An inception report
Piloting a Joint Environmental Monitoring Programme on two Mekong mainstream dams ‘Don Sahong Hydropower Project and Xayaburi Hydropower Project’
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| Abbreviation | Definition |
|--------------|------------|
| ADCP         | Acoustic Doppler Current Profiler |
| ALS          | Automatic Listening Station |
| ARTFISH      | Approaches, Rules and Techniques for Fisheries Statistical Monitoring |
| BACI         | Before After Control Impact |
| BL           | Bedload |
| BOD          | Biochemical Oxygen Demand |
| CK           | Chiang Khan |
| CMC          | Coordination and Monitoring Center |
| COD          | Chemical Oxygen Demand |
| CRBMF        | Core River Basin Management Functions |
| DAP          | Delivered At Place (Terminology for Shipment of Goods) |
| DO           | Dissolved Oxygen |
| DSA          | Daily Subsistence Allowance |
| DSF          | Decision Support Framework |
| DSHPP        | Don Sahong Hydropower Plant |
| DSMP         | Discharge and Sediment Monitoring Program |
| DSPC         | Don Sahong Power Company Ltd. |
| DSS          | Decision Support System |
| DST          | Data Storage Tag |
| ED           | Executive Director |
| EHM          | Ecological Health Monitoring |
| EIA          | Environmental Impact Assessment |
| EMEG         | Environmental Management Expert Group |
| EUR          | Euro (currency) |
| FADM         | Fish Abundance and Diversity Monitoring |
| FAO          | United Nations Food and Agriculture Organization |
| FLDM         | Fish Larvae Diversity Monitoring |
| GB           | Giga Bytes |
| GIS          | Geographical Information System |
| GIZ          | Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH |
| GOL          | Government of Lao PDR |
| GPS          | Global Positioning System |
| HMFS         | Hydrologic monitoring and forecasting system (Xayaburi) |
| HP           | Horse Power |
| HPP          | Hydropower Plant |
| HYCOS station| Automatic hydrological monitoring station |
| ICEM         | International Centre for Environmental Management |
| ID/OD        | Interior Diameter / Outside Diameter |
| IFReDI       | Inland Fisheries Research and Development Institute |
| IWRM         | Integrated Water Resources Management |
| JEM          | Joint Environmental Monitoring |
| JMG          | Joint Monitoring Group |
| Lao PDR      | Lao People’s Democratic Republic |
| LARReC       | Living Aquatic Resources Research Centre |
| LCD          | Liquid Crystal Display |
| LMB          | Lower Mekong Basin |
| LNMC         | Lao National Mekong Committee |
| LPB          | Luang Prabang |
| MAF          | Ministry of Agriculture and Forestry (Lao PDR) |
| Abbreviation | Full Form |
|--------------|-----------|
| MC           | Member Country |
| MEM          | Ministry of Energy and Mines (Lao PDR) |
| MHz          | Mega Hertz |
| MoNRE        | Ministry of Natural Resources and Environment (Lao PDR) |
| MRC/MRCS     | Mekong River Commission / Mekong River Commission Secretariat |
| MS           | Microsoft |
| NMC          | National Mekong Committee |
| NOx          | Oxides of nitrogen |
| NRESRI       | Natural Resources and Environment Statistics and Research Institute |
| OAA          | Other Aquatic Animals |
| ORP          | Oxidation Reduction Potential |
| OTT          | OTT HydroMet |
| PAR          | Photosynthetically Active Radiation |
| PC           | Prior Consultation |
| PDIES        | Procedures for Data and Information Exchange |
| PIT tags     | Passive Integrated Transponder tags |
| PNPCA        | Procedures for Notification, Prior Consultation and Agreement |
| PO           | Purchase Order |
| PSAT         | Pop-up Satellite Archival Tag |
| QA/QC        | Quality Assurance / Quality Control |
| SOP          | Standard Operating Procedures |
| SSC          | Suspended Sediment Concentration |
| SSC SGSA     | Suspended Sediment Grain Size Analysis |
| TOR          | Terms of Reference |
| Total-N      | Total Nitrogen |
| TPH          | Total Petroleum Hydrocarbons |
| TSS          | Total Suspended Solids |
| USB          | Universal Serial Bus |
| USD          | US Dollar |
| VAT          | Value Added Tax |
| WMO          | World Meteorological Organization |
| WQ           | Water Quality |
| WQMNCL       | Water Quality Monitoring Network Laboratories of Lao PDR |
| WQN          | Water Quality Network |
| XPCL         | Xayaburi power company |
TERMINOLOGY

In the report, we have standardized the use of terms “site” and “station”:

“Site” refers to a place identified by JEM for regular monitoring. The word refers in particular to biodiversity and fish monitoring places. The term “site” has been extensively used in MRC documents in the past, in particular in the draft JEM programme document, but here its meaning is more specific.

“Station” refers to established and permanent places where hydrological, sediment and water quality are routinely measured. The word refers in particular to HYCOS monitoring places. The term “station” is standard in hydrology and sedimentology, and refers to a place where a monitoring device operates.

The terms “location” or “place” are synonyms used *ad hoc* to refer to a geographic point, but are not specific to JEM sampling. For example: “There is a fish larvae monitoring site upstream of the impoundment, in the same location as the water quality monitoring station.”
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1 INTRODUCTION

1.1 JEM Pilot Teams

In May 2019, the Mekong River Commission finalised its documents for Joint Environment Monitoring (JEM) Programme for Mekong Mainstream Hydropower Projects, which is aimed at providing information about the availability and condition of the water resources and their linkages with environmental conditions in the basin and how these are changing under present and future hydropower developments. This information will provide a common basis for constructive discussions by communities and Member Countries on the implications of hydropower development.

The Environmental Management Division of the MRC with the support of GIZ has been developing two pilot projects to trial and refine the JEM approach and monitoring and reporting protocols based upon a 2-year implementation around the Xayaburi hydropower plant (HPP) and the Don Sahong HPP. The MRCS team implementing these pilots consists of:

- Dr So Nam, Chief Environment Management Officer
- Dr Janejira Chuthong, Chief Hydrologist
- Dr Prayooth Yaowakhan, Ecological Health Specialist
- Dr Ly Sarann, Water & Climate Monitoring Specialist
- Mr Vanna Nuon, Fisheries and Aquatic Ecology Officer
- Mr Palakorn Chanbanyong, Sustainable Hydropower Specialist
- Mr Soukaseum Pichit, Data Management Specialist
- Dr Anoulak Kittikhoun, Chief Strategic and Partnership Officer

The GIZ team supporting this piloting of the JEM consists of:

- Dr Bertrand Meinier, Programme Director
- Ms Erinda Pubill Panen, Environmental Monitoring Advisor
- Ms Mayvong Sayatham, Regional Technical Advisor

In November 2019, the International Center for Environmental Management (ICEM Asia) was contracted by GIZ and the Mekong River Commission to undertake the 2-year Environmental Monitoring Pilots project for the Joint Environmental Monitoring (JEM) Programme. ICEM is the consortium lead, and is supported by OTT Hydromet (a sub-contracting partner who will supply the hydrological monitoring (HYCOS) stations. The ICEM core team consists of the following specialists:

- Dr Lois Koehnken, Hydrology and Geomorphology Specialist
- Dr Eric Baran, Fisheries and Fish Passage Specialist
- Mr Peter-John Meynell, Water Quality and Aquatic Ecology Specialist, Team Leader
- Dr Apichart Termvidckakorn, Fish Larvae and Taxonomic Specialist
- Mr Khambane Inthipunya, Database Specialist

Supported by the ICEM management team consisting of:

- Dr Jeremy Carew-Reid, Director/Environmental Impact Assessment (EIA) Specialist
- Dr Daniel Giffillan, Senior Environmental Specialist/Project Manager
- Dr Richard Cooper, Senior Environmental Specialist/Data Management Specialist
- Ms Chloe Pottinger, Communications Specialist
- Mr Pham Tran Minh, Hydrologist
- Mr Mai Ky Vinh, GIS Specialist
• Ms Luong Thi Quynh Mai, Administration Manager/Project Coordinator
• OTT Equipment Specialist – HYCOS installation specialist to be determined

The ICEM contract specifies three packages of work i) the procurement and installation of monitoring equipment (work package 1: Equipment procurement), ii) data collection, analysis and communication (work package 2: Technical support and expertise) and iii) training and awareness-raising (work package 3: capacity building).

The three work packages are built around the five component areas of the project. This inception report for the Environmental Monitoring pilot project outlines the approach being taken for these various project components:

- Hydrological and sediment monitoring
- Water quality and ecological health monitoring
- Fisheries, fish larvae and fish passage monitoring
- Equipment procurement
- Database development

Procurement of the equipment and training of the personnel who will carry out the monitoring around the focal areas of the two completed hydropower dams on the Mekong mainstem – Xayaburi and Don Sahong – are the most important initial steps to establish the pilots, and this report outlines progress on procurement and the design of the training programme. Questions for clarification are also included to enable the monitoring training programme to be finalised. Training module briefs are included in Annex 2 to this report.

