmekong.org/charts/chart*

**Figure 2.6 Data Service & Download site**

Meteorological and hydrological observation data can be downloaded from the website's "Master Catalogue" page.




*Source: http://portal.mrcmekong.org/search/search*

**Figure 2.7 Master Catalogue Site**

### 2.2.2 Observation Data Item

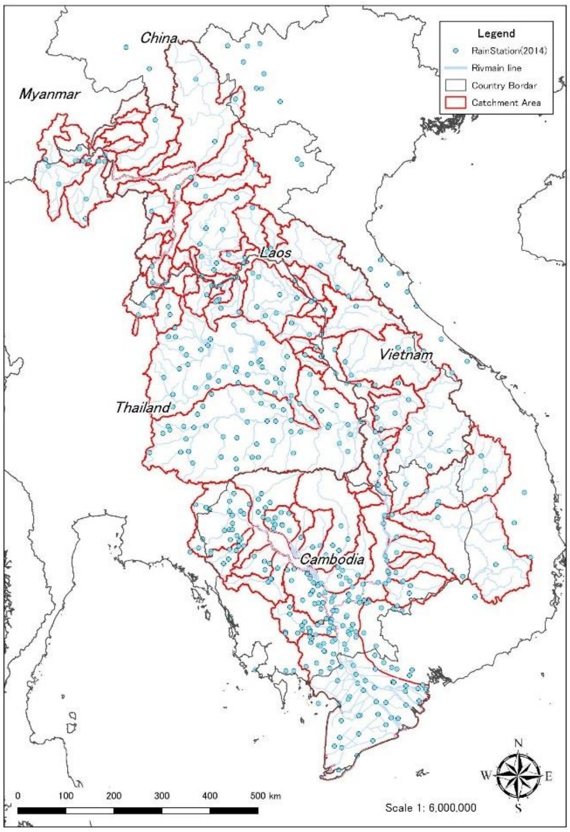
The following 11 observation items can be downloaded from MRC Data Service & Download.

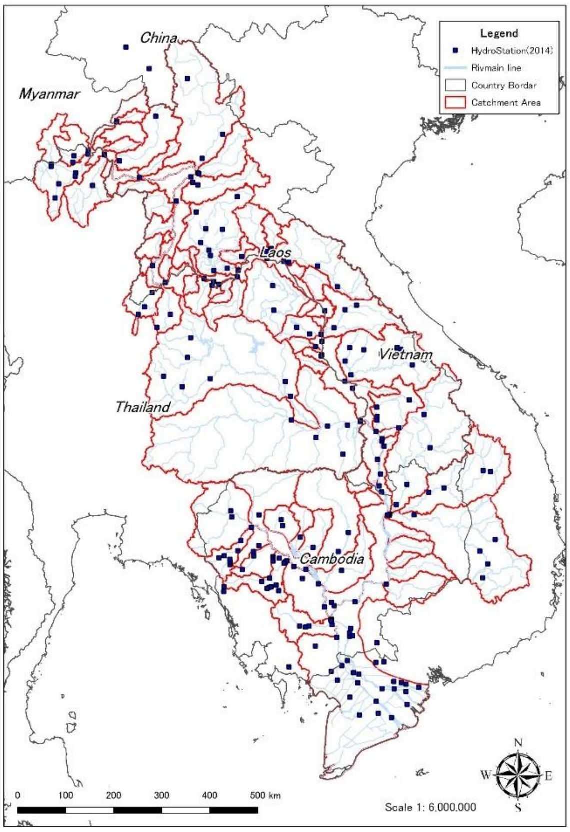
Weather: wind speed (m/sec), wind direction (degrees), solar radiation (w/m$^2$), solar radiation time (hrs.), relative humidity (%), evaporation (mm), atmospheric temperature (°C), atmospheric pressure (hPa)

Hydrological: water level (m), discharge (m$^3$/s), sediment concentration (ppm)

### 2.2.3 Current Status of Data Archive

The locations of rainfall stations and water level stations in 2014 are shown in Figure 2.8 and Figure 2.9 respectively. According to these figures, there are 463 rainfall stations and 214 water level stations.




*Source: MRC, GIS section*

**Figure 2.8 Location of Rainfall Station** **Figure 2.9 Location of Water Level Station**

Based on GIS data provided by the MRC, the total area of the LMB is approximately 624,600 km$^2$. There are 463 rainfall stations, so approximately 1 rainfall station is installed at a density of about 1,350 km$^2$. Table 2.2 is the station density recommended by the World Meteorological Organization (WMO). The rainfall observation density of the LMB is larger than the recommended value, and improvement of the observation network should be considered in the future.

**Table 2.2 Recommended Density of Hydrometeorological Station (WMO, units km$^2$)**

| Physiographic unit | Precipitation | | Evaporation | Streamflow | Sediments | Water quality |
|---|---|---|---|---|---|---|
| | Non-recording | Recording | | | | |
| Coastal | 900 | 9000 | 50000 | 2750 | 18300 | 55000 |
| Mountains | 250 | 2500 | 50000 | 1000 | 6700 | 20000 |
| Interior plains | 575 | 5750 | 5000 | 1875 | 12500 | 37500 |
| Hilly/undulating | 575 | 5750 | 50000 | 1875 | 12500 | 47500 |
| Small islands | 25 | 250 | 50000 | 300 | 2000 | 6000 |
| Urban areas | – | 10–20 | – | – | – | – |
| Polar/arid | 10000 | 100000 | 100000 | 20000 | 200000 | 200000 |

*Source: Guide to Hydrological Practices Volume I, World Meteorological Organizations, WMO No. 168*

The main three items related to watershed management, water level, discharge, and rainfall, were reviewed at 242 stations in 4 countries posted on the MRC site (shown in Table 2.3 and Table 2.4). The period is from 1987 to 2018, which is during the preparation of the forest cover map described later.

It was confirmed from the table that the water level data of 183 stations were prepared. On the other hand, though rainfall data are not always available at all stations, but there are only 13 locations in 4 countries. Flow data have been identified at 109 stations in 4 countries.

When data from individual station were downloaded, data from many stations existed only until 2008, and data from 2009 onward could not be downloaded. This may be related to the baseline period of 1985 to 2008 in the discussion of the Council Study hydrological simulation described later. Because the data from 2009 onward have not been consolidated, the possibility that the Council Study used data up to 2008 cannot be ruled out.

In any case, of the 463 rainfall and 214 water level stations in the MRC database, only about 3% (13/463) of the rainfall data and about 86% (183/214) of the water level data are available. As rainfall data is important hydrological information as well as water level data, so it is necessary to improve the data management system including increase of observation density

# Table 2.3 Status of development of meteorological and hydrological data (Cambodia and Lao PDR)

| No. | Country | Station | Items (1987.1.1～2018.12.31) | | | No. | Country | Station | Items (1987.1.1～2018.12.31) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Water Level | Rainfall | Discharge | | | | Water Level | Rainfall | Discharge |
| 1 | Cambodia | Stung Treng | ○ | N/A | ○ | 74 | Laos | Xieng Kok | N/A | N/A | N/A |
| 2 | | Kratie | ○ | N/A | ○ | 75 | | Ban Houi Sai | N/A | N/A | N/A |
| 3 | | Chroy Chang Var | ○ | N/A | ○ | 76 | | Pak Beng | ○ | N/A | N/A |
| 4 | | Kompomg Cham | ○ | N/A | ○ | 77 | | Luang Prabang | N/A | N/A | ○ |
| 5 | | Neak Luong | ○ | N/A | ○ | 78 | | Ban Pakkhone | ○ | N/A | N/A |
| 6 | | Stung Slot | ○ | N/A | N/A | 79 | | Paktay | N/A | N/A | N/A |
| 7 | | Prek Koy | ○ | N/A | N/A | 80 | | Vien Tiane | N/A | N/A | N/A |
| 8 | | Spean Tras | ○ | N/A | N/A | 81 | | Paksane | N/A | N/A | N/A |
| 9 | | Phnom Penh Port | ○ | N/A | ○ | 82 | | Thakhek | N/A | N/A | N/A |
| 10 | | Prek Kdam | ○ | N/A | ○ | 83 | | Keng Kabao | N/A | N/A | N/A |
| 11 | | Kg. Chhnang | ○ | N/A | N/A | 84 | | Ban Savang | N/A | N/A | N/A |
| 12 | | Kg. Luong | ○ | N/A | N/A | 85 | | Savannakhet | ○ | N/A | ○ |
| 13 | | Snoc Trou | ○ | N/A | N/A | 86 | | Paktaphane | ○ | N/A | N/A |
| 14 | | Bassac Chaktomouk | ○ | ○ | ○ | 87 | | Pakse | ○ | N/A | ○ |
| 15 | | Koh Khel | ○ | N/A | N/A | 88 | | Ban Mouang | ○ | N/A | N/A |
| 16 | | Tuk Chhoo | ○ | N/A | N/A | 89 | | Ban Chan Noi | ○ | N/A | N/A |
| 17 | | Takhmao | N/A | N/A | N/A | 90 | | Ban Hat SaiKhoune | ○ | N/A | N/A |
| 18 | | Bac Prea | ○ | N/A | N/A | 91 | | Veunkham | N/A | N/A | N/A |
| 19 | | Ban Khmoun | ○ | N/A | ○ | 92 | | Muong Nam Tha | ○ | N/A | N/A |
| 20 | | Siempang | ○ | N/A | ○ | 93 | | Ban Hat Kham | N/A | N/A | N/A |
| 21 | | Chantangoy | ○ | N/A | ○ | 94 | | Ban Hong Leuay | ○ | N/A | N/A |
| 22 | | Ban Kamphun | ○ | N/A | ○ | 95 | | Ban Hat Kham | ○ | N/A | N/A |
| 23 | | Voeun Sai | ○ | N/A | ○ | 96 | | Muong Ngoy | ○ | N/A | ○ |
| 24 | | Andaung Meas | ○ | ○ | ○ | 97 | | Ban Hatsa | N/A | N/A | N/A |
| 25 | | Lumphat | ○ | N/A | ○ | 98 | | B.Fay | N/A | N/A | N/A |
| 26 | | Mong Kolborey | ○ | ○ | ○ | 99 | | Ban Sibounhom | ○ | N/A | N/A |
| 27 | | Sisophon | ○ | N/A | ○ | 100 | | Ban kok Van | ○ | N/A | ○ |
| 28 | | Kralanh | ○ | N/A | ○ | 101 | | Ban Mixay(Ban Mout) | ○ | N/A | ○ |
| 29 | | Treng | ○ | N/A | ○ | 102 | | Ban Pak Bak | ○ | N/A | ○ |
| 30 | | Battambang | ○ | N/A | ○ | 103 | | Ban Phone Kheng | N/A | ○ | N/A |
| 31 | | Sre Ponleu | ○ | N/A | ○ | 104 | | Ban Houa Khoua | N/A | N/A | N/A |
| 32 | | Mong Russey | ○ | N/A | N/A | 105 | | Ban Nong Nieng | N/A | N/A | N/A |
| 33 | | Bot Chhvear/Untac Br | ○ | N/A | ○ | 106 | | Ban Pak Kanhoung | N/A | N/A | ○ |
| 34 | | Prasat Keo | ○ | N/A | N/A | 107 | | Tha Ngon | N/A | N/A | ○ |
| 35 | | Kompong Kdei | ○ | N/A | ○ | 108 | | Ban Pak Ngum | N/A | N/A | N/A |
| 36 | | Pursat | ○ | ○ | ○ | 109 | | Ban Tha Lat | N/A | N/A | N/A |
| 37 | | Taing Leach | ○ | N/A | ○ | 110 | | Keng Hay | ○ | N/A | N/A |
| 38 | | Bac Trakoun | ○ | N/A | ○ | 111 | | Ba Na Bong | ○ | N/A | N/A |
| 39 | | Khum Viel | ○ | N/A | ○ | 112 | | Veunkham | ○ | N/A | N/A |
| 40 | | Lo Lok Sar | ○ | N/A | N/A | 113 | | Ban Na Luang | ○ | N/A | N/A |
| 41 | | Phum Kos | ○ | N/A | N/A | 114 | | Ban Phien Luang | ○ | N/A | N/A |
| 42 | | Kbal hong(up) | ○ | N/A | N/A | 115 | | Ban Hin Heup | N/A | N/A | ○ |
| 43 | | Kbal hong(down) | ○ | N/A | N/A | 116 | | Ban Nam Pot | N/A | N/A | N/A |
| 44 | | Peam | ○ | N/A | ○ | 117 | | Muong Kasi | ○ | N/A | ○ |
| 45 | | Prey Klong(down) | ○ | N/A | ○ | 118 | | Vang Vieng | ○ | N/A | ○ |
| 46 | | Prey Klong(up) | ○ | N/A | N/A | 119 | | Ban Hat Khay | ○ | N/A | N/A |
| 47 | | Sanlong(up) | ○ | N/A | N/A | 120 | | Dam Site | N/A | N/A | N/A |
| 48 | | Sanlong(down) | ○ | N/A | N/A | 121 | | Tadleuk | ○ | N/A | N/A |
| 49 | | Svay At | ○ | N/A | N/A | 122 | | Muong Mai | ○ | N/A | ○ |
| 50 | | Campang | ○ | N/A | N/A | 123 | | Muong Borikhane | ○ | N/A | N/A |
| 51 | | Svay Don Keo | ○ | ○ | ○ | 124 | | Ban Hatxiengtom | ○ | N/A | N/A |
| 52 | | Kroch seuch(up) | ○ | N/A | N/A | 125 | | Ban Phone Si | ○ | N/A | ○ |
| 53 | | Kroch seuch(down) | ○ | N/A | N/A | 126 | | Ban Pak Ca Ding | N/A | N/A | N/A |
| 54 | | Wat Liep(down) | ○ | N/A | N/A | 127 | | Kham Keut | N/A | N/A | ○ |
| 55 | | Wat Liep(up) | ○ | N/A | N/A | 128 | | Ban Signo | N/A | N/A | ○ |
| 56 | | Tlea Maam(1) | ○ | N/A | N/A | 129 | | Se Bang Fai | N/A | ○ | ○ |
| 57 | | Thlea Maam(up) | ○ | N/A | N/A | 130 | | Ban Ton Hen | N/A | N/A | N/A |
| 58 | | Banteay Krang | ○ | N/A | ○ | 131 | | Ban Xaysoung | N/A | N/A | N/A |
| 59 | | Boribo | ○ | N/A | ○ | 132 | | Ban Phak Phua | N/A | N/A | N/A |
| 60 | | Kompong Chen | ○ | N/A | ○ | 133 | | Ban Tha Khan | N/A | N/A | N/A |
| 61 | | Kg. Thom | ○ | N/A | ○ | 134 | | Ban Pak Se Bang Fai | N/A | N/A | N/A |
| 62 | | Kompong Putrea | ○ | N/A | ○ | 135 | | Mahaxai | N/A | N/A | N/A |
| 63 | | Panha Chi | ○ | ○ | N/A | 136 | | Kuanpho | N/A | N/A | N/A |
| 64 | | Kg. Thmar | ○ | ○ | ○ | 137 | | Ban Keng Done | N/A | N/A | N/A |
| 65 | | Anlong Touk | ○ | N/A | ○ | 138 | | Tchepon(Sop Nam) | N/A | N/A | N/A |
| 66 | | Thnous Loung/Kg.Spe | ○ | N/A | N/A | 139 | | Highway Bridge | ○ | N/A | N/A |
| 67 | | Peamkhley-dam site | ○ | ○ | ○ | 140 | | Muong Nong | N/A | N/A | N/A |
| 68 | | Srok Sandan | ○ | N/A | N/A | 141 | | Ban Muong Chan | ○ | N/A | N/A |
| 69 | | Svay Rieng | ○ | N/A | N/A | 142 | | Highway Bridge | ○ | N/A | N/A |
| 70 | | Kompong Trabek | ○ | N/A | N/A | 143 | | Ban Phalane | ○ | N/A | N/A |
| 71 | | Prey Veng | ○ | N/A | N/A | 144 | | Kengkok | ○ | N/A | N/A |
| 72 | | Stung Banam | ○ | N/A | N/A | 145 | | Dong Hen | ○ | N/A | N/A |
| 73 | | Kompong Ampil | ○ | ○ | N/A | 146 | | Muong Atsaphone | N/A | N/A | N/A |
| | | | | | | 147 | | Ban Sebangnouane | N/A | N/A | N/A |
| | | | | | | 148 | | Ban Nanai | N/A | N/A | N/A |
| | | | | | | 149 | | Khong Sedone | ○ | N/A | N/A |
| | | | | | | 150 | | Saravanne | ○ | N/A | N/A |
| | | | | | | 151 | | Souvanna Khili | ○ | N/A | N/A |
| | | | | | | 152 | | Ban Done Xe | ○ | N/A | N/A |
| | | | | | | 153 | | Km35 | ○ | N/A | N/A |
| | | | | | | 154 | | Km8 | ○ | N/A | N/A |
| | | | | | | 155 | | BanBangLieng | ○ | N/A | N/A |
| | | | | | | 156 | | Km40 | ○ | N/A | N/A |
| | | | | | | 157 | | B.MaiVangMakxeo | ○ | N/A | N/A |
| | | | | | | 158 | | M.May(Attopeu) | ○ | N/A | ○ |
| | | | | | | 159 | | VeunKhene | ○ | N/A | ○ |
| | | | | | | 160 | | Khoueng Sekong | ○ | N/A | N/A |
| | | | | | | 161 | | BanFangDeng(Attapue) | ○ | N/A | N/A |
| | | Number of available stations | 72 | 9 | 38 | | | Number of available stations | 48 | 2 | 19 |

## Table 2.4 Status of development of meteorological and hydrological data (Thailand and Vietnam)

| No. | Country | Station | Items (1987.1.1～2018.12.31) | | | No. | Country | Station | Items (1987.1.1～2018.12.31) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Water Level | Rainfall | Discharge | | | | Water Level | Rainfall | Discharge |
| 162 | Thailand | ChiangSean | ○ | N/A | ○ | 209 | Vietnam | Tan Chau | ○ | N/A | ○ |
| 163 | | SopKok | N/A | N/A | ○ | 210 | | My Thuan | ○ | N/A | ○ |
| 164 | | ChiangKhong | N/A | N/A | N/A | 211 | | My Tho | ○ | N/A | N/A |
| 165 | | BanSangKhom | N/A | N/A | N/A | 212 | | Cho Moi | N/A | N/A | N/A |
| 166 | | Chiang Khan | ○ | N/A | ○ | 213 | | Hoa Binh | N/A | N/A | N/A |
| 167 | | Pa Mong Dam Site | N/A | N/A | N/A | 214 | | Cao Lanh | N/A | N/A | N/A |
| 168 | | Nong Khai | ○ | N/A | ○ | 215 | | Chau Doc | N/A | N/A | N/A |
| 169 | | Tha Bo | ○ | N/A | N/A | 216 | | Long Xuyen | ○ | N/A | N/A |
| 170 | | Phon Phisai | ○ | N/A | N/A | 217 | | Can Tho | ○ | N/A | ○ |
| 171 | | Ban Nong Bua | ○ | N/A | N/A | 218 | | Dai Ngai | ○ | N/A | ○ |
| 172 | | Nakhon Phanom | ○ | N/A | ○ | 219 | | Kontum | ○ | N/A | ○ |
| 173 | | That Phanom | ○ | N/A | N/A | 220 | | Trung Nghai | ○ | N/A | ○ |
| 174 | | Mukdahan | ○ | N/A | ○ | 221 | | Buon Krong Buk | N/A | N/A | ○ |
| 175 | | Khemarat | ○ | N/A | N/A | 222 | | Buon Krong Ana | ○ | N/A | ○ |
| 176 | | Khong Chiam | ○ | N/A | ○ | 223 | | Duc Xuyen | ○ | N/A | ○ |
| 177 | | Ban Pa Yang | ○ | N/A | ○ | 224 | | Cau 14(Buon Bur) | ○ | N/A | ○ |
| 178 | | Ban Huai Yano Mai | N/A | N/A | ○ | 225 | | Drayling I | ○ | N/A | ○ |
| 179 | | Chiang Rai | N/A | N/A | N/A | 226 | | Drayling II | ○ | ○ | ○ |
| 180 | | Ban Tha Ton | ○ | N/A | ○ | 227 | | Ban Don | ○ | N/A | ○ |
| 181 | | Ban Tha Mai Liam | N/A | N/A | ○ | 228 | | Iahleo | ○ | N/A | ○ |
| 182 | | Ban Tha Sai | N/A | N/A | ○ | 229 | | Vung Tau | ○ | N/A | N/A |
| 183 | | Dam Site | N/A | N/A | ○ | 230 | | Moc Hoa | ○ | N/A | N/A |
| 184 | | Dam Site | N/A | N/A | ○ | 231 | | My Hoa | ○ | ○ | N/A |
| 185 | | Thoeng | N/A | N/A | ○ | 232 | | Cho Lach | ○ | N/A | N/A |
| 186 | | Ban Pak Huai | ○ | N/A | ○ | 233 | | Vam Nao | ○ | N/A | ○ |
| 187 | | Dan Sai | ○ | N/A | ○ | 234 | | Tra Vinh | ○ | N/A | N/A |
| 188 | | Dam Site | ○ | N/A | ○ | 235 | | Xuan To | ○ | N/A | N/A |
| 189 | | Wang Saphung | ○ | N/A | ○ | 236 | | Tri Ton | ○ | N/A | N/A |
| 190 | | Ban Wang Sai | ○ | N/A | ○ | 237 | | Long Dinh | ○ | N/A | N/A |
| 191 | | Ban Tha Kok Daeng | ○ | N/A | ○ | 238 | | Tan Hiep | ○ | N/A | N/A |
| 192 | | Nam Kae | ○ | N/A | ○ | 239 | | Vi Thanh | ○ | N/A | N/A |
| 193 | | Ban Tham Hai Bridge | ○ | N/A | ○ | 240 | | Phung Hiep | ○ | N/A | N/A |
| 194 | | Ban Nong Aek Bridge | ○ | N/A | N/A | 241 | | Cai Lay | N/A | N/A | N/A |
| 195 | | Ban Na Kham Noi | ○ | N/A | ○ | 242 | | Hung Thanh | N/A | N/A | N/A |
| 196 | | Yasothom | ○ | N/A | ○ | | | | | | |
| 197 | | Ban Chot | ○ | N/A | ○ | | | | | | |
| 198 | | Ban Kae(Si Chomphu) | ○ | N/A | ○ | | | | | | |
| 199 | | Ban Tha Dua | ○ | N/A | ○ | | | | | | |
| 200 | | Ban Nong Kiang | ○ | N/A | ○ | | | | | | |
| 201 | | Ban Tad Ton | ○ | N/A | ○ | | | | | | |
| 202 | | Ban Na Thom | ○ | N/A | ○ | | | | | | |
| 203 | | Ubon | ○ | N/A | ○ | | | | | | |
| 204 | | Pak Mun | ○ | N/A | ○ | | | | | | |
| 205 | | Kaeng Saphu Tai | ○ | N/A | ○ | | | | | | |
| 206 | | Rasi Salai | ○ | N/A | ○ | | | | | | |
| 207 | | Ban Huai Khayuong | ○ | N/A | ○ | | | | | | |
| 208 | | Ban Fang Phe | ○ | N/A | ○ | | | | | | |
| | | Number of available stations | 36 | 0 | 37 | | | Number of available stations | 27 | 2 | 15 |

## 2.3 Hydropower Dam

Figure 2.10 and Figure 2.11 show the location of hydropower dams (Existing and Planned) of the Mekong River and its tributaries in 2014. There are 11 dams in the mainstream of Mekong River and 125 dams in the tributaries.

About the dam in the tributary river, it differs in number from the 58 dams arranged in the Council Study of the MRC described in subsection 2.5.2.4 This difference is considered to be due to differences in managers.

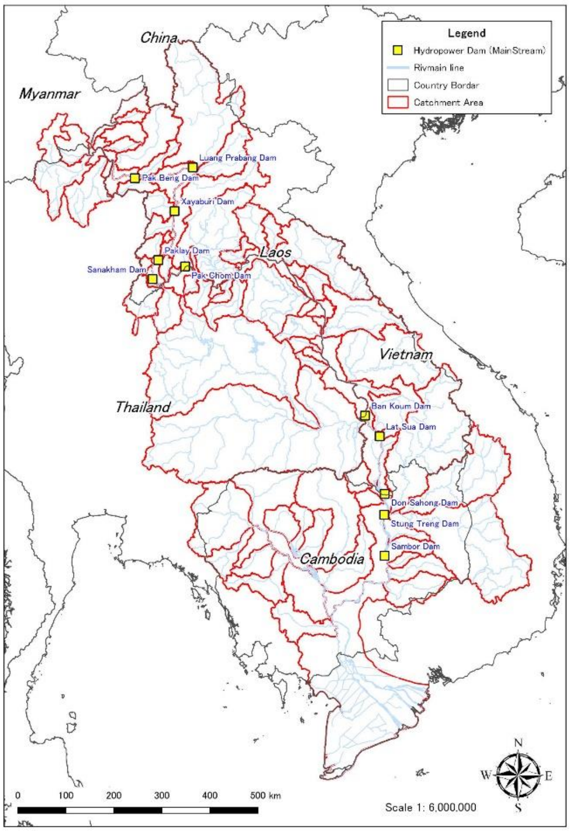



**Figure 2.10 Dam Location of Mekong River**

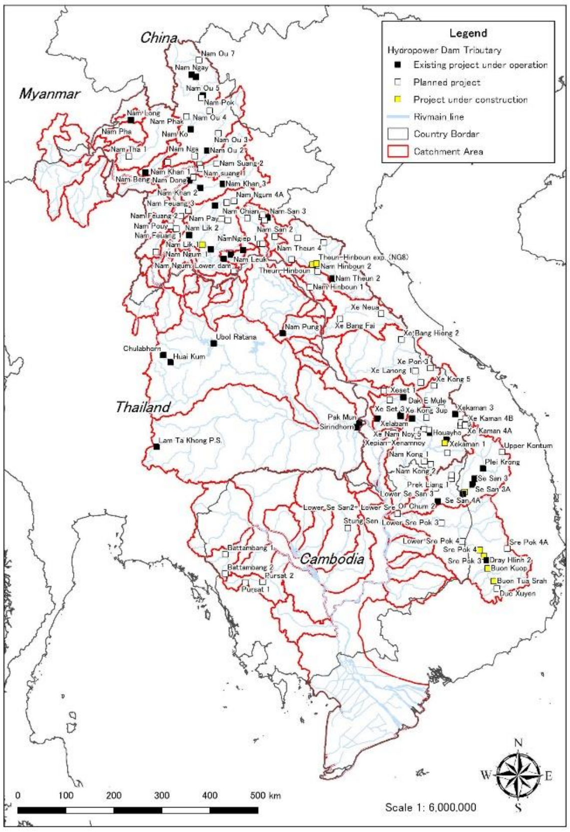



**Figure 2.11 Dam Location of Tributaries**

The dam in the main river should be noted. The Council Study of the MRC described below, reports that 2 dams; the Xayaburi Dam in northern Lao PDR and the Don Sahong Dam, located on a branch of the Mekong River, called the Husahon in Champasak Province (Corn Falls), Lao PDR, will be completed in 2019. The team confirmed from satellite images (Obtained in 2019) that the 2 dams are under construction and are nearing completion.

The Xayaburi dam is assumed to be a flow-in type dam. In this case, the entrapment of soil and sand is small and the effect on the balance of soil and sand is expected to be small. On the other hand, the Don Sahong dam is built in one channel of the reticular channel of the Mekong River, and the structure which seems to be the circumference levee is constructed in the upstream side of the dam. It is not possible to judge the power generation type from the satellite image. It is necessary to collect detailed information on dams installed in the river, because they may cause social and environmental problems.


*Source: Google Map*    *Source: Google Map*

**Figure 2.12 Xayaburi Dam**


*Source: Google Map*

**Figure 2.13 Don Sahong Dam**

## 2.4 Climate Change

The MRC has already conducted studies to assess the impacts of watershed development and climate change. The Climate Change Adaptation Initiative (CCAI) was researched and published in 2015. The Council Study published in 2018, which will be described later, also assesses the impacts of climate change under assumed development scenarios.

The study conditions of climate change by CCAI are shown in Table 2.5. In the CCAI, calculation conditions are set with reference to the 5th IPCC Assessment Report which is the latest climate change study.

**Table 2.5 Study conditions of climate change by CCAI (2015)**

| No. | Items | Summary |
|---|---|---|
| 1 | watershed management model | Adopts MRC Toolbox DSF<br>Base line: 2007<br>Model: Data set approved by MRC and all NMC |
| 2 | climate change scenarios | Based on the AR5 typical concentration pathway scenario (Representative Concentration Pathways, RCP)<br>Low: RCP 2.6<br>Medium: RCP 6.0/4.5<br>High: RCP 8.5 |
| 3 | atmospheric circulation model (GCM) | Adopts model developed by Geophysical Fluid Dynamics Laboratory (Institute of Fluid Dynamics) (Verifying) |
| 4 | evaluation period | Short, medium- and long-term forecast calculations are carried out as follows<br>Short: 2030 (2021 -2040)<br>Mid: 2060 (2031 -2070)<br>Long: 2090 (2081 -2100) |