1.2 Context & background

The need for joint environmental monitoring of hydropower developments has been appreciated by the Lower Mekong countries as a result of the Procedures for Notification, Prior Consultation and Agreement (PNPCA) processes of the hydropower projects being developed on the Mekong mainstream, especially for Xayaburi, Don Sahong, Pak Beng and Pak Lay, and the ongoing process for Luang Prabang HPP, which identified the potential changes in water resources and quality, river health and fisheries as one of the key impacts of hydropower development. The MRC’s Initiative on Sustainable Hydropower undertook a series of studies addressing the question of information needs for sustainable hydropower development and operations through the ISH11 project, Improved Environmental & Socio-economic baseline information for hydropower planning, and the ISH0306 project, Development of guidelines for hydropower environmental impact mitigation and risk management in the lower Mekong mainstream and tributaries. These have been incorporated into the MRC’s updated Preliminary Design Guidance for hydropower projects (PDG).

JEM Programme

Between 2018-2019 three key JEM Programme documents were developed: the “Joint Environment Monitoring of Mekong Mainstream Hydropower Projects” (version 4.0), the “JEM pilot project proposal – Don Sahong” and the “JEM pilot project proposal – Xayaburi”. The first provides guidance specifying which environmental parameters should be collected where as well as how (methodology), in order to complement the current regional environmental monitoring system set up by MRC on the whole Mekong Basin. The purpose of the JEM Programme is to ensure capture of the more localized impacts related to specific developments. The design documents focus on the two hydropower projects with the aim of designing an environmental monitoring system that will capture the impacts of these specific projects. The JEM Programme document provides the basis for the design of the monitoring
system, as well as for piloting the programme in the two operational hydropower projects (Xayaburi and Don Sahong). One of the outputs from these pilots will be recommendations for updating of the JEM Programme guidelines based upon the experience gained.

As part of its support to the MRC, GIZ has formulated several programme outputs of which the objective of Output 2 is: *A joint monitoring of the environmental impacts of the Xayaburi and Don Sahong hydropower projects have been established.*

- The Don Sahong Dam is located on a river channel of the Mekong River mainstream in the border area between Laos in the upper course and Cambodia in the lower course, the so-called Khone Falls.
- The Xayaburi Dam is a run-of-river dam which is built across the mainstream of the Mekong river approximately 100 Km downstream of Luang Prabang and 200 Km upstream of where the Mekong becomes the border between Thailand and Laos.

The JEM design documents specify which parameters should be collected at which site/station, following which methodologies and using which equipment. These three key documents have been defined considering the questions that need to be answered in terms of environmental impacts, the environmental monitoring systems already in place at national and regional levels, the existing capacity, knowledge and facilities available in Member Countries, as well as budget constraints. The documents have been presented, discussed and accepted by the MRC Member Countries through an iterative consultation process at regional and national levels conducted in 2018 and 2019.

The JEM Programme builds on MRC’s longstanding monitoring of the river’s resources and condition, through a monitoring network of sampling sites/stations monitored regularly by national teams. These cover five key discipline areas, hydrology and hydraulics, sediment and geomorphology, water quality, aquatic ecology, and fisheries. The JEM Programme document suggests additional sampling sites/stations and new measurement parameters in order to assess particular changes that may result from hydropower development, construction and operation. The linkage between the JEM monitoring and the historic and regular monitoring undertaken by the Member Countries is important in that regular monitoring provides baseline and control information with which to compare the specific results from the hydropower sampling sites/stations. This historic and routine monitoring is described in Section 1.3.

The JEM Programme recognises that the two hydropower developers also carry out regular monitoring, particularly of hydrology, sediments, water quality and fish passage. The JEM monitoring programme uses a system independent of that used by the hydropower project developers. It is expected that future hydropower projects will carry out their own monitoring programmes as part of their compliance with ESIA licences. It is also expected that in the future relevant government agencies will share developers’ monitoring information with the MRC, and that this will complement the JEM results. The current information about monitoring carried out by the developers is described in Section 1.3.6.

This joint nature of the monitoring is enshrined in the two Joint Action Plans for the Implementation of the Statement on the Prior Consultation Process for the Pak Beng and Pak Lay Hydropower Projects, which specifies the two-way sharing of monitoring information.

Monitoring information from the JEM Programme, from regular MRC monitoring programmes, and from monitoring conducted by developers is expected to be used to increase understandings about the changes and impacts that hydropower projects have on the river and its natural resources, as well as for developing mitigation and management measures to improve the environmental performance of existing and future hydropower projects.
This pilot project is intended to trial and finalise the JEM Programme for future application on upcoming mainstream dams, and to show how the results may be used to develop potential mitigation and management measures for the impacts that are identified and to complement the advice of the updated Preliminary Design Guidance. The results will also be used to illustrate how monitoring can inform adaptive management of hydropower operations.

1.3 Links with ongoing MRC and other hydropower monitoring

The JEM is consistent with, and builds on, previous monitoring and information gathering initiatives related to water use, and environmental and ecological assessment, in the lower Mekong Basin (LMB). Monitoring of water resources within the basin underpins the 1995 Mekong River Agreement for the reasonable and equitable use of water resources and is one of the Core River Basin Management Functions (CRBMF) of the MRC. Collaborative monitoring and data sharing between the Member Countries underpins the Procedures for Water Use Monitoring, and Procedure for Water Quality and is recognised as essential for the effective management of water resources in the basin.

The Member Countries have also agreed on Procedures for Data and Information Exchange (PDIES). These procedures have three objectives: (i) To operationalize the data and information exchange among the 4 Member Countries, (ii) To make available basic data and information for public access as determined by the national Mekong committees concerned, and (iii) To promote understanding and cooperation among MRC Member Countries, according to specific principles of efficient, equitable, reciprocal, cost effective, relevant, timely and accurate, amongst others. The PDIES identifies the 12 major groups/types of data and information to be gathered and shared with the MRC Information System (MRC-IS). These 12 groups of information are Water Resources, Topography, Natural resources, Agriculture, Navigation and Transport, Flood management and mitigation, Infrastructure, Urbanization/Industrialization, Environment/Ecology, Administrative boundaries, Socio-economy, Tourism.

In all disciplines, the monitoring results will be integrated and compared with both the historic MRC data, which provides a baseline condition, as well as the ongoing routine data collection, which will provide control information.

1.3.1 Hydrology & hydraulics and discharge & sediment monitoring

The Mekong River Commission established the Mekong HYCOS system which includes 45 hydro-meteorological stations and 13 drought stations (total of 58 near-real time telemetry stations), that collect near-real time data of water level and rainfall every 15 minutes. This information is shared with the Member Countries for their respective flood forecasting and river monitoring networks. In 2009 sediment monitoring was added at 16 of the hydro-meteorological station under the Discharge and Sediment Monitoring Project (DSMP), and in 2012 an additional sediment station was added in the 3S River system upstream of the confluence with the Mekong. The location of the HYCOS and sediment monitoring stations are shown in Figure 1-1 and Figure 1-2, respectively.

The discharge monitoring results to date have allowed the continuous water level records at the hydrologic monitoring station to be converted into discharge time-series. The sediment results combined with the discharge information have allowed the calculation of sediment transport rates and sediment budgets throughout the LMB. Discharge and sediment information is relevant to all other themes. The proposed JEM monitoring adopts the same standard operating procedures and data management system as the existing monitoring program, but extends monitoring to more stations and increases the sediment parameters measured at some of the existing stations.
Figure 1-1: Existing discharge and sediment monitoring stations
Figure 1-2: Existing HYCOS stations in the Lower Mekong Basin
1.3.2 Water quality monitoring

The Water quality network (WQN) was established on the Mekong and its tributaries in 1985 and has been developed over the years so that there is a nearly 40-year dataset of monthly water quality results in many of the WQN stations (Figure 1-3). In 2011, a total of 48 stations were monitored of which 17 were located on the Mekong River and 5 were located on the Bassac River. The other 26 stations were located in the tributaries of the Mekong River. As of 2005, all 48 stations were classified as “primary stations,” designed to detect changes and capture pressures and threats to the Mekong water quality. These water quality results provide an excellent water quality baseline with which to compare data that will be recorded in the JEM pilots.

Figure 1-3: The MRC’s existing water quality monitoring stations on Mekong mainstream
1.3.3 Aquatic ecological health monitoring

Biomonitoring of Mekong mainstem and tributaries was initiated in 2002 and has been repeated bi-annually in a number of sites as shown in Figure 1-4. A total of 68 sites were sampled from 2004 to 2008 in the LMB, some of them visited several times. Of these, 12 sites are directly located along the Mekong mainstream and 56 in the tributaries; some were sampled in the junctions of the Mekong and tributaries. In 2011 and 2013 a total of 41 of sites were investigated for ecological health monitoring by national Mekong committees and line agencies, including the 12 Mekong mainstream sites and 29 tributary sites. In Laos, Thailand and Viet Nam 8 sites were sampled each. In Cambodia 17 sites including 9 new sites never sampled before were monitored. The locations of these 41 sites are shown in Table 5-2. The results have been published as Aquatic Ecological Health report cards every two years. The four biomonitoring groups include littoral macroinvertebrates, benthic macroinvertebrates, zooplankton and benthic diatoms. This biomonitoring work provides a good baseline with which to compare the results and data that will be recorded in the JEM pilots.

Figure 1-4: The MRC’s Aquatic ecological health monitoring sites
1.3.4 Fisheries monitoring

The MRC Fisheries Programme, and latterly the MRC Environment Division, has been supporting fisheries monitoring programmes to track the status and trends of fisheries in the Lower Mekong Basin (LMB) since 1994. The programme is broken down into several components: (1) Fish Abundance and Diversity Monitoring Program, (2) Fish Larvae Density Monitoring Program, (3) Dai Fishery Monitoring Program; (4) Lee Trap Monitoring Program. However, implementation has been fragmented and not fully compliant with monitoring standards, and thus these components are not strongly supportive of impact assessment and decision-making relating to major infrastructure developments in the LMB.

The Fish Abundance and Diversity Monitoring (FADM) Programme is the only programme common across all countries that is based on standard operating procedures. Other MC programmes recognise the need for monitoring but do not provide strategic guidance. These programmes, however, do provide substantial background information on which to describe baseline conditions in the LMB.
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Figure 1-5: The MRC’s existing FADM monitoring sites
Figure 1-6: The MRC’s existing Fish larvae monitoring sites
1.3.5 Initiative for Sustainable Hydropower

The MRC Initiative for Sustainable Hydropower has also addressed the question of information needs for sustainable hydropower development and operations through the ISH11 project, *Improved Environmental & Socio-economic baseline information for hydropower planning*, and the ISHO306 project, *Development of guidelines for hydropower environmental impact mitigation and risk management in the lower Mekong mainstream and tributaries*.

1.3.6 Monitoring carried out by hydropower developers

The two hydropower projects that have recently started operating, have been conducting environmental monitoring during the construction process. As part of the JEM project, a workshop was held in January 2019, which include the developers of Xayaburi and Don Sahong. Each developer provided a presentation providing an overview of their previous, ongoing and planned monitoring. Based on the presentations, the following monitoring was being undertaken by each developer (Table 1-1).

| Table 1-1: Monitoring carried out by Xayaburi and Don Sahong HPPs |
|---------------------------------------------------------------|
| Hydrology - Gauging Stations used: Don Sahong                  |
| 1. Pakse Automatic                                             |
| 2. AR01 Don Tan (Upstream of Hou Sahong)                      |
| 3. AR02 Thakhor (Hou Phapheng)                                |
| 4. AR03 Hang Khone                                             |
| 5. GB01 Downstream of Hou Sahong                               |
| 6. GB03 Downstream of Hou Phapheng                             |
| 7. GB04 Hou Sadam                                              |
| 8. GB05 Hou Xang Pheuak                                       |
| Hydrology - Gauging Stations used: Xayaburi                   |
| 1. Ban Xiengkôk                                                |
| 2. Ban Tonphueng                                              |
| 3. Pak Beng Bridge                                            |
| 4. Nam Ou Bridge                                              |
| 5. Nong Khiaw                                                 |
| 6. Ban Sibounhom                                              |
| 7. Soupanouvong                                               |
| 8. Ban Mixay                                                  |
| 9. Thadeua Bridge                                             |
| 10. Xayaburi HPP                                              |
| Sediment Water Quality                                       |
| 1. Not measured                                               |
| 2. Sedimentation online monitoring                            |
| River ecology                                                 |
| 1. Not measured                                               |
| 2. Phyttoplankton, Zooplankton, Benthic Invertebrates, Fishes  |
|   - St. 1. 500 m upstream from XHPP Dam                       |
|   - St. 2. 1 km downstream from XHPP Barrage                  |
|   - St 3. 2 km downstream from XHPP Barrage                   |
| Fishery                                                       |
| 1. Methods                                                    |
|   - CPUE                                                      |
|   - HH Catch                                                  |
|   - Underwater Video                                          |
|   - Fish Tagging                                              |
|   - Larval fish sampling                                      |
|   - Local fish market monitoring                              |
| 2. Fish Biomass and Migration Study                           |
|   (March 2012-March 2013)                                     |
| 3. Fish Swimming Ability Study                                |
|   (2014 - 2015)                                               |
| 4. Fish Passage Facilities Effectiveness                      |
| 5. Baseline Monitoring (Mekong River)                         |
| 6. Fishery Monitoring at the Navigation Lock                  |
| 7. PIT Tag Research Project                                   |
The Xayaburi power company (XPCL) has developed an extensive hydrologic monitoring and forecasting system (HMFS) that includes 10 gauging stations. The network provides real time rainfall and water level data and is used for forecasting the available Mekong River water for generation. A map of the hydrologic monitoring stations is shown in Figure 1-7.

XPCL are also implementing an online sediment monitoring system aimed at continuously measuring the sediment concentration of the Mekong River with the aim of having reliable information about the quantities of sediment passing through the system.

The Don Sahong Hydropower Project (DSHPP) has also established an extensive hydrologic network that monitors water level at 8 stations, as shown in Figure 1-8. The company does not conduct any sediment monitoring.
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These developer monitoring programmes can be seen to be very complementary to the five disciplines of the proposed JEM Programme. At present this monitoring information is submitted to relevant government agencies of Lao PDR as part of their Environmental Social Impact Assessment (ESIA) compliance requirements but is not yet shared with the MRC. The JEM pilot project aims to develop mechanisms for two-way sharing of monitoring information and analysis.

In order to develop mitigation and adaptation strategies with the hydropower developers, it will be necessary also to obtain information on the operation of each hydropower plant, so that changes in monitoring parameters can be related to changes in the operational regime if appropriate.

The Government of Lao (GOL) is in the process of establishing a Coordination and Monitoring Center (CMC) for coordination of operations between the mainstream dams. One of the sub-objectives of the CMC is “Environmental and Social management” which is directly relevant to the JEM activities.

1.4 JEM Programme monitoring strategy

The JEM Programme is designed to monitor the changes or impacts in five different disciplines – (i) hydrology and hydraulics, (ii) sediment and geomorphology, (iii) water quality, (iv) aquatic ecology, and (v) fisheries.

The impacts that the JEM Programme is designed to monitor are those resulting from the construction and operation of Mekong mainstream dams. The pilot programme tests the
monitoring strategy in two of the dams that have recently begun operating and will form the basis for monitoring of future mainstem dams.

The monitoring strategy is designed using the BACI concept – Before, After, Control, Impact – which suggests that monitoring of the impacts of hydropower should be carried out before construction and operation in order to provide a baseline range of each parameter, after construction and during operation to determine the changes that are occurring during these phases. Monitoring of Control sites is used to distinguish changes that are occurring due to other factors such as climatic changes, and the Impact is the resulting long-term change in the condition and ecological health of the river as a result of the hydropower plant (Figure 1-9). Where applicable, the monitoring results from the ongoing MRC monitoring programs can be used as the 'before' or baseline condition.

In the case of these pilot JEM studies, the Before conditions will be taken from earlier monitoring records – the baseline – in years before construction of the two dams, recognising that the monitoring sites will not be exactly in the same stations. The After conditions will be taken from the pilot JEM monitoring sites and Impact deduced from the long-term changes in the river geomorphology, ecological health of the river and fisheries. There are no really feasible locations for control sites on the Mekong that are not affected by the mainstem dams, but the changes in conditions due to other factors will have to be assessed from the changes occurring in other monitoring stations away from the JEM sites/stations. In the JEM pilots the construction phase of the two hydropower dams has already finished, and so it is not be possible to monitor construction impacts, but records of some parameters could be used from the developers, if these were made available.

The choice of stations for the JEM monitoring is critical to the assessment of impacts. The JEM documents provide a plan of locations of monitoring sites/stations for different phases of development of a hydropower project with responsibilities divided between the MRC and the
developed (Figure 1-10). The siting of the pilot JEM monitoring sites/stations at Xayaburi and Don Sahong dams has been based upon this guidance, including monitoring within the Xayaburi impoundment. The results from developer monitoring programmes are also important for assessing impacts, and one JEM objective is to build and establish co-operation with the developers for mutual sharing of monitoring results and mutual understanding of impacts.

Reconnaissance fieldtrips for identifying suitable locations for new or relocated hydrologic and sediment monitoring and for environmental and fisheries monitoring sites/stations were completed in November and December 2019 by representatives of GIZ, the relevant national Mekong committees, and hydrologic monitoring personnel. One trip to Lao People’s Democratic Republic (Lao PDR) was used to evaluate potential sites/stations for moving the existing Luang Prabang monitoring site/station upstream of the Xayaburi backwater, and for the establishment of a new site downstream of Xayaburi. The second reconnaissance mission evaluated potential locations for a new site/station upstream of Stung Treng, and around the Don Sahong Dam.

The Back to Office reports of these field missions in November and December 2019, provides site information and justification for choice of the sites/stations for each discipline (MRC, 2019a, 2019b). These are specified in technical sections for each discipline.