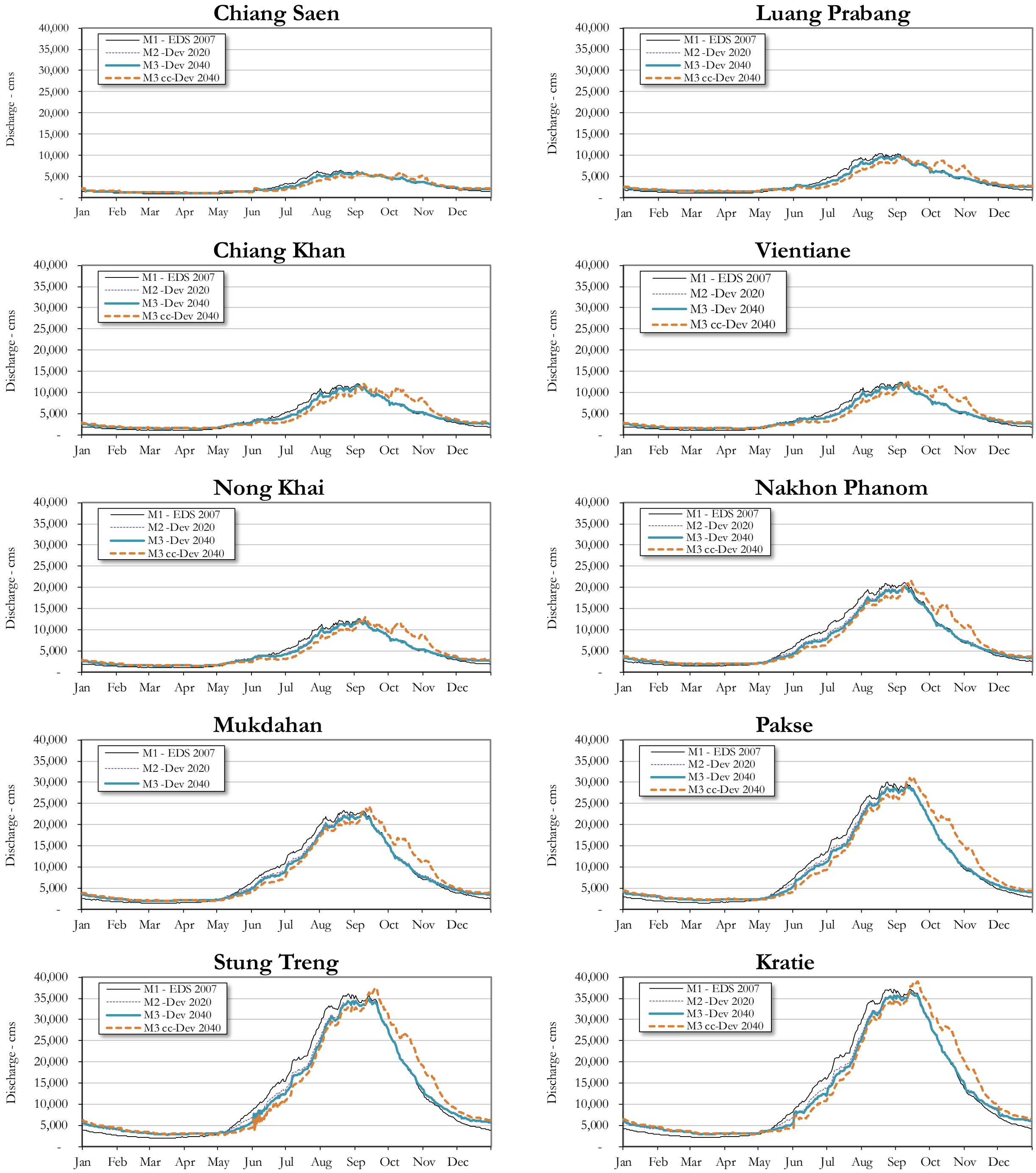
The Council Study used climate change projections for 2040. Scenario M3CC shown in Table 2.6 is a case study considering climate change. The M3CC scenario considers sub scenarios; C2 (wet tendency) and C3 (dry tendency).

**Table 2.6 Development scenario of the Council Study**

| | Scenario | Level of Development for water-related sectors | | | | | | Climate |
|---|---|---|---|---|---|---|---|---|
| | | ALU | DIW | FPF | HPP | IRR | NAV | |
| M1 | Early Development Scenario 2007 (Base Sc.) | 2007 | 2007 | 2007 | 2007 | 2007 | 2007 | 1985-2008 |
| M2 | Definite Future Scenario 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 1985-2008 |
| M3 | Planned Development Scenario 2040 | 2040 | 2040 | 2040 | 2040 | 2040 | 2040 | 1985-2008 |
| M3 CC | Planned Development Scenario 2040 | 2040 | 2040 | 2040 | 2040 | 2040 | 2040 | More seasonal |

**ALU: Agriculture & Lan Use, DIW: Drinking & Industrial Water use, FPF: Flood Protection, HPP: Hydro Power Plants, IRR: Irrigation, NAV: Navigation. CC: Climate Change, Source: MRC*

Figure 2.14 shows the hydrograph at the mainstream of Mekong River by development scenario. Table 2.7 shows a numerical list of calculation results. The impact of climate change can be confirmed by comparing the M3 scenario with the M3CC scenario. According to those hydrographs, the river flow from June to August decreases and the river flow from August to November increases due to the climate change. In addition, it can be also found that the peak of Mekong River discharge increases.




Source: MRC

**Figure 2.14 Estimated Hydrograph at Each Scenario**

Table 2.7 The Comparison flow (CMS) result between M1, M2 , M3 and M3cc from SWAT-IQQM Simulation Period 1985 - 2008

| Station | Scenario | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Wet (May -Oct) | Dry (Nov - Apr) | Average | Compare with M1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chiang Saen | M1 - EDS 2007 | 1,240 | 994 | 863 | 826 | 1,240 | 2,177 | 4,450 | 5,845 | 5,397 | 4,018 | 2,686 | 1,635 | 3,854 | 1,374 | 2,614 | | | |
| | M2 -Dev 2020 | 1,534 | 1,244 | 1,145 | 1,074 | 1,355 | 1,942 | 3,556 | 5,376 | 5,270 | 4,077 | 2,827 | 2,029 | 3,596 | 1,642 | 2,619 | -7% | 20% | 0% |
| | M3 -Dev 2040 | 1,533 | 1,242 | 1,143 | 1,073 | 1,354 | 1,941 | 3,554 | 5,376 | 5,268 | 4,076 | 2,825 | 2,028 | 3,595 | 1,641 | 2,618 | -7% | 19% | 0% |
| | M3cc - Dev 2040 | 1,602 | 1,292 | 1,172 | 1,093 | 1,316 | 1,699 | 2,797 | 4,618 | 5,264 | 4,915 | 3,190 | 2,143 | 3,435 | 1,749 | 2,592 | -11% | 27% | -1% |
| Luang Prabang | M1 - EDS 2007 | 1,505 | 1,166 | 1,020 | 1,046 | 1,825 | 3,210 | 6,746 | 9,605 | 8,432 | 5,394 | 3,469 | 2,053 | 5,869 | 1,710 | 3,789 | | | |
| | M2 -Dev 2020 | 1,904 | 1,516 | 1,385 | 1,346 | 1,903 | 2,880 | 5,660 | 8,991 | 8,288 | 5,462 | 3,656 | 2,526 | 5,531 | 2,056 | 3,793 | -6% | 20% | 0% |
| | M3 -Dev 2040 | 1,964 | 1,586 | 1,469 | 1,426 | 1,919 | 2,807 | 5,436 | 8,827 | 8,253 | 5,456 | 3,678 | 2,601 | 5,450 | 2,121 | 3,785 | -7% | 24% | 0% |
| | M3cc - Dev 2040 | 2,135 | 1,684 | 1,534 | 1,469 | 1,803 | 2,284 | 4,309 | 7,666 | 8,588 | 7,458 | 4,494 | 2,844 | 5,351 | 2,360 | 3,856 | -9% | 38% | 2% |
| Chiang Khan | M1 - EDS 2007 | 1,558 | 1,183 | 1,057 | 1,142 | 2,300 | 3,913 | 7,439 | 10,823 | 10,074 | 6,320 | 3,817 | 2,170 | 6,811 | 1,821 | 4,316 | | | |
| | M2 -Dev 2020 | 1,984 | 1,536 | 1,422 | 1,446 | 2,353 | 3,593 | 6,335 | 10,220 | 9,928 | 6,386 | 4,004 | 2,662 | 6,469 | 2,176 | 4,322 | -5% | 19% | 0% |
| | M3 -Dev 2040 | 2,081 | 1,613 | 1,502 | 1,523 | 2,325 | 3,521 | 6,092 | 10,071 | 9,902 | 6,387 | 4,028 | 2,761 | 6,383 | 2,251 | 4,317 | -6% | 24% | 0% |
| | M3cc - Dev 2040 | 2,310 | 1,715 | 1,552 | 1,515 | 2,108 | 2,835 | 4,858 | 8,800 | 10,534 | 9,216 | 5,137 | 3,044 | 6,392 | 2,546 | 4,469 | -6% | 40% | 4% |
| Vientiane | M1 - EDS 2007 | 1,569 | 1,186 | 1,053 | 1,134 | 2,314 | 4,037 | 7,481 | 11,098 | 10,535 | 6,523 | 3,906 | 2,201 | 6,998 | 1,841 | 4,420 | | | |
| | M2 -Dev 2020 | 1,998 | 1,538 | 1,417 | 1,440 | 2,384 | 3,735 | 6,372 | 10,483 | 10,376 | 6,581 | 4,079 | 2,679 | 6,655 | 2,192 | 4,424 | -5% | 19% | 0% |
| | M3 -Dev 2040 | 2,110 | 1,601 | 1,480 | 1,504 | 2,307 | 3,655 | 6,089 | 10,348 | 10,368 | 6,577 | 4,131 | 2,795 | 6,557 | 2,270 | 4,414 | -6% | 23% | 0% |
| | M3cc - Dev 2040 | 2,382 | 1,705 | 1,532 | 1,492 | 2,103 | 2,957 | 4,830 | 9,044 | 11,044 | 9,502 | 5,318 | 3,073 | 6,580 | 2,584 | 4,582 | -6% | 40% | 4% |
| Nong Khai | M1 - EDS 2007 | 1,573 | 1,187 | 1,056 | 1,140 | 2,341 | 4,092 | 7,548 | 11,204 | 10,674 | 6,581 | 3,920 | 2,209 | 7,073 | 1,848 | 4,460 | | | |
| | M2 -Dev 2020 | 2,003 | 1,540 | 1,421 | 1,447 | 2,410 | 3,792 | 6,439 | 10,588 | 10,514 | 6,641 | 4,098 | 2,690 | 6,731 | 2,200 | 4,465 | -5% | 19% | 0% |
| | M3 -Dev 2040 | 2,114 | 1,600 | 1,483 | 1,510 | 2,334 | 3,711 | 6,154 | 10,453 | 10,505 | 6,636 | 4,148 | 2,804 | 6,632 | 2,276 | 4,454 | -6% | 23% | 0% |
| | M3cc - Dev 2040 | 2,387 | 1,706 | 1,534 | 1,497 | 2,124 | 3,001 | 4,896 | 9,145 | 11,220 | 9,614 | 5,346 | 3,086 | 6,667 | 2,593 | 4,630 | -6% | 40% | 4% |
| Nakhon Phanom | M1 - EDS 2007 | 2,117 | 1,593 | 1,416 | 1,637 | 3,667 | 8,292 | 13,619 | 19,393 | 18,463 | 10,184 | 5,482 | 3,083 | 12,270 | 2,555 | 7,412 | | | |
| | M2 -Dev 2020 | 2,910 | 2,252 | 1,999 | 2,037 | 3,373 | 6,941 | 11,717 | 18,191 | 17,939 | 10,272 | 5,987 | 3,862 | 11,405 | 3,174 | 7,290 | -7% | 24% | -2% |
| | M3 -Dev 2040 | 2,731 | 2,006 | 1,853 | 1,932 | 3,025 | 6,544 | 11,151 | 17,780 | 17,715 | 10,023 | 5,699 | 3,645 | 11,040 | 2,978 | 7,009 | -10% | 17% | -5% |
| | M3cc - Dev 2040 | 3,061 | 2,158 | 1,947 | 1,917 | 2,716 | 5,519 | 10,195 | 16,647 | 19,017 | 13,852 | 7,574 | 4,006 | 11,325 | 3,444 | 7,384 | -8% | 35% | 0% |
| Mukdahan | M1 - EDS 2007 | 2,121 | 1,602 | 1,445 | 1,723 | 3,842 | 8,844 | 15,263 | 21,814 | 20,336 | 10,756 | 5,588 | 3,106 | 13,476 | 2,598 | 8,037 | | | |
| | M2 -Dev 2020 | 3,069 | 2,375 | 2,137 | 2,215 | 3,632 | 7,589 | 13,516 | 20,865 | 20,073 | 11,127 | 6,336 | 4,095 | 12,800 | 3,371 | 8,086 | -5% | 30% | 1% |
| | M3 -Dev 2040 | 2,859 | 2,100 | 1,974 | 2,102 | 3,286 | 7,174 | 12,945 | 20,457 | 19,848 | 10,846 | 5,996 | 3,837 | 12,426 | 3,145 | 7,785 | -8% | 21% | -3% |
| | M3cc - Dev 2040 | 3,189 | 2,252 | 2,061 | 2,054 | 2,905 | 6,053 | 12,070 | 19,373 | 21,379 | 14,907 | 7,906 | 4,202 | 12,781 | 3,611 | 8,196 | -5% | 39% | 2% |
| Pakse | M1 - EDS 2007 | 2,398 | 1,733 | 1,536 | 1,868 | 4,245 | 10,701 | 18,361 | 27,562 | 26,936 | 14,883 | 7,228 | 3,727 | 17,115 | 3,082 | 10,098 | | | |
| | M2 -Dev 2020 | 3,304 | 2,489 | 2,208 | 2,348 | 4,052 | 9,379 | 16,472 | 26,332 | 26,475 | 14,992 | 7,822 | 4,638 | 16,283 | 3,801 | 10,042 | -5% | 23% | -1% |
| | M3 -Dev 2040 | 3,390 | 2,509 | 2,179 | 2,322 | 3,457 | 8,817 | 15,736 | 25,917 | 26,532 | 14,895 | 7,659 | 4,583 | 15,892 | 3,774 | 9,833 | -7% | 22% | -3% |
| | M3cc - Dev 2040 | 3,684 | 2,668 | 2,320 | 2,329 | 2,984 | 7,413 | 14,418 | 24,653 | 28,093 | 20,028 | 10,560 | 5,234 | 16,265 | 4,466 | 10,365 | -5% | 45% | 3% |
| Strung Treng | M1 - EDS 2007 | 3,210 | 2,311 | 2,010 | 2,440 | 5,286 | 12,476 | 21,921 | 33,569 | 33,152 | 19,343 | 9,000 | 4,780 | 20,958 | 3,958 | 12,458 | | | |
| | M2 -Dev 2020 | 4,590 | 3,432 | 2,882 | 3,042 | 4,765 | 10,443 | 19,110 | 31,463 | 32,405 | 19,622 | 9,975 | 6,230 | 19,635 | 5,026 | 12,330 | -6% | 27% | -1% |
| | M3 -Dev 2040 | 4,727 | 3,512 | 2,898 | 3,012 | 4,068 | 9,702 | 18,183 | 30,968 | 32,530 | 19,584 | 9,887 | 6,279 | 19,172 | 5,052 | 12,112 | -9% | 28% | -3% |
| | M3cc - Dev 2040 | 5,083 | 3,722 | 3,041 | 2,981 | 3,488 | 8,176 | 16,553 | 29,734 | 34,073 | 25,127 | 13,188 | 7,051 | 19,525 | 5,844 | 12,685 | -7% | 48% | 2% |
| Kratie | M1 - EDS 2007 | 3,485 | 2,544 | 2,172 | 2,514 | 5,196 | 12,514 | 22,181 | 34,626 | 34,990 | 21,416 | 10,203 | 5,369 | 21,820 | 4,381 | 13,101 | | | |
| | M2 -Dev 2020 | 4,881 | 3,673 | 3,053 | 3,133 | 4,739 | 10,495 | 19,393 | 32,427 | 34,192 | 21,630 | 11,142 | 6,793 | 20,479 | 5,446 | 12,963 | -6% | 24% | -1% |
| | M3 -Dev 2040 | 4,946 | 3,734 | 3,008 | 3,064 | 4,193 | 9,835 | 18,405 | 31,984 | 34,396 | 21,682 | 11,102 | 6,702 | 20,083 | 5,426 | 12,754 | -8% | 24% | -3% |
| | M3cc - Dev 2040 | 5,337 | 3,933 | 3,162 | 3,046 | 3,758 | 8,257 | 16,650 | 30,736 | 35,752 | 27,156 | 14,562 | 7,605 | 20,385 | 6,274 | 13,330 | -7% | 43% | 2% |

Data Source: MRC

## 2.5 Review of Council Study

### 2.5.1 Introduction

The Study aims at clarifying the principal issues and their counter measures, which could lead to the sustainable and resilient watershed management for the Lower Mekong Basin (hereinafter referred to as "LMB"). The Study is still in preliminary level and the necessary information for the Study are largely from the Council Study by Mekong River Commission in 2017[1] (hereinafter referred to as "the MRC Council Study).