Source: JEM Programme MRC (2019)

*Figure 1-10: Principles for siting of monitoring sites/stations at different phases of hydropower construction and operation*

JEM monitoring is a key element in providing evidence of impacts - the changes in environmental and natural resource conditions as a result of hydropower development. The JEM Programme is aimed at providing information that will allow decisions to be made on mitigation measures that need to be built into hydropower projects in the future and for
adaptive management of existing hydropower plants, and the subsequent adaptation of those measures.

Figure 1-11 illustrates how monitoring data and analysis drives mitigation and adaptive management, with the monitoring of indicators informing the evaluation of the performance of mitigation measures, and the subsequent adaptation of those measures.

**Figure 1-11: How monitoring data and analysis drives adaptive management**

### 1.5 Aims and objectives of the assignment

The main purposes of the Joint Environment Monitoring of Mainstream Hydropower Projects (JEM) are to:

i. have a common, standardised and scientifically robust programme for jointly monitoring key environmental indicators for impact assessment of Mekong mainstream hydropower projects on hydrology and hydraulics, sediment and geomorphology, water quality, aquatic ecology, and fisheries;

ii. support mainstream hydropower project proponents to collect sufficient and robust scientific environment data and information for project planning and design, construction and operation of sustainable hydropower projects;

iii. support MCs to monitor and report the transboundary environmental impacts of Mekong mainstream hydropower projects during construction and operation to inform mitigation and adaptive management measures;

iv. after the completion of the six-month Prior consultation (PC) process to support the MRC Member Countries to establish formal coordination mechanisms to work with project proponents to collect and share fisheries and environment data and enable adaptive management of the operation of hydropower projects.

For this pilot phase of the JEM, the monitoring programme will be established at the existing mainstream dam developments (Xayaburi and Don Sahong). The aim of the pilots is to trial the current draft guidance and test their feasibility, both technically and financially, for future implementation at other mainstream dam developments. Recommendations will be made for
improvements and changes to the JEM Programme guidance, based on the pilots project experience, and the guidance will then be finalised to provide *a common, standardised and scientifically robust programme for jointly monitoring key environmental indicators for impact assessment of Mekong mainstream hydropower projects on hydrology and hydraulics, sediment and geomorphology, water quality, aquatic ecology, and fisheries*.

The ICEM contract specifies three work packages for implementing the two pilots, i.e. establishing the monitoring system following the design specified in the JEM documents Annex 2 (for Don Sahong) and Annex 3 (for Xayaburi).

- **Work package 1**: Equipment procurement - the procurement and installation of monitoring equipment for each of the five disciplines
- **Work package 2**: Technical support and expertise - data collection, analysis and communication
- **Work package 3**: Capacity building - training and awareness-raising

The regular JEM monitoring in the field in all five disciplines over the next two years will be undertaken by the national monitoring teams, who will be contracted by the MRC, and paid for out of the MRC Basket Fund. This is in addition to the routine monitoring that these teams undertake already. The following Work Agreements between MRC and the national teams have been agreed:

1. Lao Work Agreement on JEM_EHM;
2. Lao Work Agreement on JEM_DSM;
3. Lao Work Agreement on JEM_FLM;
4. Lao Work Agreement on JEM_FADM;
5. Lao Work Agreement on JEM_HYCOS;
6. Lao Work Agreement on JEM_MANUAL;
7. Lao Work Agreement on JEM_WQM;
8. Thai Work Agreement on JEM_DSM
9. Cambodian Work Agreement on JEM_FADM;
10. Cambodian Work Agreement on JEM_FLM; and
11. Cambodian Work Agreement on JEM_DSM

### 1.6 Underlying principles

The underlying principles that will be used to implement the two JEM pilots at Don Sahong and Xayaburi are:

- The requirement to assess the financial and technical feasibility of the proposed draft JEM Programme’s methods and approaches in order to adjust and adapt and ensure long-term sustainability of the JEM
- Development of a common standardised approach to the monitoring programmes in each of the disciplines, through testing, adjusting and improving the draft JEM Programme;
- Recognition that compatibility to previous monitoring and datasets that have been carried out by MRC is critical to maintain the continuity of records and understanding of the changes;
- Recognition of the importance of two-way sharing of monitoring information and analysis with hydropower developers
- The need for a common database of results from these pilots that is intimately linked with ongoing monitoring in other parts of the basin;
• The importance of strengthening the capacity of the national and local teams that will be carrying out the monitoring on a regular basis, including the proficiency with additional monitoring techniques and application of appropriate QA/QC;

• Building the understanding of the reasons why particular measurements are taken, what to look out for in the results and linkages between the different parameters, to develop a comprehensive interpretation of results.

The following chapters describe the outputs and the associated reports reflecting these underlying principles for each of the disciplines.
2 HYDROLOGY

2.1 Background and Justification

An accurate understanding of the hydrology of the Mekong is critical for determining flow changes due to developments in the basin, and for understanding changes to all other disciplines as hydrologic changes will alter all ecosystem components (sediment transport and geomorphology, water quality, aquatic ecology, fisheries) which in turn will affect the societal uses and dependencies on the river system. A sound understanding of the hydrology of the river is also required to underpin several of the MRC’s Procedures such as the Procedures for Water Use Monitoring (PWUM), the Procedures for the Maintenance of Flows on the Mainstream (PMFM) and the Procedures for Notification, Prior Consultation and Agreement (PNPCA). The hydrology of the LMB is presently monitored through a two-pronged approach based on the continuous measurement of precipitation and water level at stations throughout the LMB by the HYCOS network, and river discharge measurements through the Discharge and Sediment Monitoring Programme (DSMP), (Figure 1-1). The discharge measurements and corresponding river levels are used to derive rating curves/equations, which in turn can be used to convert the HYCOS water levels to discharge volumes. The acquisition of accurate water level and discharge measurements are critical for quantifying flows and identifying potential changes. These methods are internationally recognised as best practices, and Standard Operating Procedures that incorporate these have been developed by the MRCS, and are being applied to the JEM.

2.2 Purpose and objective of JEM

The purpose of hydrological monitoring in the JEM is to understand how or if the operations of the hydropower stations at Xayaburi and Don Sahong are affecting the hydrology of the Mekong. The hydrology component of the JEM addresses both water level and discharge measurements. It includes the installation of new river level recording stations at places relevant to hydropower development, and increasing the sites/stations and improving the methodologies used to collect discharge measurements at the new and existing stations.

The objective of the JEM monitoring plan is to quantify near-field flow changes associated with the operation of the hydropower projects, with the existing basin-wide HYCOS stations providing a context/control against which the near field flow changes can be compared. In addition to flow changes, the use of ADCP to measure discharge at new and existing hydrology stations is providing. It will continue to provide, insights into changes to hydraulics of the river (flow velocities, water depths, etc.) near the projects as well as in downstream areas that are relevant to sediment transport and aquatic ecology.

2.3 Approach and methodology

The approach and methodology adopted for the hydrology component of the JEM is consistent with the existing methodology used by the Member Countries in the HYCOS and the Discharge and Sediment Monitoring Programme, and is based on the collection of continuous water level readings, and repeated discharge measurements at the same stations. The discharge results and corresponding water level information can be combined to derive a rating curve for each station, which in turn can be used to convert the continuous water level record to a continuous flow record.

A very important aspect of hydrologic monitoring is where stations are located. As ideally, a hydrologic station should have the following characteristics: be a single channel under all flow conditions, have a uniform cross-section with respect to flow rates, not be located in or near a
river bend, not be located near a tributary that may create backwater effects, have river banks which are suitable for the establishment of a water level recorder, and be suitably accessible for manual readings and maintenance.

For both the Xayaburi and Don Sahong components of JEM, additional hydrology stations are being established to improve the understanding of local and regional flow rates. The activities associated with each project are outlined in the following sections with respect to stations, parameters and monitoring frequency.

2.3.1 Monitoring stations at Xayaburi

The review of the hydrology monitoring completed during the initial phase of the JEM recommended the following, with respect to monitoring at Xayaburi:

- A new station should be established downstream of Xayaburi
- The existing Luang Prabang station should be moved upstream of the Xayburi backwater
- Hydrologic monitoring at Chiang Khan should be upgraded from a current meter to an ADCP

Each of these is discussed in the following sections.

2.3.1.1 New station downstream of Xayaburi

An additional water level monitoring station should be established downstream of the Xayaburi Hydropower project to record short-term changes to discharge and to provide hydrological information to underpin the other monitoring components (sediments, water quality, fisheries, etc.). The initial JEM review recommended either obtaining permission from the Xayaburi operator to access the data collected by the company’s existing gauge downstream of the HPP or establishing a new station. To ensure continuous and unrestricted access to the data, the establishment of a new station is the preferred option. It is a suitable station identified during a reconnaissance trip on 11 – 14 November 2019 by representatives of the MRCS, the LNMC, Ministry of Energy and Mines (MEM), Ministry of Agriculture and Forestry (MAF) and Ministry of Natural Resources and Environment (MRC 2019g). Station selection included consideration of channel characteristics and access. A station located approximately 4 km downstream of the Xayaburi HPP was selected, and the proposed name of the station is Pak Huong (Figure 2-1). This station will be maintained by the Department of Meteorology and Hydrology (DMH), Ministry of Natural Resources and Environment.