The MRC Council Study assessed the socio-economic and hydrological impacts (both positive and negative) across the LMB brought by various scenarios of the future water resources developments and climate changes.

### 2.5.2 Watershed Features of the LMB

#### 2.5.2.1 Catchment Area

The Mekong River is a trans-boundary river with the channel length of about 4,350 km and the catchment area of about 795,000 km$^2$ originating from the Tibetan Plateau, running through China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam, and finally flowing into the South China Sea (Ref. 1). The shares of the catchment area for each of the countries are as listed in Table 2.8. The objective Study Area is placed to the LMB, the lower reaches from the border of China , which has a catchment area of about 606,000km$^2$ expanding over four countries Lao PDR, Thailand, Cambodia, and Vietnam[2] (refer to Figure 2.15).

**Table 2.8 Catchment Area of Mekong River Basin**

| Country | Area (km$^2$) | Share |
|---|---|---|
| 1. China | 165,000 | 20.8% |
| 2. Myanmar | 24,000 | 3.0% |
| 3. Lao PDR | 202,000 | 25.4% |
| 4. Thailand | 184,000 | 23.1% |
| 5. Cambodia | 155,000 | 19.5% |
| 6. Vietnam | 65,000 | 8.2% |
| Upper Mekong (Total of 1 & 2) | 189,000 | 23.8% |
| Lower Mekong (Total of 3 to 6) | 606,000 | 76.2% |
| Whole Basin (Total of 1 to 6) | 795,000 | 100.0% |

*Source: Overview of the Hydrology of the Mekong Basin. MRC, Vientiane, Lao PDR, 2005*


*Source: Basin Development Plan Programme of the Atlas Lower Mekong River Basin Planning, 2011, MRC*

**Figure 2.15 The Watershed of LMB**

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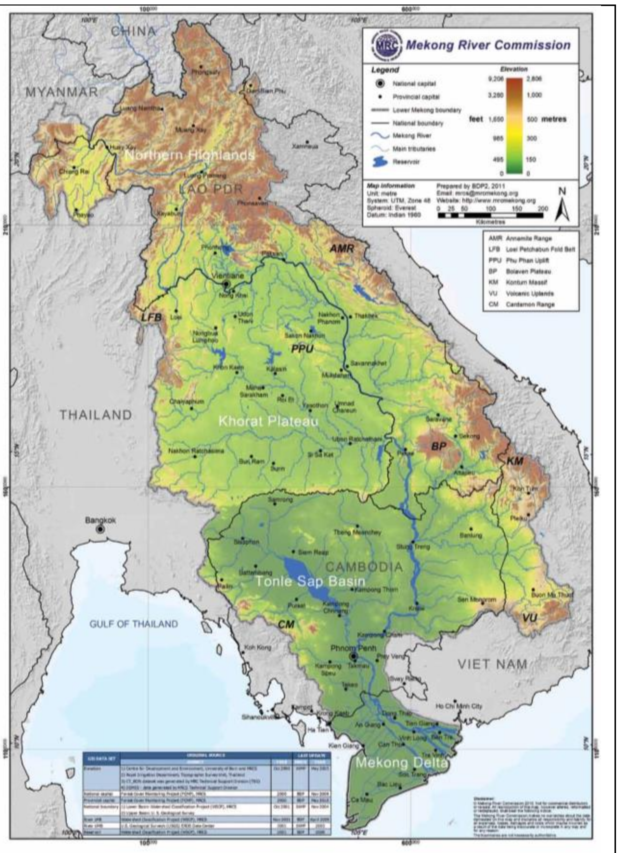
1 The Study on the Sustainable Management and Development of the Mekong River Basin, including Impacts of Mainstream Hydropower by MRC, 2017

2 A small part of Myanmar is also covered by the LMB exactly. However, of Myanmar is excluded from the Study Area due to insufficient information for the Study.

### 2.5.2.2 Topography

The ground elevation of the LMB ranges from just over 2,800 m above mean sea level (MSL) to zero at the coast in the Delta in Viet Nam. In viewpoints of the geographic features the LBM is broadly divided into four regions, namely Northern Highlands, Khorat Plateau, Tonle Sap Basin and the Mekong Delta as shown in Figure 2.16 (Ref. 3). The key characteristics of the said four physiographic regions are described below.




*Source: Basin Development Plan Programme of the Atlas Lower Mekong River Basin Planning, 2011, MRC*

**Figure 2.16 Topography of the Study Area**

#### (1) Northern Highlands

The Northern Highlands is in northern part of Lao PDR and Thailand being largely covered with the mountainous ridges with ground elevations of about 500 to 2,800m. In this region, the Mekong River and its major tributaries run through steep-sided valleys, which induce plan of five hydropower dams on the mainstream (called as the "Lao Cascade Dams").

#### (2) Khorat Plateau

The Khorat Plateau forms rather flat plateau with ground elevation of about 300m above MSL. The Plateau is bounded by the aforesaid Annamite Range Mountains in the east, which runs north south along the border between Lao PDR and Vietnam border.

#### (3) Tonle Sap Basin

The Tonle Sap Basin is the flat alluvial plains with low ground levels below about 100m above MSL being bounded by the ridge of the Khorat Plateau in the north and the Cardamon Range in the southwest.

#### (4) The Mekong Delta

The Mekong Delta begins from Phnom Penh and spreads out along the downmost stream of the Mekong River. The Mekong River firstly splits into two main distributary channels in the Delta and then further split into several smaller channels downstream finally flowing into the South China Sea. The Delta is extremely low-laying and flat ground level from 100m to zero m above MSL. The inland side of the Delta has been formed by the river sedimentation, while the seaside by the ocean sedimentation brought by tides, waves and ocean currents.

### 2.5.2.3 Land Use

The Team of the MRC Council Study developed the present land use map (the baseline map as of 2007) for the watershed of the LMB based on the land use data furnished from the member countries of the LMB and the MRC's database. Then, the team of the MRC Council Study forecasted the future forest area and the agricultural area (as of 2040) based on the following information:

- The trends of the recorded past land use changes,
- The on-going land/or committed and development projects,

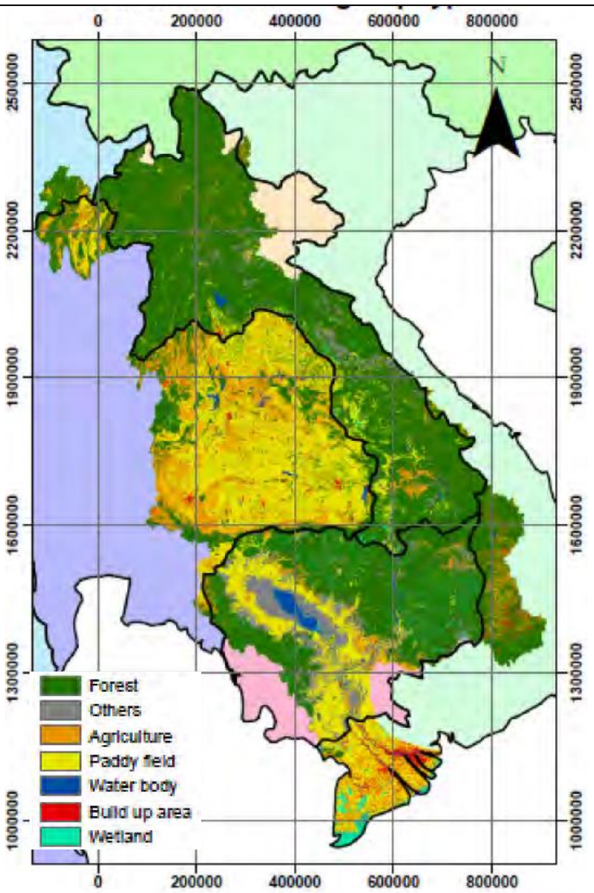
- The policies/laws/ regulations on the land development or conservation in the MRC countries, and
- The potential land for agriculture development.

As shown the present land use map of the LMB in Figure 2.17, the forest, the paddy and the agriculture areas are dominant among areas of the various land use categories.

The forest spreads over almost all part of the Lao PDR and a large part of the Cambodia except the periphery of Tole Sap Lake. On the other hand, the paddy and agriculture areas are in the almost whole land of Thailand (the Northern Highlands and the Khorat Plateau), the periphery of Tole Sap Lake of Cambodia and the Mekong Delta of Vietnam.

The MRC Study reported the extents of the present and future agriculture area (rain-fed area), irrigated paddy area and forest area as shown in Table 2.9 and Table 2.10. From these Tables, the following features of the distribution of these land uses are clarified:

- The countries in the LMB except Vietnam will largely increase the irrigated paddy area from 2007 to 2040 as compared with the rainfed agricultural area and forest. On the other hand, in Vietnam (more specifically in the Mekong Delta), a part of the irrigated paddy area along the corridor between Ho Ci Minh City and Phnom Penh City will be transferred to urban area, which leads to slight reduction of the irrigated paddy area from 2007 to 2040.




*Source: The MRC Study (Ref. 6)*

**Figure 2.17 Present Land Use Map as of 2007**

- The rainfed agriculture in the countries of the LMB except Cambodia will slightly increase from 2007 to 2040. Cambodia only will remarkably increase its rainfed agriculture area.
- In contrast to the irrigated paddy area and the rainfed agriculture area, the forest area in Cambodia, Thailand and Vietnam will decrease from 2007 to 2008. As for Lao PDR, the forest area will increase but its incremental rate is limited to 6.5% only.
- The present rainfed agriculture area as of 2007 (about 22million ha) is far wider (about 7.4 times) than the irrigated area (about 3million ha), while the difference in the two areas will be narrowed due to the dominant growth rate of the irrigated paddy than the rainfed agriculture especially in Thailand.

**Table 2.9 Present Rainfed Agriculture Area, Irrigated Paddy Area and Forest as of 2007**

| Country | Rainfed Agriculture Area | | Irrigated Paddy Area | | Forest | |
|---|---|---|---|---|---|---|
| | Area (ha) | Share | Area (ha) | Share | Area (ha) | Share |
| Cambodia | 3,719,442 | (16.8%) | 273,337 | (9.2%) | 8,303,852 | (25.9%) |
| Lao PDR | 1,925,550 | (8.7%) | 209,116 | (7.0%) | 17,379,583 | (54.3%) |
| Thailand | 13,484,104 | (60.8%) | 776,980 | (26.1%) | 4,133,540 | (12.9%) |
| Vietnam | 3,057,033 | (13.8%) | 1,713,130 | (57.6%) | 2,204,119 | (6.9%) |
| Total | 22,186,129 | (100.0%) | 2,972,563 | (100.0%) | 32,021,094 | (100.0%) |

*Source: The MRC Study (Ref. 6)*

**Table 2.10 Future Rainfed Agriculture Area, Irrigated Paddy Area and Forest as of 2040**

| Country | Rainfed Agriculture Area | | Irrigated Paddy Area | | Forest | |
|---|---|---|---|---|---|---|
| | Area (ha) | Share | Area (ha) | Share | Area (ha) | Share |
| Cambodia | 6,073,999 | (24.1%) | 678,030 | (14.2%) | 5,949,295 | (19.5%) |
| Lao PDR | 2,148,168 | (8.5%) | 597,893 | (12.6%) | 18,516,307 | (60.8%) |
| Thailand | 13,391,904 | (53.2%) | 1,810,650 | (38.0%) | 4,170,693 | (13.7%) |
| Vietnam | 3,565,749 | (14.2%) | 1,674,915 | (35.2%) | 1,842,196 | (6.0%) |
| Total | 25,179,820 | (100.0%) | 4,761,488 | (100.0%) | 30,478,491 | (100.0%) |

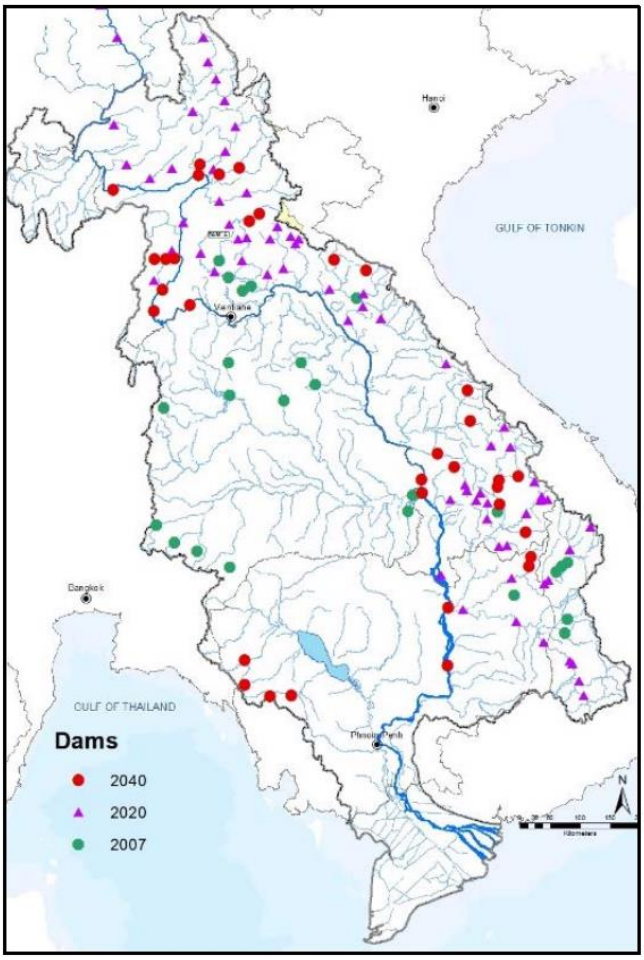
*Source: The MRC Study (Ref. 6)*

### 2.5.2.4 Hydropower Dam Development

As shown in Table 2.11, there exist 38 hydropower dams across the tributaries of the LMB, while any hydropower dam has not been constructed across the mainstream. The principal hindrance to construction of the mainstream dam could be related to the significant negative impact to the ecology and morphology of the Mekong River and the large number of resettlements caused by the dam construction and the reservoir impounded by the dam.

In order to fulfill the recent rapid increase of the power demand in the member countries of the LMB, however, the two mainstream hydropower dams (Xayaburi Dam and Don Sahong Dam) together with 20 tributary dams are now under construction. Moreover, another nine mainstream hydropower dams are being planned.

As for the share by country in number of dams, the largest number of the existing/ongoing/ planned hydropower dams is 52 dams in Lao PDR followed by 10 dams in Vietnam, 5 dams in Thailand and 2 dams in Cambodia. The locations of these hydropower dams are as shown in Figure 2.18.