Under the JEM, the equipment will be provided and installed by OTT, with training also provided by OTT. It is important that the HYCOS standard operating procedures (SOP) be adopted at the new station.
2.3.1.2 Relocation of the Luang Prabang water level station

During the first phase of the JEM project, it was recognised that the backwater from the Xayaburi HPP extended to, and beyond the location of the HYCOS gauging station at Luang Prabang. As shown in Figure 2-2, the water level at the station has been higher and more uniform for the past year owing to the impoundment of Xayaburi. This is consistent with the Full Supply Level of Xayaburi being 275 m a.s.l.; the zero level of the Luang Prabang HYCOS gauge is 267.2 m a.s.l., with a constant water level of 8 – 9 m, totalling ~275.2 m a.s.l.

Ideally, the Luang Prabang HYCOS station should be moved upstream, or a new station should be established upstream, such that the backwater impacts are absent from the place. It is also desirable for the new station to remain downstream of the confluence with the large Nam Ou tributary. So the data collected at the new station can be integrated with the historic data set from Luang Prabang, which includes the Nam Ou flow (recognising the inflow of tributaries such as the Nam Khan will be absent). A strategic new station could also monitor downstream of the proposed Luang Prabang hydropower project if / when it is developed.

An initial reconnaissance trip was completed in November 2019 by the same team as described for the downstream Xayaburi reconnaissance mission. Based on field observations, it was concluded that the Xayaburi backwater extends considerably upstream, and possibly to the confluence of the Nam Ou under some hydrologic conditions. These observations were confirmed during discussions with the Luang Prabang hydropower developer. Despite this constraint, three potential stations located downstream of the confluence of the Nam Ou and Mekong River were investigated for the establishment of a 'manual' water level station (Figure 2-3). This station will have a level gauge installed, and the water level will be manually recorded on a daily basis. The information will be collected following the established MRC protocol for manual stations, and be reported and stored by the MRC but not incorporated into the flood
forecasting network. This information will provide an understanding of how frequently and under what conditions the backwater extends to or near the station.

The preferred location identified during the field trip was on the Mekong River at Ban Sang Hai, which had a suitable cross-section and is located near a village allowing easy access and reading of the water level. During the JEM pilot studies, the existing Luang Prabang station will be maintained, but discharge and sediment measurements will be completed at the upstream station. Data from the two stations may be able to be used to derive a new rating curve for Luang Prabang based on the water level from both stations to correct for the backwater effects.

If it is not feasible to accurately measure flows at Ban Sang Hai, upstream of Luang Prabang town, due to backwater effects, there is also the prospect of relying on the new station downstream of Xayaburi (the Mekong at Pak Huong) for accurate Mekong River discharge information. All information collected from a newly established or moved HYCOS stations will report to the MRCS via the existing HYCOS telemetry network, consistent with the SOP.

Figure 2-2: Water level observations at the Luang Prabang HYCOS station showing a consistent increase in water level associated with the backwater of the Xayaburi HPP extending beyond the HYCOS station.
due to backwater effects, there is also the prospect of relying on the new station report to the MRCS via the existing HYCOS telemetry network, consistent with the SOP. Information collected from a newly established or moved HYCOS stations will downstream of Xayaburi (the Mekong at Pak Huong) for accurate Mekong River discharge reading of the water level. During the JEM pilot studies, the existing Luang Prabang station will increase in water level associated with the backwater of the Xayaburi Hydro Project extending beyond the forecasting network. This information will provide an understanding of how frequently and 

**Figure 2-3:** Google Earth image showing the location of the existing Luang Prabang HYCOS station (011201), the confluence of the Nam Ou and Mekong Rivers. The area investigated for potentially relocating the station is outlined in red and shown in more detail in Figure 2-4. Arrow indicates flow direction.

Source: Report on Field visit trip for the selection of the new HYCOS and Discharge and Sediment Monitoring Station Locations, Nov 2019.

**Figure 2-4:** Locations of stations investigated for the 'new' upstream Luang Prabang gauging station.
2.3.2 Parameters and monitoring frequency at Xayaburi stations

Water level measurements need to be converted to discharge to understand the hydrology of the river. This is done through the derivation of a rating curve, that is based on concurrently collected discharge and water level measurements. Under the JEM, water level and discharge measurements related to Xayaburi will be completed as follows:

- Water level at the Mekong at Ban Sang Hai will be recorded on a daily basis.
- Discharge at the new Mekong at Ban Sang Hai station will be monitored 24-times per year by the Luang Prabang Department of Meteorology and Hydrology (DMH) hydrographic team using ADCP.
- Water level at the new Mekong at Pak Huong station will be continuously recorded by a water level probe and telemetered back to the MRC consistent with the SOP.
- Discharge at the new Mekong at Pak Huong station will be monitored 24-times per year by the Luang Prabang DMH hydrographic team using ADCP.
- At the existing Chiang Khan station, the discharge monitoring equipment will be upgraded from a current meter to an ADCP unit, allowing more detailed discharge and bathymetric information to be collected. The JEM project will provide the ADCP unit. The water level at the place will continue to be continuously recorded at the existing HYCOS station, and discharge will be measured 24 times per year by a hydrographic team from the Office of National Water Resources (ONRW) Thailand.

2.3.3 Monitoring stations at Don Sahong

The review of hydrologic monitoring completed during the initial phase of the JEM concluded that the operation of the Don Sahong hydropower project was unlikely to alter the volume or timing of flow at a large scale. However, it was recommended that an additional HYCOS station is established on the Mekong mainstream upstream of the backwater of the 3S confluence within Cambodian borders. The new station would provide flow information about how flow in the Mekong changes between the upstream station of Pakse (~145 km upstream) and the confluence of the large 3S river system. A new flow monitoring station upstream of Stung Treng town would also document the integrated flow changes associated with all developments upstream of the 3S. It has previously been demonstrated that the large number of tributary projects in the LMB, combined with the Lancang cascade have the altered flows at a large scale (Cochrane et al., 2014), and a new station would provide more insight into these changes as additional development proceeds in the LMB.

A new station upstream of Stung Treng town had already been identified as desirable under the Mekong HYCOS extension project, and Cambodia has commenced construction of a water level gauging station at Koh Key (MRC, 2019f). During a reconnaissance mission in November 2019 by GIZ, it was observed that sand deposits characterise the area, and concerns were raised about the stability of the channel. Based on the known distribution of bedrock in the area (Figure 2-5), it is likely that the channel is stable, although infilling and scouring may occur. Ongoing review and analysis of the bathymetric profiles collected at the station will be required to confirm channel stability. The HYCOS standard operating procedures (SOP) will be implemented at the new station to ensure compatibility with the existing HYCOS.

Discharge at the new station will be monitored at the ADCP-1 site indicated in Figure 2-5 under most flow conditions. During periods of very low flow, when access to ADCP-1 station is not possible, the discharge will be measured at ADCP-3 station. No backwater from the 3S confluence must be affecting ADCP-3 site when this station is used.
Figure 2-5: Location of new upstream Stung Treng water level gauge at Koh Kel (106°2'54.70"E 13°40'48.10"N). Discharge to be measured at ADCP-1 except during periods of very low flow when measurements will be completed at ADCP 3.
As part of the JEM Programme, hydrographic surveys of the Dolphin Pools near the border of Cambodia and Lao PDR will be completed twice per year, by joint Lao and Cambodian teams. The main aim of these surveys is to monitor the bathymetry of the pools (discussed in more detail in the sediment section). Still, the information gathered will also provide a measure of the discharge entering Cambodia via the main Mekong channel. This information can be compared to the discharge results at Koh Key to understand better the distribution of flow between the various river channels. It may be of use to both the fisheries and aquatic health monitoring themes.
2.3.4 Parameters and monitoring frequency at Don Sahong

The following parameters and monitoring frequency will be incorporated into the hydrologic monitoring for JEM.

- At the new Koh Key HYCOS station, located on the Mekong River mainstream upstream of Stung Treng town, the water level will be recorded at 15-minute intervals and telemetered to the MRC, consistent with the existing SOP. MOWRAM will maintain the station in Cambodia.
- The discharge will be monitored 24 times per year using ADCP to establish a rating curve at Koh Key. During all periods except very low flow, the discharge measurement will be completed at station ADCP-1. When access to ADCP-1 station is not possible due to low flow conditions, the measurements will be made at ADCP-3 station. MOWRAM (Cambodia) hydrographic teams will complete the field measurements.
- Discharge at Pakse will be measured 24 times per year with a new ADCP, providing more detailed information about discharge and hydraulics. The fieldwork will be completed by DMH teams (Lao PDR).
- Discharge in the main Mekong channel at the Dolphin Pools will be jointly measured twice per year by Cambodia and Lao PDR hydrographic teams, with Cambodia responsible for reporting the results.

2.3.5 Data analysis and reporting

The HYCOS water level data are reported directly to the MRC via telemetry consistent with the HYCOS SOP. The MCs maintain a manual log of water levels that can be used in the event of a problem with the transmission. The MRC will complete the QA/QC of these data and the results will be added to the existing HYCOS database.

Monitoring of water level at Ban Sang Hai upstream of Luang Prabang town will be completed manually for at least the first year of the JEM trial. The station will be monitored twice per day with the water level and time recorded. As proposed in the Work Agreement, the data will be reported to the MRC using the existing reporting form every two weeks. Ideally, the water levels and times could be sent to the MRC on a daily basis as well.

The reporting of discharge results will continue using the data reporting sheets developed as part of the DSMP. This reporting mechanism is discussed in Section 7.4. The hydrologic data collected during the JEM Programme trial will be used to establish provisional rating curves at the new monitoring stations (Ban Sang Hai, Pak Huoung, and Koh Key) and compared against the existing curves for the existing stations (Chian Khan and Pakse). An analysis of water level at Ban Sang Hai will be made to estimate when and for what duration backwater effects from the Xayaburi impoundment are present at the station. The downstream Xayaburi station results will be used to identify any flow changes due to hydropower operations using the upstream new and existing DSM stations for comparison.

Discharge measurements and discharge time-series will be integrated with the sediment monitoring results to derive sediment time series, annual loads and sediment budgets for the areas upstream and downstream of Xayaburi and Don Sahong.

2.4 National Monitoring Teams and Work Plan

The national monitoring teams and the work plan are the same for the Hydrology and Sediment components of JEM. This information is provided in Section 3.4 and 3.5.
3 SEDIMENT AND GEOMORPHOLOGY

3.1 Background and justification

Sediment transport is essential for providing and maintaining habitat variability and quality, and for providing structural integrity to the river channel, flood plain and delta. Sediments and their associated nutrients play a crucial role in water quality, directly affecting the dispersion of nutrients in the river system, and indirectly by controlling light penetration which in turn affects water temperature and primary productivity. It is recognised that the Lancang Cascade has considerably reduced the sediment load entering the LMB from China and that additional sediment reductions due to damming of tributaries are also reducing loads relative to historic conditions. Understanding these changes and predicting future changes is necessary to underpin sustainable development in the LMB. The interpretation of sediment monitoring results is strongly dependent on accurate hydrologic monitoring and gauging to quantify sediment transport, derive catchment budgets and identify change. So the monitoring of sediment transport at the same time as the discharge is fundamental to understanding the dynamics of a river system.

At a larger scale and over more extended time-periods sediment transport translates into a change in geomorphology, including river bank slope and characteristics, channel morphology, and importantly, the integrity of the Mekong delta. For these reasons, understanding sediment transport over a range of spatial and temporal scales is critical for understanding how rivers respond to change.

Sediment monitoring in the Mekong is completed at the stations shown in Figure 3-1. Monitoring has occurred at variable frequencies since 2009, and the results have been used to quantify sediment loads and understand at a large scale the reduction in sediment transport that has occurred in the LMB in response to the Lancang cascade and other activities.

3.2 Purpose and objective of the JEM pilots project

Hydropower developments have the potential to alter sediment transport and geomorphology through three main processes: (i) Sediments can be trapped due to reduced water velocities in impoundment promoting deposition; (ii) Erosion downstream of dams can increase due to a lack of sediment deposition to offset river erosion; and (iii) Changes to the flow regime due to flow regulation can alter the timing and dispersal of sediment in the downstream river system.

The sediment and geomorphology related purpose of the JEM pilots project is to better understand local changes in sediment transport and geomorphology associated with the operation of the Xayaburi and Don Sahong hydropower projects and to provide the information required to understand these changes in the broader LMB context. The JEM Programme builds on the existing sediment monitoring in the LMB (Discharge Sediment Monitoring Programme) by (i) Expanding the monitoring network, (ii) Upgrading the equipment and methodology used at existing stations, and (iii) Establishing new stations to increase the level of understanding of hydropower impacts at local scales. The JEM pilots project provides an opportunity to trial new monitoring techniques and evaluates whether they are suitable for inclusion in the ongoing MRC monitoring programmes.

The specific approach and methodology for the Xayaburi and Don Sahong JEM monitoring strategies are discussed in the following sections.
3.3 Approach and methodology

3.3.1 Sediment monitoring stations at Xayaburi

The approach of the JEM sediment monitoring at Xayaburi includes:

- Quantifying the sediment load and grain-size characteristics entering the Xayaburi impoundment based on the flow and suspended and bedload grain-size information;
- Quantifying the sediment load and grain-size characteristics downstream of the Xayaburi Dam; and,
- Quantifying how sediment loads change between downstream of Xayaburi and Chiang Khan, which is located approximately 220 km downstream, in Thailand. Quantifying changes to the load downstream of Xayaburi will provide information about the existing ‘buffering’ capacity of the river to replace lost sediment and will assist in predicting timeframes for potential transboundary impacts.

The sediment and geomorphology monitoring stations are shown in Figure 3-2 and Figure 3-3. The monitoring methodology adopted is summarised in Table 3-1 and includes:

- Sediment monitoring will be implemented at the new Sang Hai and Pak Huoung sites on the Mekong River with the same hydrographic teams completing the work as per the hydrologic measurements; and,
- Sediment monitoring will be completed at the existing DSMP station of Chiang Khan at the same frequency as the new stations to provide information about larger-scale river responses, including river geomorphology changes, to the operation of Xayaburi.

3.3.2 Monitoring parameters and sampling frequency

At each of these new (Pak Huoung, Sang Hai) and existing (Chiang Khan) stations, the following parameters will be determined at the stated frequency. The parameters and frequency align with the approach developed for the DSM and use the established monitoring protocols.

- Depth integrated suspended sediment monitoring using a D-96 sampler, with a new sampler to be provided under the JEM to Chiang Khan. The monitoring frequency will be 24 times per year. Sampling at each station includes the collection of depth integrated water samples at five points across the river transect based on the equal discharge method. The samples are analysed using standard laboratory methods.
- Suspended sediment grain-size distribution will be determined 12 times per year through the collection of a large volume depth integrated water sample and analysed using standard laboratory sieving and techniques.
- Bedload transport using the ADCP loop-test method to be completed 24 times per year, with a new ADCP to be provided under the JEM to Chiang Khan;
- Bed material grain-size distribution to be completed 12 times per year and analysed using standard laboratory sieving techniques.

Sediment transport monitoring will be supplemented with geomorphic monitoring of river banks. This component will extend the understanding of changes in sediment transport and hydrology in the LMB to changes to river bank slopes and channel characteristics. This will include the following components:
• Repeat photographs of the river banks near the discharge monitoring stations, and any other river banks that are readily accessible to the field monitoring parties. The aim is to collect a series of photographs of existing bank features from the same vantage point over a period of time to allow large scale changes (river bank slopes, landslips, changes to vegetation, sediment deposition, etc.) to be recorded. These observations can assist with interpreting how the river channel at a larger scale is responding to the flow in the river.

There is potential to use these photos to investigate whether geomorphic monitoring using satellite imagery is feasible. Whether changes observed at the ground level are visible in satellite photos will indicate whether satellite imagery is applicable to river reach scale changes. It is proposed that the stations to be included in photo monitoring are identified by the relevant teams prior to the discharge and sediment training course, with examples brought to the course for discussion.

Repeat surveys of alluvial reaches upstream of Vientiane / Nong Khai. The proposed northern Lao PDR hydropower cascade is located in a long bedrock-controlled section of the river, however downstream of the final proposed damlocation, Sanakham, there is a long reach characterised by large alluvial deposits. Understanding how this reach of the river is responding to flow and sediment changes will provide an indication into the river geomorphic processes occurring and the associated time-scales.

It is proposed to survey three cross-sections of the Mekong River twice per year in the reach upstream of Vientiane / Nong Khai, as shown in Figure 3-1.