*Source: Mekong Sediment from the Mekong River Commission Study*

**Figure 2.18 Location Map of Present and Future Hydropower Dams**

**Table 2.11 Number of Existing, On-going and Planned Hydropower Dam Projects in the LMB**

| Country | Mainstream Dam | | | | Tributary Dam | | | |
|---|---|---|---|---|---|---|---|---|
| | Existing | On-going | Planned | **Total** | Existing | On-going | Planned | **Total** |
| Cambodia | 0 | 0 | 2 | **2** | 0 | 0 | 0 | **0** |
| Lao PDR | 0 | 2 | 7 | **9** | 23 | 20 | 0 | **43** |
| Thailand | 0 | 0 | 0 | **0** | 5 | 0 | 0 | **5** |
| Vietnam | 0 | 0 | 0 | **0** | 10 | 0 | 0 | **10** |
| **Total** | **0** | **2** | **9** | **11** | **38** | **20** | **0** | **58** |

*Source: Greater Mekong Observatory (Ref. 16)*

The salient features of the hydropower dams in LMR are as shown in Table 2.12, whereby the following characteristics of the dams are clarified:

- The 11 mainstream dams with their installed capacity of 13,004 MW could generate annual average energy of 62,257 GW, which is far larger than 9,900 GW generated by the 58 tributary dams with their installed capacity of 9,900 MW. Judging from the differences in the said installed capacities and the annual energies of the mainstream and tributary dams, the generating efficiency of the mainstream dams is evaluated to be much higher than that of the tributary dams. Thus, the mainstream hydropower dams could be the core for the hydropower generation in the LMB.
- However, the mainstream dams would create the reservoir area of 132 $km^2$ on average, which is much wider than 66$km^2$, the average reservoir area of the tributary dams. Moreover, the population along the mainstream is far higher than population along the tributary. Accordingly, the mainstream dam would require the far larger resettlements of the residents than the tributary dam.
- The two hydropower dams under construction (i.e., Xayaburi Dam and Don Sahong Dam) is the run-of-flow type for power generation, which would also be applied to another nine planned mainstream dams, because the run-of-flow type could cause the less impact to the river flow regime than the storage type for power generation (Ref. 15). On the other hand, many of the tributary dams would need to choose the storage type because of the large fluctuation of the dam inflow discharges. For this reason, the average dam height of the mainstream dams(44m) is lower than that of the tributary dams (66m).

**Table 2.12 Salient Features of Hydropower Dams in LMB**

| Item | Mainstream Dam (11 dams) | | | | Tributary Dam (58 dams) | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | Max | Min | Ave. | Total | Max | Min | Ave. |
| Installed capacity (MW) | 13,004 | 2,600 | 256 | 1,182 | 9,900 | 1,075 | 15 | 165 |
| Mean annual energy (GW) | 62,257 | 11,749 | 2,000 | 5,660 | 37,388 | 5,936 | 53 | 645 |
| Gross storage volume (million $m^3$)* | n.a | n.a | n.a | n.a | 38,680 | 4,700 | 0.76 | 967 |
| Max reservoir area ($km^2$) | 1,456 | 620 | 2.20 | 132 | 2,702 | 450 | 0.027 | 66 |
| Dam height (m) | | 85 | 22 | 44 | | 182 | 6.00 | 66 |
| Dam crest length (m) | | 18,002 | 318 | 3,892 | | 7,729 | 75 | 693 |

**: Estimation on the gross storage volumes is not available, because the available information is limited to only three dams out of total 11 dams.*
*Source: Greater Mekong Observatory (Ref. 16)*

### 2.5.2.5 Flood

The overflow of the Mekong River has occurred almost every year causing extensive inundation and severe flood damages including losses of life. The flood inundation is confined within the limited extent along the riverine in Lao PDR and Thailand. In contrast, the extensive flood inundation tends to occur in Cambodia and Vietnam, especially the floodplain around Tonle Sap in Cambodia and the Mekong Delta in Vietnam (refer to Figure 2.19). This uneven distribution of the flood inundation also brings the uneven distribution of flood damages. The floods in 2000 and 2011, which are dominant among the recent floods, brought on more sever flood damages in Cambodia and Thailand but less in Thailand and Vietnam as shown in Table 2.13.

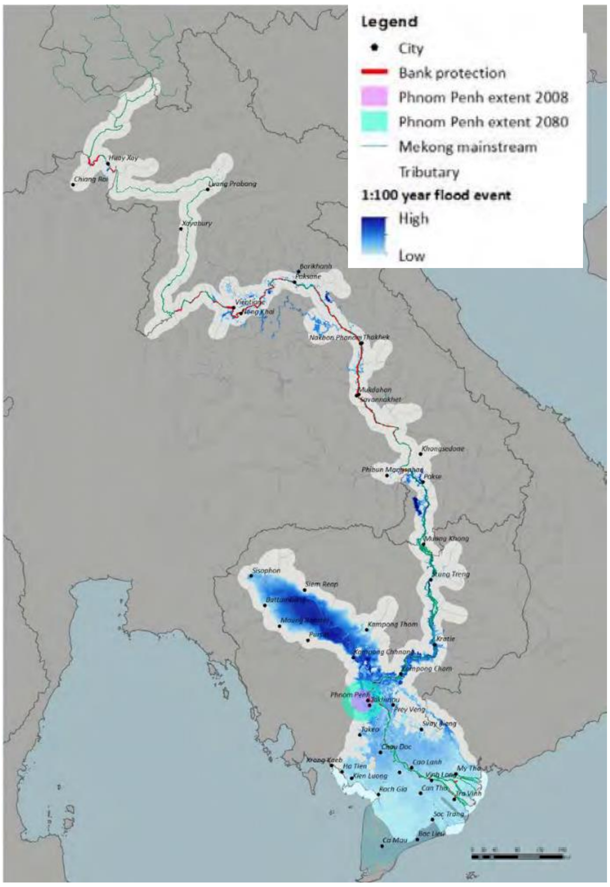
**Table 2.13 Number of Fatalities and Value of Loss Recorded in Flood 2000 and 2011**

| Country | 2000 Flood | | 2011 Flood | |
|---|---|---|---|---|
| | Number of Fatalities | Value of Loss (million US$) | Number of Fatalities | Value of Loss (million US$) |
| Cambodia | 350 | 159 | 250 | 634 |
| Vietnam | 320 | 125 | 104 | 260 |
| Thailand | 25 | 30 | n.a. | n.a. |
| Lao PDR | 15 | 21 | 42 | 208 |
| Total | 710 | 335 | 396 | 1,102 |

*Source: The MCR Study (Ref. 8 )*

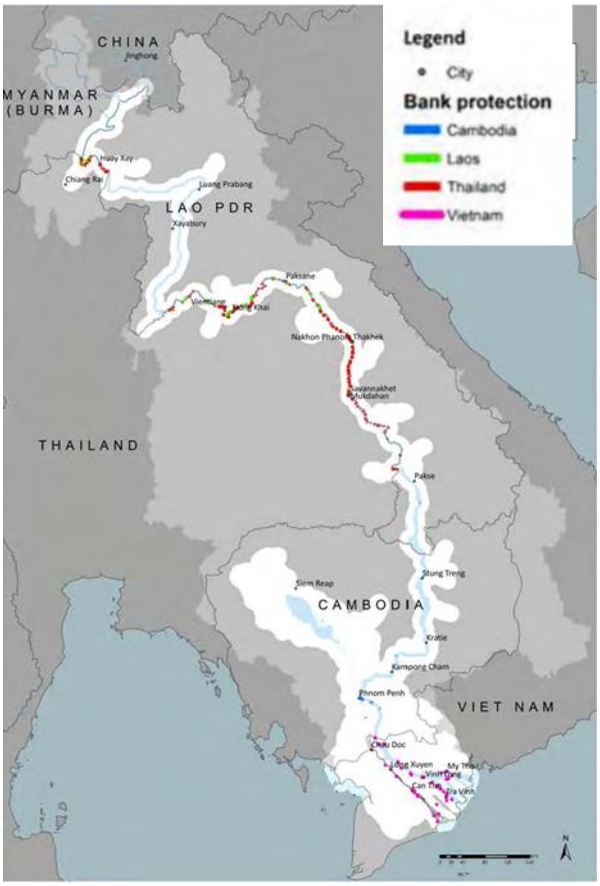
The floods in the LMB have been partly accepted through a concept of "Live with Floods". However, the need for flood protection is rising along with the increment of flood damages induced by more advanced land use in the floodplains and the progress of the climate changes. Under such conditions, the member countries of the LMB are undertaking the riverbank protection and the flood plain management as the principal flood protection works (Ref. 8).

The riverbank protection aims at protecting the riverbank against the ongoing serious river erosion of the Mekong River mainstream and preventing from river overflow by construction of the river dike. Of the entire river length, however, the proportion of the completed part of the riverbank protection in the member countries of the LMB is still limited. According to the estimation by the MRC Study, the proportions for each member county of the LMB is 5.8% in Lao PDR, 17.0% in Thailand, 1.7%in Cambodia and 6.3% in Vietnam (refer to Figure 2.20) (Ref. 8). As for the flood management, Cambodia has a plan to complete the road network in the Cambodian Floodplain, which could function to interrupt the flood flow into the floodplain. Vietnam has already introduced many ring dikes to the Mekong Delta in order to interrupt the flood flow into the agricultural land and/or urban area there.




*Source: The MRC Council Study (Ref. 8 )*

**Figure 2.19 100-year Flood Extent in the LMB Estimated by the MRC Study**




*Source: The MRC Council Study (Ref. 8 )*

**Figure 2.20 Location of Completed Riverbank Protection Works**

### 2.5.2.6 Natural Environment

#### (1) River Water Quality

The MRC Study presented the spatial variations of the following four river water quality parameters monitored at 22 stations along of the Lower Mekong mainstream and its tributary(see Figure 2.21) (Ref. 9).

- Chemical Oxygen Demand (COD),
- Total Phosphorus Concentrations (TOTP),
- Ammonium Concentration ($NH_4$), and
- Nitrate/Nitrite Concentration ($NO_3/NO_2$).

Based on the monitoring results of the river water quality shown in Figure 2.21, the relation between the observed concentration values of the above four parameters and their corresponding threshold values are clarified as shown in Table 2.14. As shown in the Table, the monitored values of the $NH_4$ and $NO_3/NO_2$ are mostly below the threshold values and preliminarily judged to be acceptable for the aquatic life and the human health. However, some monitored vales of COD exceed the threshold value (5mg/L). Moreover, many monitored values of TOTP exceed the threshold value (0.13 mg/L), whereby the MRC Study cited that the TOTP in the Mekong River increased from mean concentration of about 0.058 mg/L in 2000 to about 0.13 mg/L in 2014 (Ref. 9). The high concentration values of TOTP monitored in Mekong River suggests that the River is somewhat polluted by agricultural chemicals runoff and/or effluent of municipal wastewater.

The MRC Study revealed that 82% of the households in Cambodia and 55% in Lao PDR are likely to still use raw water from the Mekong River for drinking: the said percentages of households are derived from the sample survey (Ref. 9). Considering such water use of the Mekong River together with the aforesaid deterioration in the river water quality, the water security of Mekong River may be one of the important issues of the watershed management of the LMB.

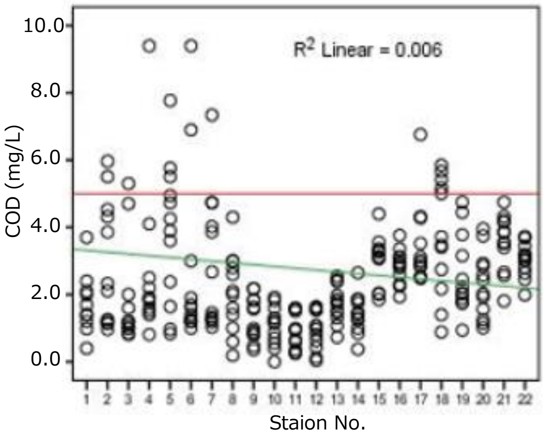
**Table 2.14 Relationship between the Monitored Concentration Values of Water Quality Parameters and Threshold Values**

| Parameter | Threshold Value* | Results of monitoring in 2004 |
|---|---|---|
| COD | 5.0 mg/L | Seven water quality stations recorded the rather many values of the COD concentration above the threshold value. |
| TOTP | 0.13 mg/L | All monitoring stations recorded values of the TOTP concentration above the threshold value, |
| $NH_4$ | 0.5 mg/L | All the monitored values except the value of monitored at Station No. 19 one time are below the threshold value. However, even the overtop value is 0.6mg/L exceeding by 0.1 mg/L only. |
| $NO_3/NO_2$ | 5.0 mg/L | All the monitored values are below 1.2mg/L and well below the threshold value. |

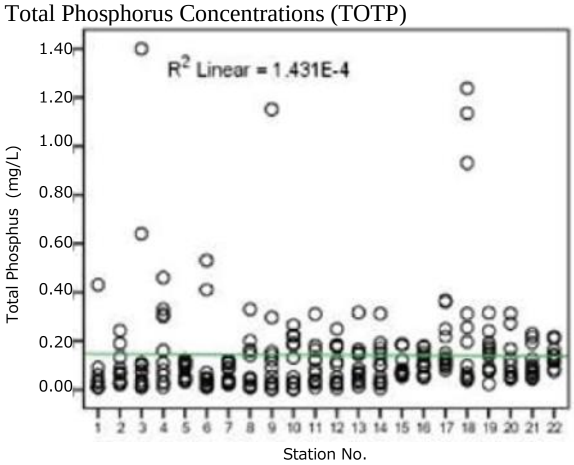
** : Threshold value set up in the "MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life".*

**Source: The MRC Study (Ref. 9)*

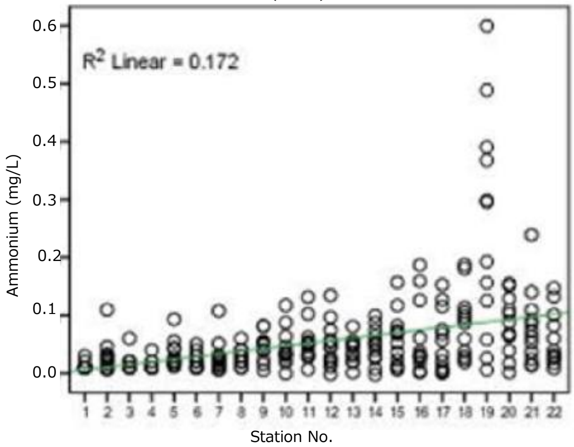
Chemical Oxygen Demand (COD)



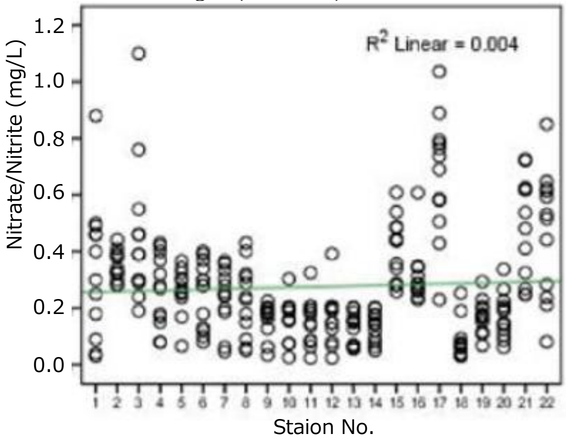

Total Phosphorus Concentrations (TOTP)




Ammonium Concentration ($NH_4$)




Nitrate/Nitrite Nitrogen ($NO_2$/$NO_3$)