Figure 3-1. Proposed locations for repeat cross-section in the Mekong to understand how alluvial reaches are responding to flow and sediment changes in the river.
Table 3.1. Summary of discharge and sediment monitoring for the JEM.

| Station                          | MC responsible | Activity                                                                 | Frequency       |
|---------------------------------|----------------|--------------------------------------------------------------------------|-----------------|
| Mekong at Pak Huoung            | Lao PDR        | Manual recording of water level & time<br>Field monitoring of discharge, suspended sediment & bedload<br>Photo monitoring of river banks<br>Suspended and bedload grain-size distribution | 2/day, 24/year, 12/year |
| Mekong at Ban Sang Hai          | Lao PDR        | Continuous water level<br>Field monitoring of discharge, suspended sediment & bedload<br>Photo monitoring of river banks<br>Suspended and bedload sediment grain-size distribution | 15-min recorded 24/year, 24/year, 12/year |
| Chiang Khan                     | Thailand       | Continuous water level<br>Field monitoring of discharge, suspended sediment & bedload<br>Photo monitoring of river banks<br>Suspended and bedload sediment grain-size distribution | 15-min recorded 24/year, 24/year, 12/year |
| Alluvial reach downstream of Sanakham | Lao PDR / Thailand | Detailed survey of 3 river cross-sections | 2/year |
Figure 3-2. Proposed new downstream Xayaburi monitoring station and existing DSMP monitoring stations of Luang Prabang, Chiang Khan and Nong Khiaw.
Figure 3-3: Detailed map of discharge and sediment sampling stations immediately downstream of Xayaburi
3.3.3 Sediment monitoring stations at Don Sahong

As discussed in the Hydrology section, the Don Sahong hydropower project is unlikely to substantially alter sediment loads in the Mekong due to its small size and configuration of the inlet to the impoundment which directs bedload sediment away from the water body. Finer grained material is expected to pass through the turbines with minimal deposition occurring behind the dam. However, enhancing the understanding of sediment transport in this area of the river is essential, and the JEM monitoring has the following objectives:

- Better quantify the sediment loads and sediment characteristics at Pakse and at Koh Key upstream of the 3S confluence to gain an understanding of sediment storage or removal through the hydraulically complex Si Phan Don river reach;
- Quantify the volume of sediment derived from the upper LMB to establish the volume of sediment derived from the upper catchment as compared to entering from the 3S system that enters the Cambodian floodplain and Vietnamese delta;
- Quantify geomorphic changes occurring within the river channels, especially the deep pools used as refugia by the Irrawaddy dolphin population resident near the Lao PDR – Cambodian border.

The JEM Programme around Don Sahong includes monitoring at existing discharge and sediment stations (Pakse, Stung Treng) and establishing a new monitoring station upstream of the 3S confluence and backwater (at the new Koh Key HYCOS station, Figure 3-4). This will provide an accurate measurement of the sediment load derived from the upstream Mekong River. When compared with measurements from the existing sediment monitoring stations, it will provide an indication of how sediment transport changes through the Si Phan Don reach, as well quantities of sediment in the Mekong as compared to entering from the 3S river system. The methodologies that will be adopted include the following:

- Monitor depth-integrated suspended sediments, bedload, suspended and bed material grain size at Koh Key to quantify the material in the Mekong downstream of Don Sahong and upstream of the 3S;
- Increase the parameters monitored at the existing Stung Treng station to include bedload and grain-size distribution to provide a better understanding of the sediment load and characteristics entering from the 3S;
- Upgrade the suspended sediment monitoring equipment at Pakse from an Epsilon-Nilsen sampler to a D-96 which is more appropriate for the depth and flow conditions in the river at Pakse;
- Upgrade the current meter at Pakse to an ADCP to allow the collection of detailed flow, hydraulic and bathymetric data, and measurement of bedload using the loop-test method;

Geomorphic monitoring of riverbanks through repeat photography will be implemented at Koh Key to provide an indication of how banks are changing at a larger scale. This information may be used to investigate the potential for using satellite imagery to monitoring geomorphic change in the Mekong, as discussed in the Xayaburi monitoring section.

Bathymetric surveys of the Dolphin Pools near the Cambodian Lao PDR border will be surveyed twice per year to identify whether any changes (infilling, erosion) are occurring on the river bed. This work will be jointly completed between Cambodia and Lao PDR.
A summary of the proposed JEM monitoring related to Don Sahong is presented in Table 3-2. The monitoring will include the same parameters and methods as described for Xayaburi.

**Table 3-2. Summary of discharge and sediment monitoring to be completed under JEM near Don Sahong.**

| Station                                  | MC responsible | Additional work                                                                 | Frequency       |
|------------------------------------------|----------------|---------------------------------------------------------------------------------|-----------------|
| Koh Key on Mekong River (new JEM station) | Cambodia       | New HYCOS water level station Field monitoring of discharge, suspended sediment & bedload Suspended and bedload grain-size distribution | Continuous Q 24/year (min) 12/year |
| Stung Treng & 3S (existing DSMP station) | Cambodia       | Include bedload measurement in DSMP Include grain-size distribution              | 24/year 12/year |
| Pakse (existing DSMP station)            | Lao PDR        | Discharge measurement using ADCP Bedload measurement using ADCP                  | 24/year 12/year |
| Photo monitoring of river banks near Koh Key | Cambodia        | Photograph select locations on river banks to document large scale change        | 24/year         |
| Station             | MC responsible              | Additional work                                      | Frequency |
|---------------------|-----------------------------|-----------------------------------------------------|-----------|
| Repeat discharge    |Cambodia & Lao PDR           |Survey bathymetry of Dolphin Pools                   |2/year    |
| bathymetric survey  |                             |                                                     |           |
| Dolphin Pools       |                             |                                                     |           |

**3.3.5 Laboratory analyses**

The sediment analyses to be completed on the collected samples include the following:

- Suspended sediment concentrations: 5 samples per cross-section per monitoring run with the analyses completed using the standard laboratory method of filtering the sample through a pre-weighed filter to determine the mass of the suspended material.
- Suspended sediment grain-size distribution: 1 sample per cross-section per monitoring run. The analysis of grain-size will be completed using standard sieving and hydrometer methods.
- Bedload grain-size distribution: 3 to 5 samples per cross-section per monitoring run. The samples will be analysed using standard sieving procedures.

The methodology to be used by the laboratory is the same as adopted for the DSMP and contained in the SOP for sediment sampling.

**3.3.6 Data reporting and analysis**

Until a new data reporting and management system is developed, monitoring of the following results will be reported using existing DSMP monitoring forms: (i) Depth integrated suspended sediment measurements, (ii) ADCP discharge measurements, and (iii) grain-size distribution from the new and existing DSMP stations. In contrast, new forms will be developed for the reporting of the loop-test bedload measurements.

As is currently the case, the Member Countries will be responsible for initial QA/QC of field and laboratory results, with the MRC completing additional QA/QC.

The sediment and discharge results from the JEM monitoring will be combined to provide the following types of information, noting that this type of analysis has previously been completed on the DSMP data set (Koehnken, 2015):

- The discharge and water level results will be used to derive discharge rating curves for the new monitoring stations, and used to evaluate the existing discharge curves at the existing stations;
- The mass load of suspended sediment transported at each of the monitoring stations on each monitoring day. Because each of the 5 sub-samples is analysed separately, the data can provide an understanding of how sediment transport varies across the river.
- Time-series of sediment transport: The sediment load on each date will collectively provide a time series of sediment transport at each monitoring station. This information provides information about the timing of sediment delivery at each station and an indication of how sediment loads vary between stations over time;
- Suspended sediment grain-size results provide information about the size fractions being transported at each station over time. They can be used to understand the percentage of sand, silt and clay in the suspended load.
- ADCP bedload measurements based on the loop-test will provide an estimate of bedload movement at each station on each monitoring date. The data will show the progressive change in bedload movement over time at each station, and between
stations. The results can be used to derive discharge vs. bedload velocity rating curves for each of the stations, which can be used to estimate annual bedload movement.

- Bed material grain-size measurements will be integrated with the bedload data to provide estimates of the size fractions moving at each station over the monitoring period.

The information from the JEM stations will provide detailed information about what changes to flow and sediment transport are linked to hydropower operations, and when integrated with information from the other DSMP stations, how the local changes impacting the larger LMB.

### 3.4 National Monitoring teams

The monitoring teams for the JEM pilot are the same as engaged in the MRC coordinated ongoing Discharge and Sediment Monitoring (DSM). In Lao PDR the responsible line agency is the Department of Meteorology and Hydrology (DMH) in the Ministry of Natural Resources and Environment. The team that completes the ongoing monitoring at Luang Prabang will complete the JEM pilot work at the new station upstream of Luang Prabang (Sang Hai) and the new station downstream of Xayaburi (Pak Huong).

In Cambodia, the responsible line agency is the Department of Hydrology and River Works (DHRW) in the Ministry of Water Resources and Meteorology. The hydrographic team that completes the ongoing monitoring at Stung Treng will monitor the new Koh Key station upstream of Stung Treng.

All results will be submitted on the existing DSM reporting forms to the MRC via the national Mekong committees as presently occurs for the ongoing monitoring.

### 3.5 Workplan: key deliverables and timeframe

The monitoring schedule included in the Work Agreement defines the workplan and timeframes for deliverables. The sampling frequency for the different monitoring parameters and the schedule for reporting are shown in Table 3-3. The Work Agreements require the reporting of monitoring results by the monitoring teams as follows:

- Results collected in March-July 2020 to be submitted to the MRCS by August 2020,
- Results collected in August 2020 to February 2021 to be submitted by March 2021
- Results collected in March 2021 to July 2021 to be submitted by August 2021
- Results collected in August 2021 to December 2021 and final report to be submitted by March 2022

A detailed workplan is provided in Annex 3. However, in summary, upon receipt of the results by August 2020 and March 2021, the JEM team will produce Half-yearly Pilot Station Progress Reports, with one report provided for each dam. The JEM team will also produce a Combined Yearly report following receipt of the March 2021 data. The 12-month data set will be integrated with longer-term monitoring results held by the MRC and analysed to identify characteristics, changes and trends related to hydropower operations at each of the dams.