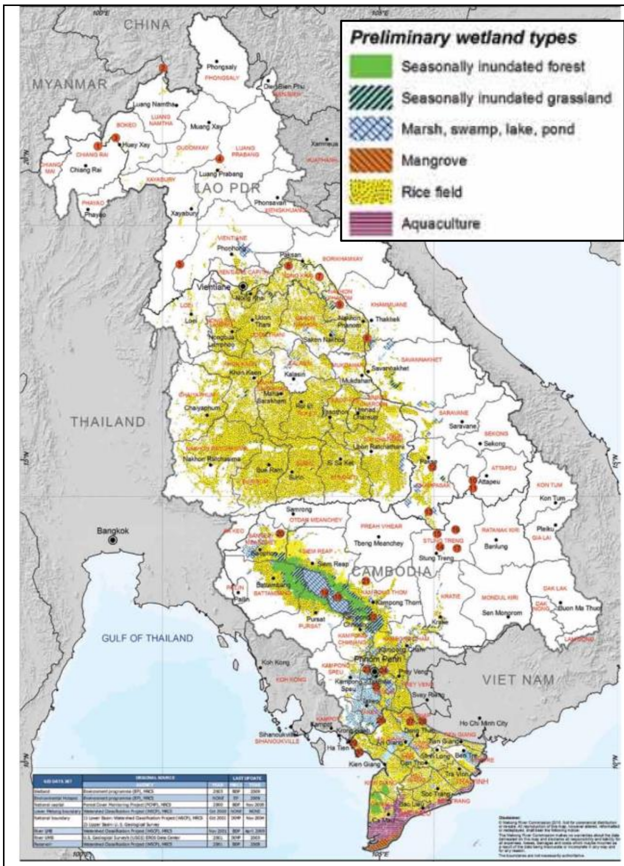

*Note: The stations of 1-17 are along the Mekong (1-17) and 18-22 are along the tributary, Bassac River in Mekong Delta.*
*Source: The MRC Study (Ref. 9)*

**Figure 2.21 Spatial Variation in Water Quality Parameters of COD, TOTP, $NH_4$ and $NO_2$/$NO_3$ on Mekong River and Tributary Bassac River in 2014**

**(2) Wetland**

The MRC defined the wetland in the LMB covers six land use categories; namely (i) seasonally inundated forest, (ii) seasonally inundated grassland, (iii) marsh, swamp, lake, pond (iv) mangrove, (v) rice field and (vi) aquaculture area. Such wetland has a variety of functions, which are indispensable to the sustainable and resilient watershed management, as enumerated below (Ref. 3):

- To purify the river waters, .
- To provide important habitat for flora,
- To provide important sources of food (fish protein), water, wood and fibrous plants for building material and traditional medicines.,
- To mitigate flood damage,
- To trap sediments and nutrients and
- To prevent the river bank and coastal line from erosion.




*Source: Basin Development Plan Programme of the Atlas Lower Mekong River Basin Planning, 2011, MRC*

**Figure 2.22 Map of Wetland in the LMB**

In accordance with the above definitions of the wetland, the location map of the wetland lands in the LMB are delineated as shown in Figure 2.22 (Ref. 3). As shown in the Figure, the rice fields take the largest part of the wetland covering a substantial part of the northeast Thailand. Next to the rice field, the marshes, swamps, lakes and ponds take the second largest, but they are scattered throughout the lower part of the LMB, in southern Lao PDR and Cambodia, particularly along the Mekong and Tonle Sap river corridors. The seasonally inundated forest and grasslands are predominantly surrounding the Tonle Sap Lake and in the Delta. Mangrove forests are mainly confined to coastal areas in the southwest of the Mekong Delta in Vietnam. On the other hand, the aquaculture areas are in the southwest of the Delta and coastal areas further to the east.

**(3) Fishery Resources**

The LMB is one of the major habitats for the inland fishes in the world, and the fishery together with the rice cultivation is indispensable for the food security and the livelihood especially for the rural communities in the LMB.

At least 189 species of fish inhabit the LMB and 80% of them (165 species) make seasonal migration. During the dry season, the migratory fishes stay in the deep portions in the river, while at the beginning of the wet season, they move toward the floodplains from their dry season refuges for breeding and feeding. The maximum distance of this movement ranges over hundreds of kilometers on the mainstream of Mekong River (Ref. 3).

The commercially valuable fish species are generally divided into the “black fish”, the “white fish”, and the “gray fish”. The black fish tends to inhabit in the floodplains almost throughout a year without migration between the downstream and upstream. On the other hand, the white fish is the migratory specie inhabiting in the flood plains during the wet season but in the river channel during the dry season. The grey fish fall somewhere between the other two. The black fish accounts for about 13% of total living fishes and 50% of the catch in the LMB, while the white fish 37% of the living fishes and 36% of the catch (Ref. 13).

### 2.5.2.7 Major Impacts on Environment in the LMB

#### (1) Scenarios on Water Resources Development, Land Use and Climate Changes in the LMB

The MRC Study assessed the potential changes in the hydrology, the river morphology, the ecology and the socio-economy of the LRB affected by various scenarios of the water resources development projects, the land use and climate changes in the LMB. The outline of the said scenarios assumed in the MRC Study is as listed in Table 2.15 below (Ref. 5). The results of the assessment of the MRC Study are useful to examine the sustainable and resilience watershed management for the LMB. Hence, the results of the impact assessment in the MRC Study was reviewed and used as the eligible information for this Study.

**Table 2.15 Scenarios of Water Resources Development, Land Development and Climate Changes Assumed in the MRC Study**

| Scenario | Basic Concept | Water resources development projects assumed in the scenario | Land Use States | Climate Change |
|---|---|---|---|---|
| M1 | (i) Early development scenario<br>(ii) Baseline scenario | The water resources development projects completed in 2007 is remained as it is without any further development in the future. | The present land use as of 2007 | Not considered |
| M2 | Definite future water resources development scenario | The ongoing and firmly committed water resources development is completed in 2020. | The future land use in 2020 | Not considered |
| M3 | Planned development scenario | The above M2 Scenario is realized in 2020, and further, all the planned water developments are completed in 2040. | The future land use in 2040 | Not considered |
| M3CC | Planned development scenario (M3) affected by climate change | Same as Scenario M3 | Same as Scenario M3 | Considered<br>( medium level of climate change (applying IPSL for GCM Model and RCP 4.5 for green-house gas emissions |

*Note: The MRC study further assumed a few sub-scenarios for each of the water resources development projects and the climate change in order to clarify the more sensitive impact on the LMB.*

*Source: The MRC Study (Ref. 5)*

The above assessment in the MRC Study is subject to the following conditions:

- The water resources development projects described in the above Table 2.15 are classified into six themes, namely: (i) hydropower development, (ii) irrigated agriculture development, (iii) non-irrigated agriculture development, (iv) domestic and industrial water development, (v) navigation development, and (vi) flood protection.
- The land use in the M1, M2 and M3 scenarios are estimated based on the annual rates of land use change, which

Box-A

Definition of GCM and RCP

- The General Circulation Model or GCM is the numerical model representing physical processes in the atmosphere, ocean, cryosphere and land surface, and it is the most advanced tool currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations
- .The Representative Concentration Pathway or RCP is a greenhouse gas concentration trajectory adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. IPCC set five levels of RCP, whereby the RCP 4.5 is regarded as the intermediate levels of greenhouse gas concentration.

*(Source: JICA Study Team with referring to documents of IPCC)*

are derived from (a) the land use data stored in the MRC database and the national database of the land uses in the study area and (b) the topographies of the study area and (c) the policies/laws/regulations on the land development in the MRC countries.

- The climate change assumed for the scenario M3CC is subject to the medium level of climate change applying IPSL for general circulation model (GCM) and RCP 4.5 for green-house gas emissions (see Box-A).
- The socio-economic and hydrological impacts across the Lower Mekong River Basin are quantified through simulation of 24-year time series hydro-meteorological gauging data (1985 -2008) under the above scenarios.

**(2) Impacts of Water Resources Developments on Environment of the LMB.**

1) Impacts of Hydropower Development

All the hydropower dams so far constructed in the LMB are placed on the tributaries of Mekong River, and none across the mainstream. However, two hydropower dams (Xayaburi Dam and Don Sahong Dam) are now under construction and another nine dams are further planned on the mainstream of the Mekong River (see foregoing subsection 2.5.2.4 ). Due to the progress of hydropower development on the mainstream of Mekong River, the future impacts on the LMB will largely increase in the various aspects although the present impacts of the hydropower dams on the LMB is small as described hereinafter.

2) Impact on Economy

The MRC Study estimated the net present values (NPV) of four water resources development sectors under development scenarios M1, M2, and M3 as shown in Table 2.16.

As described above, there exist no hydropower dam on the mainstream of Lower Mekong River and therefore, the NPV of the hydropower development as of 2007 in the scenario M1 (9.1 million US $) is much smaller than those of other development sectors as shown in Table 2.16 (Ref. 7). On the other hand, because 11 hydropower developments are to be newly completed by 2040 under scenario M3, the hydropower development will take the largest increment (151.7million US $) from 2007 to 2040 among four water resources development sectors. Thus, the hydropower development could apparently contribute to the highest economic growth to the LMB among the four development sectors in 2040, provided that all ongoing and planned hydropower dams on the mainstream of Mekong River are completed by 2040 as per the scenario M3.

In contrast to hydropower development, the fishery development makes degradation of the future NPV under scenarios M2 and M3 as shown in Table 2.16. This degradation of the NPV largely depends on the under-mentioned significant negative impacts on the inland fishery inflicted by the hydropower development. Moreover, the hydropower dams could also induce harmful effects to the river morphology of Mekong River. These negative impacts of the hydropower dams are not incorporated into the NPVs.

**Table 2.16 Net Present Value (NPV) for Water Resources Development Sectors under Development Scenarios M1, M2 and M3**

(Unit: Million US$)

| Development Sector | NPV for Scenarios of M1, M2 and M3 | | | Increment from M1 (2007) to | |
|---|---|---|---|---|---|
| | M1 (States in 2007) | M2 (States in 2020) | M3 (States in 2040) | M2 (2007 to 2020) | M3 (2007 to 2040) |
| Hydropower | 9.1 | 72.3 | 160.8 | 63.2 | 151.7 |
| Agriculture | 358.2 | 449.8 | 461.7 | 91.6 | 103.5 |
| Fishery | 72.9 | 56.3 | 50.2 | -16.6 | -22.7 |
| Navigation | 7.3 | 12.2 | 76.2 | 4.9 | 68.9 |

*Source: The MRC Study (Ref. 11)*

3) Impacts on Resettlement

The number of resettlements required due to the ongoing two dams, Xayaburi Dam and Don Sahong Dam has been estimated at about 2163 persons in total (2,100 persons for Xayaburi Dam and 63 persons for Don Sahong Dam (Ref. 18 and Ref. 19).

It is also estimated that about 202,000 people will be affected by the ongoing Xayaburi Dam due to the loss of agriculture/forest resources and the various means of their livelihoods(Ref. 18).

**Table 2.17 Max Reservoir Area of Hydropower Dams on Mainstream of Mekong River**

| Project | Location of Project | States | Max reservoir area ($km^2$) |
|---|---|---|---|
| Don Sahong | Lao PDR | Ongoing | 2.2 |
| Xayaburi | Lao PDR | Ongoing | 49.0 |
| Total reservoir area for on-going dams | | | 51.2 |
| Ban Khoum | Lao PDR | Planned | 132.5 |
| Latsua | Lao PDR | Planned | 13.0 |
| Luangprabang | Lao PDR | Planned | 72.4 |
| Pak Beng | Lao PDR | Planned | 87.0 |
| Pak Lay | Lao PDR | Planned | 108.0 |
| Sambor | Cambodia | Planned | 620.0 |
| Sanakham | Lao PDR | Planned | 81.0 |
| Pak Chom | Lao PDR | Planned | 80.3 |
| Stung Treng | Canbodia | Planned | 211.0 |
| Total reservoir area for the planned dams | | | 1,405.2 |

*Source: Greater Mekong Observatory (Ref. 16)*

The max reservoir area of the ongoing two hydropower dam is 51.2km$^2$ in total, while the total reservoir area for the planned nine dams would largely increase to 1,405.2km$^2$, which corresponds to about 27 times of the total reservoir area for the ongoing dams. The definite number of the resettlements and other persons affected by the planned 11 dams is unknown. However, in view of the number of resettlements for the ongoing hydropower dam project and the increment of the reservoir area of the planned dams, the number of resettlements required to the planned hydropower dams may reach tens to hundreds of thousands of people.

4) Impacts on Fishery and Other Aquatic Resources

As described in the foregoing subsection 2.5.2.6 (3) , 165 species of fish or about 80% of the total fishes in the LMB make seasonal migration for hundreds of kilometers along the mainstream of Mekong River. Hence, the ongoing and planned hydropower dams across the mainstream of Mekong River become the great hindrance to the migratory fishes.

The World Wildlife Fund (WWF) specifically reported that the ongoing Xayaburi Dam would drive the critically endangered Mekong giant catfish to extinction (Ref. 18). The WWF also reported that the ongoing Don Sahong Hydropower Project would pose a major threat to the Mekong River's critically endangered population of Irrawaddy dolphin. (Ref. 18).

In general, the fish passages installed at the hydropower dams/weirs may support the migration of fishes. In case of the LMB, however, there are a variety of migratory fish species, which have the different body sizes and different abilities of ascending against current of river flow. Hence, it is virtually difficult to prepare a suitable fish passage, which could allow all migratory fish species to pass through the fish passage According to the MRC, the fish passage would be available only for 50% of the migratory fishes (Ref. 19).

5) Impacts on Sediment Discharge and Erosion of Riverbank

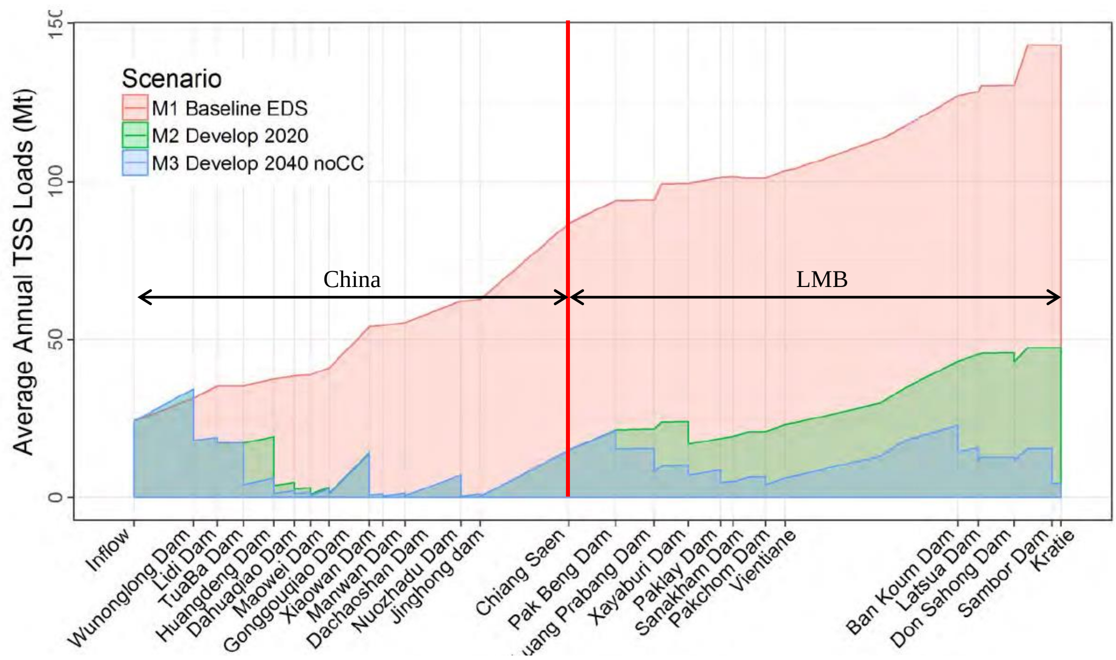
The results of simulation in the MRC Study suggest that the hydropower dams across the mainstream of Mekong River would trap large volume of sediment runoff flowing into the dam reservoir and remarkably reduce the sediment outflow volumes toward downstream from the dams.

The MRC Study also estimated that due to the land use and climate changes, the natural sediment runoff volume from the entire Mekong River Basin will gradually increase as shown in Table 2.18 below. There is, however, a substantial reduction in the sediment volume to flow downstream from the hydropower dams. According to the simulation on movement of TSS loads in the MRC Study, the annual average TSS loads transported to Kratie City, which is located at the downstream end of all mainstream dams, is estimated at 143 million tons under the Scenario M1 (2007 baseline), while it will be reduced to 4 million tons only under Scenario M3 (2040) due to the sediment trapping effects by the hydropower dams developed from 2007 to 2040 (see Figure 2.23) (Ref. 20).

**Table 2.18 Annual Average Basin Sediment Runoff Volume**

| Scenario/Year | Average Annual Basin Sediment Runoff Volume (million tons/year) |
|---|---|
| M1 (States as of 2007 without climate change) | 150.9 |
| M2 (States as of 2020 without climate change) | 159.2 |
| M3 (States as of 2040 without climate change) | 161.2 |
| M3CC (States as of 2040 with climate change) | 178.2 |

*Source: The MRC Study (Ref. 7)*




*Source: MRC Study (Ref. 7)*

**Figure 2.23 Annual Average TSS Loads on the Mekong River under Scenarios M1, M2, M3**

The above remarkable reduction of the sediment supply to the downstream from the hydropower dams would cause the serious riverbank erosion as well as loss of the riparian vegetation, and exposure of bedrock. Such harmful impacts on the river morphology of Mekong River would further induce with severe impacts on the habitats of aquatic lives in the river and flood plains causing a drop in floodplain fish productivity, and fundamental changes to the fish communities (Ref. 7).

The MRC Study suggest that flushing of sediment from the hydropower dam may mitigate the reduction of sediment accumulated in the dam reservoirs to a certain degree. However, the periodic flushing of sediments could result in releasing large volume of sludges of anoxic sediments toward downstream and removal of riffles causing harmful impacts on the aquatic life (Ref. 7).

> Box-B
>
> Definition of Run-of-River Type Power Generation
>
> The principal feature of the run-of-river type power generation is such that the hydropower dam is provided with small or no water storage pond. In case the small storage pond is provided, it is referred to as "pondage".
>
> A hydropower dam without pondage is subject to natural river flows regime, thus the dam is operated as an intermittent energy source. On the other hand, the hydropower dam with pondage stores the river water to meet daily or weekly fluctuation of power load demands.
>
> Apart from the run-of-river type hydropower dam, there is also the reservoir type hydropower dam, whereby the reservoir is provided. The reservoir stores the river water to meet the annual fluctuation of power load demands. .
>
> The hydropower dam with the run-of-the-river type power generation

6) Impact on River Flow Regimes

According to the MRC Study, the ongoing and planned 11 hydropower dams on the mainstream of Mekong River are likely to apply the run-of-river type power generation from the following points of views. The run-of-river type power generation is as defined in the Box-B.

- Both on-going two hydropower dams on the mainstream (Xayaburi dam and Don Sahong Dam) have been labeled as the run-of-river type dam by the developers (Ref. 17) and (Ref. 18).
- The MRC Study cited that out of the planned nine hydropower across the mainstream, five dams along the Las Cascade would apply the run-of-river type. The MRC Study further cites that most of another four planned hydropower dams are expected to have similar design as the said five dams along the Lao Cascade (Ref. 7).

If all the ongoing/planned hydropower dams on the mainstream of Mekong River applied the run-of-river type as stated above, the impact on the river flow regimes of the hydropower dams would be minimized. However, the "run-of-river type" for the ongoing Xayaburi Dam is deemed to be mislabeled judging from the huge storage capacity of 1,300 million $m^3$ and the extensive reservoir area of $49km^2$.  Moreover, the designs for the planned nine hydropower dams are still in flux, and therefore the run-of-river scheme would not be necessarily applied to all planned dams.

If the ongoing Xayaburi Dam and/or the planned nine dames are not the run-of-river type but the storage type, they would cause significant fluctuations of river water stage/discharge during the drawdown and filling reservoir operation. In order to mitigate such adverse impacts on the river flow regime, the rule on the minimum discharge for river maintenance flow and the maximum ramping rate3 for drawdown and filling operation of the dam reservoir should be set up and adopted to all hydropower dams in the LMB.

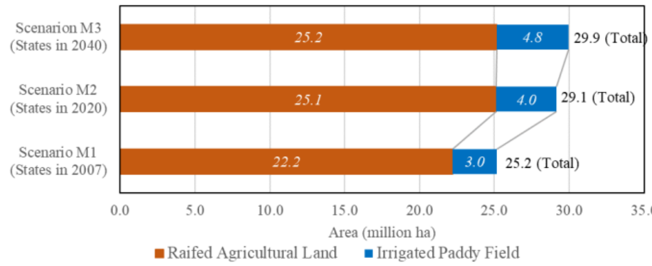
## (3) Impact of Agricultural Development

The MRC Study evaluated that the agricultural development would make a large impact on the economy of the LMB but imperceptibly impact the river morphology, hydrology and ecology as described hereinafter.

1) Impacts on Socio-Economy

[3] Definition of ramping rate: The rate of increasing and decreasing flow levels downstream of hydropower dam

As described in the foregoing subsection 2.5.2.7 (1) , the MRC Study forecasted the future expansion of the agricultural area in the LMB based on the information related to (i) the trends of the recorded past land use changes, (ii) the on-going land/or committed and development projects, (iii) the policies/laws/ regulations on the land development or conservation in the MRC countries, and (iv) the potential land for agriculture development ( Ref. 6). The future agricultural area thus estimated is as shown in Figure 2.24.




*Source: The MRC Study ( Ref. 6)*

**Figure 2.24 Change of Agricultural Area in Scenarios M1, M2 and M3**

According to the results of the above forecast of the MRC Study, the irrigated rice field would steadily increase through 2020 and 2040 although its whole extent is about 20% of the rainfed agricultural land. On the other hand, the rainfed agricultural land will make marginal increase from 25.1 million ha in 2020 to 25.2 million ha in 2040 only despite its the rather large increment projected from 2007 to 2020 (22.2 million ha in 2007 to 25.1 million ha in 2020).

The marginal increment of the rainfed agricultural land from 2020 to 2040 may be primarily attributed to the following conditions:

- ➢ The easier/more economical land for rainfed agricultural development tends to be brought forward earlier (say before 2020) and a large part of land difficult in rainfed agricultural development will be left behind.
- ➢ The number of work forces may shift from the agriculture sector to secondary and/or tertiary industry sectors in the future, which would become the great hindrance for the rainfed agriculture development.

Based on the above present and future extent of agricultural land, the MRC Study further estimated the NPVs of the four major water resources development projects for the LMB under scenarios of M1, M2 and M3 as shown in Table 2.19 below (Ref. 11).

**Table 2.19 Net Present Value (NPV) for Water Resources Development Sectors under Development Scenarios M1, M2 and M3 (*Same as Table 2.16)**

| Development Sector | NPV for Scenarios of M1, M2 and M3 | | | Increment from M1 (2007) | |
|---|---|---|---|---|---|
| | M1 (As of 2007) | M2 (As of 2020) | M3 (As of 2040) | M1 to M2 (2007 to 2020) | M2 to M3 (2020 to 2040) |
| Agriculture | 358.2 | 449.8 | 461.7 | 91.6 | 11.9 |
| Fishery | 72.9 | 56.3 | 50.2 | -16.6 | -6.1 |
| Hydropower | 9.1 | 72.3 | 160.8 | 63.2 | 88.5 |
| Navigation | 7.3 | 12.2 | 76.2 | 4.9 | 64.0 |

*Source: The MRC Study (Ref. 11)*

As shown in Table 2.19 above, the agricultural development would have the highest NPV among the four principal water resources developments across scenarios M1. M2 and M3. Hence, the agricultural development plays as the main force to enhance the economic viability of the LMB. However, because of the marginal increment of the rainfed agricultural land from 2020 to 2040 as described above, the NPV of the agriculture development from the scenario M2 to M3 also show small increment. Thus, the economic viability of the agricultural development may gradually decline in the future and the agricultural products in the LMB may be going up to the ceiling after 2020.

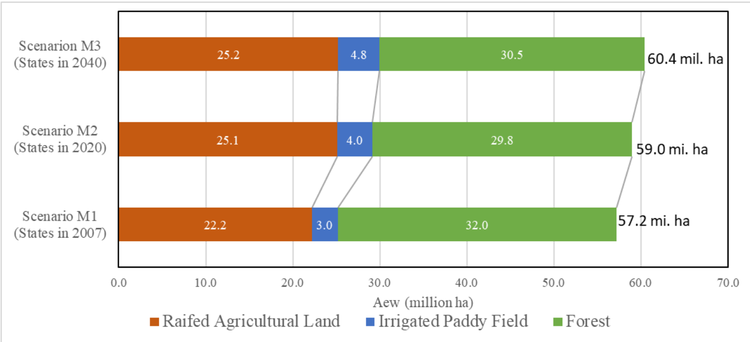
It is said that the LMB currently cover the rice as the staple food for approximately 300 million people, while the population dependent to the rice produced in the LMB will increase as the GDP rises in the LMB (Ref. 21). Hence, the member countries of LMB would be required to review agricultural area expansion policies in due consideration of the food security of the LMB and the agricultural economic viability together with the available labor forces for the agriculture sector in the future.

2) Impacts on Natural Environment

In addition to the aforesaid areas of the rainfed agricultural land and the irrigated rice field, the MRC Study estimated the forest areas in scenarios M1, M2 and M3. As the results, the MRC Study delineated the overall shares of the rainfed agriculture land, the irrigated rice field and the forest area in the entire LRB as shown in Figure 2.25.

As shown in the Figure, the area of rainfed agricultural land and the irrigated rice field tends to slightly increase through scenarios of M2 and M3, while the forest area slightly decreases.

On the premises of the above land use changes, the MRC further simulated the impacts on the natural environment associated with the said land use changes. From the results, the MRC preliminarily evaluated that the overall impact of the agricultural development and the forest conservation may be allowable on the natural conditions of the LMB as far as this evaluation is based on the results of simulation. However, the MRC Study also raised the following points to which attention should be paid:




*Source: The MRC Study (Ref. 6)*

**Figure 2.25 Change of Agricultural Area and Forest Area in Scenarios M1, M2 and M3**

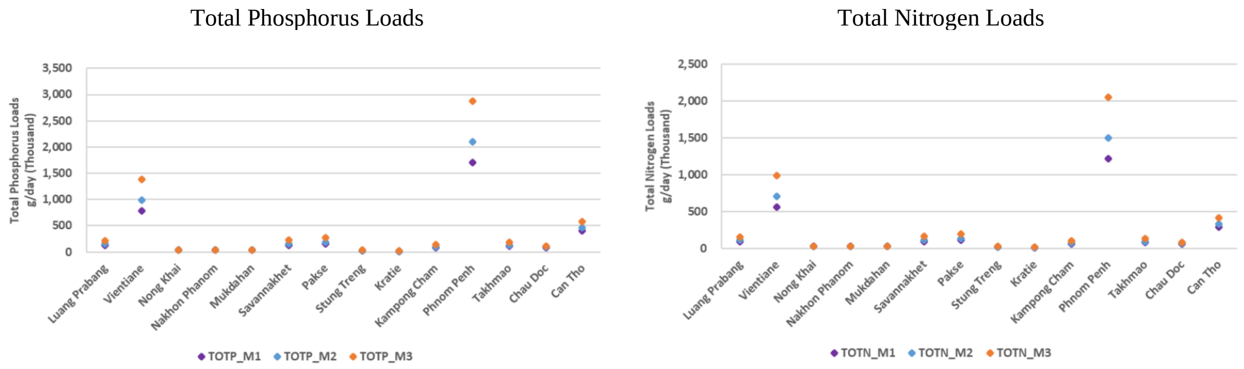
- ➢ The ecology of the watershed would be significantly affected by use of the agricultural chemicals and fertilizer for the agriculture use. The MRC Study did not verify the ecological consequence of such agricultural adverse effects.
- ➢ The simulation by the MRC Study did not capture the data on rice paddy fisheries and aquaculture such as how much fish is produced and how different farming practices affect the fisheries;
- ➢ The mainstream discharge of Mekong River during the dry season may hardly meet the massive irrigation water demand for Mekong Delta in Vietnam, especially in case dry climate conditions occur and/or Cambodia largely expands irrigation area.
- ➢ Excessive deforestation may possibly cause increase of peak flood runoff discharges and serious erosion/sediment runoff due to decrease of basin retention capacity of flood and soil. Although all the Member Countries make efforts to maintain or increase forest areas, implementation is lagging, and the progress of deforestation/reforestation in the LMB would need to be monitored.

### (4) Impact of Domestic and Industrial Wastewater

As described in the foregoing subsection 2.5.2.6 (1) , the high concentration values of Total Phosphorus (TOTP) above the threshold (0.13mg) have been already detected in Mekong River, which suggests the River has been somewhat polluted by the wastewater of the domestic and industrial water use and/or the agricultural chemical runoff. The progressive urbanization and agricultural development along Mekong River would further rise the risk of water pollution of the Mekong River.

In order to confirm the future water pollution risk of Mekong River, the MRC Study simulated the future concentration ratios of the two water quality parameters of Total Phosphorus (TOTP) and Total Nitrogen (TOTN) contained in wastewater from the major urban centers located along the Mekong River. In the simulation, firstly estimated is the volumes of domestic water demand for 32 major cities along Mekong River (14 along mainstream and 18 along tributaries) assuming the scenarios M1, M2 and M3. Then, the wastewater volume and the loads of the said two water quality parameters contained in the wastewater are estimated.

Figure 2.26 shows the estimated loads of TOTP and TOTN contained in the wastewater of 14 major cities along the mainstream Mekong River in scenarios of M1, M2 and M3. As shown in the Figure, the more populated cities such as Phnom Penh and Vientiane are subject to the extremely higher loads of TOTP and TOTN. It is also estimated that the loads of TOTP and TOTN from 2020 to 2040 (scenario M2 to M3) will make much higher increment than that from 2007 to 2020 (scenario M1 to M2): the maximum incremental rate from 2007 to 2020 is 25%, while the rate from 2020 to 2040 is 75%.




*Source: The MRC Study (Ref. 9)*

**Figure 2.26 Loads of Total Phosphorus and Total Nitrogen Discharge from Main Cities along Mekong Mainstream**

According to the MRC Study, the concentration values that correspond to the above loads of TOTP and TOTN contained in the raw wastewater are in a range of about 10.4 to 18.7 mg/L and 7.4 to 13.3 mg/L, respectively. On the other hand, the MRC Water Quality Guidelines set up the standards such that the permissible treated concentration values of wastewater to be discharged from the domestic and industrial facility to surface water should be 2mg/L for of TOTP and 5mg/L for TOTN. The surplus of the concentration values of TOTP and TOTN over the standards of the MRC Guideline need to be removed by the treatment facilities and/or the natural purification effects of the wetland. The MRC Study evaluated that such required purification effects of the treatment facility and/or the wet land could be expected to be enough. Accordingly, the MRC Study concluded that the urban wastewater to the Mekong River would not make significant impact on the water quality of the Mekong River (Ref. 9).

The above evaluation of the MRC Study on the water quality of the Mekong River would not necessarily promise the sustainably good/acceptable water quality of the Mekong River due to the following issues remained:

- The high concentration values of TOTP above the threshold (0.13mg) have been already detected in the water of Mekong River as described above.
- The MRC Study does not capture the impacts of the agricultural chemicals and pesticide used in agriculture in the LMB,
- The MRC Study assumes the natural purification effects of the wetland against the urban waste as

one of the important factors to ensure the sustainably acceptable water quality of the Mekong River. However, the quantitative purification effects of the wetland are uncertain. Furthermore, the wetland would not always exist as the buffer between the urban center and the river.

### (5) Impact of Climate Changes

The MRC Study assumed the M3CC as the main scenario for the climate change as described in subsection (1) . In order to examine the impacts of climate changes in detail, the MRC Study further assumed the following sub-scenario C2 and C3.

- C2 is oriented to wetter climate than M3CC applying GFDL for general circulation model (GCM) and RCP 4.5 for green-house gas emissions (see the foregoing Box A for definition of GCM and RCP).
- C3 is oriented to dryer climate than M3CC applying GISS for general circulation model (GCM) and RCP 4.5 for green-house gas emissions.
- According to the results of the MRC Study, climate changes in the LMB will have notable impacts on the agriculture, the ecology and the flood especially in the flood plains in and around Tonle Sap Great Lake in Cambodia and the Mekong Delta in Vietnam as described hereinafter.:

1) Impacts on Agriculture

Food security in the LMB will gradually degrade especially some Lao PDR areas and for Cambodia as the population dependent on rice as the staple food increases. Such risk of food security will be accelerated especially in the sub-scenario C3, which will cause the large reduction of agricultural products due to more unfavorable conditions such as less precipitation and higher soil evaporation.

The sub-scenario C3 will also cause significant decline of soil water in the Tonle Sap watershed and its consequent large decline in rainfed agriculture products. Moreover, the sub-scenario C3 will further increase the water necessary to irrigate Tonle Sap watershed by 20% as compared with scenario M3CC.

Moreover, the sea level rise associated with climate change will cause saltwater intrusion to the Mekong Delta leading to harmful impacts on agriculture, aquaculture and capture fisheries. Sea level rise could also result in the displacement of millions of people throughout the Mekong Delta in Vietnam.

2) Impacts on Ecology

The sub-scenario C3 will reduce the inflow discharge and the direct rainfall into Tonle Sap Lake, causing the large fluctuation of lake water levels, which will be a menace to the habitat of the aquatic life in the Lake.

The sub-scenario C3 will also reduce the flooding area and duration, both of which are important for the habiting of the aquatic life in the lower part of the LMB especially in Tonle Sap Great Lake, the Cambodian floodplains and the Viet Nam Delta. On the other hand, the sub-scenario C2 will cause large-scales flood more frequently, which will bring on difficulties in habiting of the aquatic life.

3) Impact on Flood

The climate changes, especially the sub-scenario C2 will increase frequency of flood occurrences, the flood peaks and the flood duration causing severe flood damage in the LMB, especially in the floodplain in Cambodia and the Mekong Delta in Vietnam.

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*Ref. 7 MRC, The Council Study, The Study on the Sustainable Management and Development of the Mekong River Basin, including Impacts of Mainstream Hydropower Projects, Thematic Report on the Positive and Negative Impacts of Hydropower Development on the Social, Environmental, and Economic Conditions of the Lower Mekong River Basin, 2018*

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## 2.6 Forest Cover Map

### 2.6.1 Forest Cover Map preparation situation in each country

This study has confirmed the current situation for preparing the forest cover maps in the five countries of the Lower Mekong River Basin. The forest cover maps in each country were prepared not only by several donors including JICA but also by the countries themselves. Remote sensing technology was utilized, and some countries performed the accuracy assessment. The forest cover maps were utilized for the calculation of emission volume in forestry sector at GHG inventory of the country. Table 2.20 shows the situation for the preparation of forest cover maps in each country.

**Table 2.20 Prepared situation of Forest Cover Map**

| Items | Cambodia | Myanmar | Lao PDR | Thailand | Viet Nam | ADPC |
|---|---|---|---|---|---|---|
| Year of Map | 1989 2006<br>1993 2010<br>1997 2014<br>2002 2016 | 1990<br>2000<br>2005<br>2010<br>2015 | 2000<br>2005<br>2010<br>2015 | 1961 1973 1976 1978<br>1982 1985 1988 1989<br>1991 1993 1995 1998<br>2000 2004 2005 2006<br>2008 2012 2013 2014<br>2015 2016 2017 | 1995<br>2000<br>2005<br>2010<br>2016 | 1987 – 2018<br>*Time Series Map |
| EO Satellite | Landsat TM, ETM+ and OLI | 2005:Landsat TM and ETM+<br>2010: IRS LISS<br>2015:Landsat OLI | 2005:SPOT 4/5<br>2010,2015 :RapidEye | Landsat, THEOS | 2005:Landsat<br>2010, 2015:SPOT 5<br>Refer:VNREDSat-1 | Landsat TM, ETM+ and OLI |
| Preparation method | Visual interpretation until 2002.<br>After that segmentation by object-based algorithm and manual interpretation. | Unknown | 2010 was generated by object-based segmentation and interpretation. 2000, 2005 and 2015 was generated by modification method based on extraction of change area from 2010. | Visual interpretation, Segmentation by object-based algorithm and manual interpretation since 2013. | 2010 was generated by object-based segmentation with agro-Ecological zone and manual interpretation. 1995, 2000, 2005 and 2016 was generated by modification method based on extraction of change area from 2010. | Pixel based classification (random forest with training data) by Google Earth Engine |
| Minimum Map Unit | 25ha until 2010. After that 5ha | Unknown | None | None | None | One pixel |
| Geo-coordination system | Same as topographic map at 1/100,000 | Unknown | Unknown | Same as topographic map at 1/50,000 (UTM, WGS84) | UTM, VN2000 | Geographic（WGS84） |
| Forest definition | Area：>0.5ha<br>Crown density：>10%<br>Tree height：>5m | Area：>0.5ha<br>Crown density：>10%<br>Tree height：>5m | Area：>0.5ha<br>Crown density：>10%<br>Diameter of breast height：>10cm | Area：>0.5ha<br>Crown density：>10%<br>Tree height：>5m | Area：>0.5ha<br>Crown density：>10%<br>Tree height：>5m | None |
| Land classification | 22 classes<br>(forest classification 11 classes) | 6 or 7 classes<br>(forest classification 3 classes) | 22 classes<br>(forest classification 6 classes) | Forest or Non-forest | 17 classes<br>(forest classification 12 classes) | 18 classes<br>(forest classification 6 classes) |
| Classification accuracy | Classification accuracy of 2006, 2010 and 2014 is 81.23% | Unknown | Target:<br>forest/non-forest above 80%<br><br>Classification of forest above 70% | More than 90% due to modification based on change area by visual interpretation and field survey with Google Earth | **Uncertainty**<br>Forest/non-forest: 5%<br>Within forest category: 20%<br>Within evergreen broad leaf forest: 26% (2010) | 74% (2014) |
| Emission Factor | Fixed | Not fixed yet | Not fixed yet | Not fixed yet | Fixed | None |
| References | JICA directions<br>Initial FRL for Cambodia under the UNFCCC Framework (2016)<br>Hearing from Ministry of Environment | Myanmar REDD+ Roadmap (2013)<br>Myanmar development of NFMS (2016) | FCPF ER-PIN for Lao PDR-Revision (2016)<br>Hearing from Ministry of Agriculture and Forestry | JICA directions<br>FCPF R-PP Thailand (2013)<br>Hearing from Ministry of Natural Resource and Environment | JICA directions<br>Vietnam's modified submission on REL for REDD+ result-based payments under UNFCCC (2016)<br>Hearing from Ministry of Agriculture and Rural Development | Detailed method<br>https://rlcms-servir.adpc.net/en/method/<br>Land Cover Portal<br>https://rlcms-servir.adpc.net/en/landcover/ |

*Remark: Information is added in the table was prepared by JICA study team through onsite survey in each country.*

### 2.6.2 Consideration on Application of Existing Map and Preparation of New Map

As described above, the existing forest cover maps are available in all five target countries. However, all necessary data of the existing forest cover map from each country, are not collected yet. The data had only been collected partially. Meanwhile, it was urgent to grasp the changes in forest cover, especially changes in the forest cover over the period from 2000 to 2015. For this purpose, JST decided to consider the utilization of other available data to understand the trend of forest cover change and performed the investigation.

As an investigation result, JST decided to utilize the Time Series Land Cover data from Asian Disaster Preparedness Center (ADPC). This data covers 5 countries (Myanmar, Thailand, Lao PDR, Cambodia, and Vietnam) comprising lower Mekong River Basin and it was created under the project name SERVIR-MEKONG.

In the SERVIR-MEKONG, in order to respond to various policies, planning, management and reporting needs of regional and national institutions in the Mekong River Basin for climate change, disaster, etc., the Land Cover Data was created from the LANDSAT satellite data. In the Land Cover Data creation, ADPC had the collaboration with SIG (Space Informatics Group), SEI (Stockholm Environment Institute) and Deltares, and received the support from the United States International Development Agency (USAID) and the National Aeronautics and Space Administration (NASA). The Land Cover Data that can be used to grasp the land cover situation for Mekong River Basin is for 16 years period (from 2000 to 2015). However, this study has created additional period (from 1987 to 1999, and 2016 to 2018) of Land Cover Data for grasping forest cover transition since 1980's. Outline of the Time Series Land Cover data is summarized in Table 2.20. The Figure 2.27 is for Land Cover data 2018.

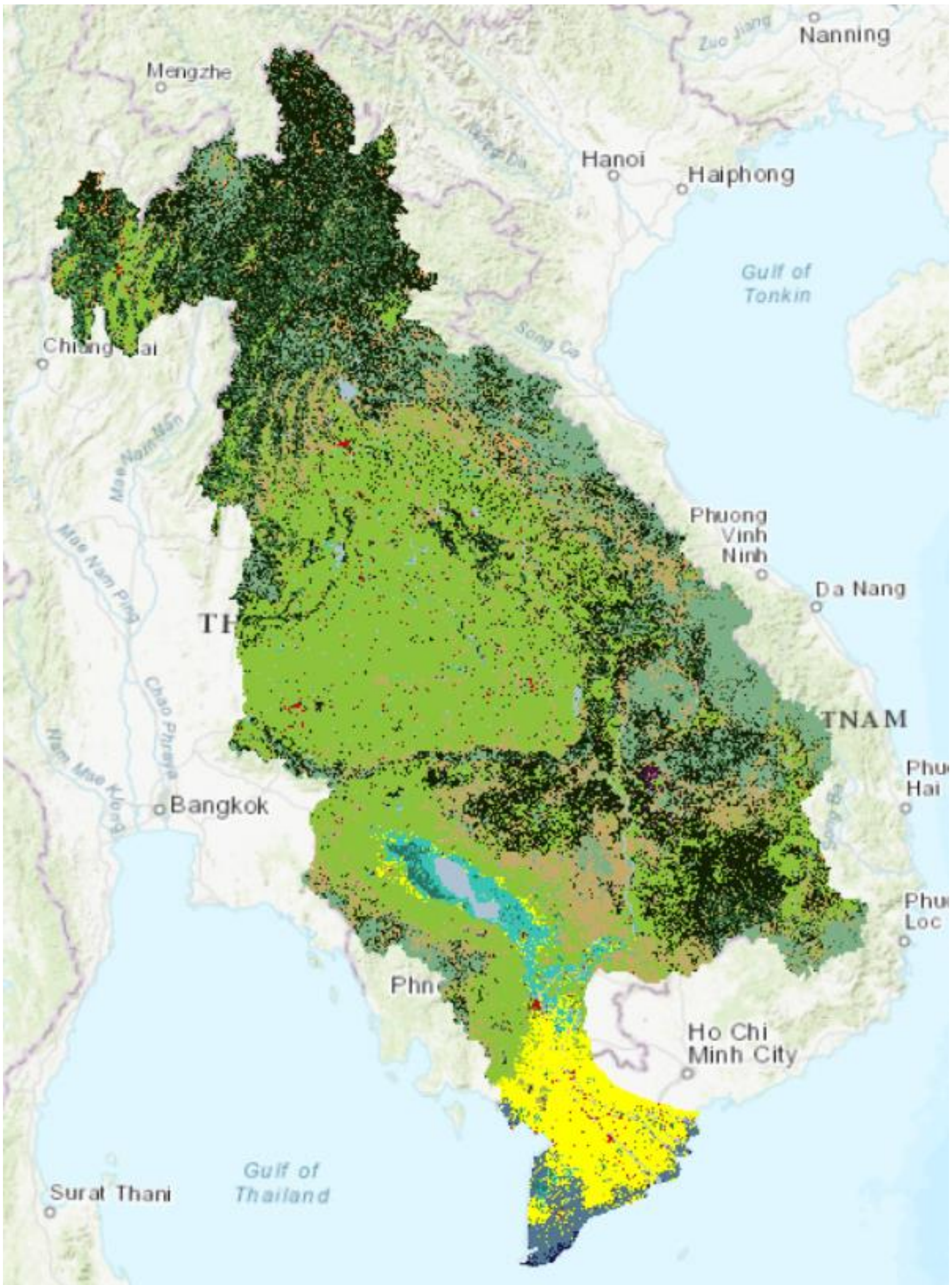


**Figure 2.27 Land Cover Map 2018**

Before going into the analysis, this study considered the verification accuracy of the Time Series Land Cover data for the utilization. The accuracy of this data was 74% as overall accuracy according to ADPC. In this study, Land Cover data 2010 was also collected from MRC, and comparison with the Land Cover data 2010 edition prepared by MRC was also conducted. The Land Cover data of MRC was also classified based on LANDSAT satellite image and at the same as Time Series Land Cover data. However, the creation method is different: Time Series Land Cover data is pixel-based classification and MRC's Land Cover data is object-based classification. In this project, the accuracy of Time Series Land Cover data was verified with the MRC's Land Cover data 2010 as a correct data. The Land Cover data of MRC was 91%[4] in overall accuracy according to the accuracy assessment by MRC.

[4] Land Cover Map of the Lower Mekong Basin, MRC Technical Paper No.59, March 2016

For the comparison, the number of statistically required sampling points[5] was generated. And, for assessment classes, it was aggregated into two groups as forest related area, agricultural related area. And then "User Accuracy", "Producer Accuracy", "Overall Accuracy" and "Uncertainty"[6] was calculated. Those results are shown in Table 2.21. The reasons for grouping into two categories are described in section 3.4.

**Table 2.21 Comparison Result**

| Grouping Class | Tree Cover | Farmland |
|---|---|---|
| Uncertainty | 2.98% | 4.61% |
| User Accuracy | 89.83% | 79.67% |
| Producer Accuracy | 85.48% | 85.46% |
| Overall Accuracy | 85.47% | |
| Overall Uncertainty | 2.56% | |

The Overall Accuracy was 85.47%. And "User Accuracy" of tree cover was 89.83%. This accuracy is the level which is enough usable for understanding of forest cover change transition.

5 Pontus Olofsson, et. al., Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation, Remote Sensing of Environment 129 (2013) 122-131

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