**Due to the tight time-frame, the monitoring teams are encouraged to submit monitoring results as soon as practical, or every or three months, and not wait for the 5 to 6 months allowed under the Work Agreements.** Early receipt of results will allow the JEM team to initiate database development and data analysis sooner. It will allow the review of the results to identify any potential issues with the field monitoring.
Table 3-3. Summary of monitoring frequency included in the JEM Pilot work agreements.

| Year | 2020 | 2021 | 2022 | Total |
|------|------|------|------|-------|
| Month | Jan 20 | Feb 20 | Mar 20 | Apr 20 | May 20 | Jun 20 | Jul 20 | Aug 20 | Sep 20 | Oct 20 | Nov 20 | Dec 20 | Jan 21 | Feb 21 | Mar 21 | Apr 21 | May 21 | Jun 21 | Jul 21 | Aug 21 | Sep 21 | Oct 21 | Nov 21 | Dec 21 | Jan 22 | Feb 22 | Mar 22 | Total |
| Freq. Q, SSC, BL | 0 | 0 | 1 | 1 | 1 | 4 | 4 | 4 | 4 | 3 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 4 | 4 | 4 | 4 | 3 | 1 | 1 | 0 | 0 | 0 | 48 |
| Freq. SSCGSA, BMGSA | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 24 |
| Results to MRCs | X | IR | X | IR | X | IR | X | FR | X | IR | X | IR | X | FR | X | IR | X | IR | X | FR | X | IR | X | FR | X | IR | X | FR |

Q: Discharge
SSC: Suspended Sediment Concentration
BL: Bedload
SGSA: Suspended Grain size analysis
BMGSA: Bed Material Grain size analysis
IR= Interim results
FR=Final report
4 WATER QUALITY

4.1 Background and justifications

Water quality is one of the main disciplines being routinely monitored by the Member Countries as part of the MRC Water Quality Monitoring Network (WQMN). As can be seen from Table 4-2, however, there are no existing WQ monitoring stations near the two hydropower projects of Xayaburi and Don Sahong. In order to ensure proper management during projects’ construction, commissioning and operational phases, quality data immediately upstream and downstream of hydropower projects is required. The JEM pilots will include monitoring stations within the impoundment, upstream, immediately downstream of the dams, as well as further downstream of these two hydropower projects. It is noted, however that the JEM pilots project has no basis for observing changes during construction, impoundment and commissioning because these two dams are already operating.

The linkage with the routine monitoring of the WQMN is an important consideration for the JEM pilots project, and so the methods of sample collection and analysis are standardized. The monitoring carried out by the hydropower developers also considers similar parameters, though methods may be slightly different. In order to test some of the specific changes in water quality associated with hydropower, additional tests to monitor turbidity and chlorophyll content, especially in the impoundment areas have been added.

The rationale for the different tests is based on the risks and consequences of hydropower development during both construction and operation as shown in Table 4-1. The tests are chosen to highlight changes in water quality that may result from developing hydropower project. It is, however, noted that some changes will not be measurable under the proposed monitoring regime (e.g. dissolved oxygen supersaturation below the dam), however it will be possible to assess most of them. Table 4-1 is therefore important for understanding changes observed upstream and downstream of the dams as well as in the impoundments. It also serves to validate the results during QA/QC process.

4.2 Purpose and Objectives of the JEM Water quality monitoring

The objective of this assignment is to ensure empirical data on the influence of the dam on water quality, from both Xayaburi and Don Sahong hydropower projects. The Lao national water quality sampling team and analytical laboratory have been contracted to:

- Conduct monthly monitoring of water quality of the Mekong River at locations listed in Table 4-3 and Table 4-4;
- Provide water quality data in an agreed format within ten working days of the month data was collected;
- Prepare Water Quality Data Assessment Report, to be submitted to the MRC Secretariat through the Lao National Mekong Committee Secretariat every six months (August 2020, February 2021, August 2021 and February 2022).
| Risk | Consequences | Monitoring |
|------|--------------|------------|
| Risks from Construction Activities | Local contamination could impact aquatic ecosystems and fish in the vicinity of the construction site | Frequent visual observation and photomonitoring of Total Petroleum Hydrocarbons (TPH) as necessary |
| Spillages of fuel and lubricants | Local contamination could impact aquatic ecosystems and fish in the vicinity of the construction site | Frequent observation, photo-monitoring during wet weather, sampling for turbidity or SS as necessary |
| Runoff of turbid water from bare soil | Local contamination could impact human health, aquatic ecosystems and fish in the vicinity of the construction site | Monitoring of total coliforms monthly, and more frequently if guidelines exceeded |
| Waste-water from accommodation facilities for workers | Local contamination could impact aquatic ecosystems and fish in the vicinity of the construction site | |
| Operational Risks | Risks to the Impoundment | |
| Increasing nutrient influx from upstream and the local catchment from non-hydropower related activities | Increased algal growth rates | Chlorophyll monitoring in impoundments |
| Reduced turbidity and increased light penetration | Increased algal growth rates | Turbidity or Photosynthetically Active Radiation (PAR) monitoring in impoundments. Chlorophyll monitoring in impoundments. |
| Risks from Impoundment Stratification | Hypolimnion becomes unavailable to fish and most invertebrates, iron and manganese released from sediments | Temperature and DO profile recorded monthly, at a location close to dam wall |
| Low dissolved oxygen in hypolimnion (bottom water) | Low pH causes corrosion of hydropower infrastructure, hypolimnion becomes toxic to biota, and metals and nutrients are released from sediments. | Sample hypolimnion monthly if profile shows stratification |
| Low pH in hypolimnion | May cause deposition issues for infrastructure river bed and downstream. | Sample hypolimnion monthly for dissolved Fe and Mn if profile shows stratification |
| High concentrations of dissolved iron and manganese in hypolimnion | Toxic metals may be taken up in biota and potentially passed up food chains and contaminate foods for humans | Sample hypolimnion 3-monthly for dissolved Hg, Cd, |
| High concentrations of toxic metals (e.g. mercury) in hypolimnion | May trigger algal blooms when impoundment water turns over when stratification breaks down – probably in December-January | Sample hypolimnion monthly if profile shows stratification |
| High concentrations of sulphides and nutrients (N & P) in hypolimnion | Rapid fluctuations in downstream water quality | Initially continuously monitor conductivity and turbidity ~ 1 km downstream of dam. If rapid fluctuations occur then extend monitoring to other parameters. |
| Risks Downstream of the Impoundment | | |
| Risk                                                                 | Consequences                                                                 | Monitoring                                                                 |
|----------------------------------------------------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Altered water temperature                                           | Negative impacts on downstream biota                                         | Continuous monitoring of downstream water temperature ~ 1 km below dam wall |
| Reduced turbidity arising from settling of particulates              | Increased algal and plant growth, impact on fish behaviour                   | Monitor chlorophyll monthly 1 km below dam wall                             |
| Reduced nutrient concentrations arising from settling of particulates | Reduced nutrient availability to instream and floodplain biota               | Monitor Total P and total N monthly below dam wall                          |
| Gas supersaturation                                                  | Fish deaths                                                                  | Monitor dissolved oxygen weekly below dam wall using a DO meter.           |
| Risks from impoundment stratification if bottom water is discharged downstream |                                                                             |                                                                           |
| Low dissolved oxygen arising from impoundment stratification         | Negative impacts on downstream biota                                         | If profile in the impoundment shows stratification, then sample DO ~ 1 km downstream of dam wall |
| Low pH arising from impoundment stratification                       | Negative impacts on downstream biota                                         | If profile in the impoundment shows stratification, then sample pH ~ 1 km downstream of dam wall |
| High concentrations of reduced metals (Fe and Mn) arising from impoundment stratification | Negative impacts on downstream habitat and biota                            | If profile in the impoundment shows stratification, then sample Fe and Mn ~ 1 km downstream of dam wall |
| High concentrations of toxic metals leaching from impoundment sediments as a result of impoundment stratification | Negative impacts on downstream biota, and potential impacts on humans consuming fish and OAAs | If profile in the impoundment shows stratification, then sample Hg and Cd ~ 1 km downstream of dam wall |
| Risks from sediment flushing                                         |                                                                             |                                                                           |
| Downstream pulse of sediment                                         | Altered downstream sediment                                                  | Should be detected by sediment/geomorphological sampling                  |
| Downstream pulse of high turbidity                                   | Downstream biota reduced through avoidance behaviour such as invertebrate drift | Continuous monitoring of turbidity downstream of the dam                   |
| Downstream pulse of low dissolved oxygen                             | Downstream biota reduced through deaths and avoidance behaviour such as invertebrate drift | Continuous monitoring of dissolved oxygen downstream of the dam           |
| Downstream pulse of toxicants                                        | Downstream biota reduced through deaths and avoidance behaviour such as invertebrate drift | Assess ecological health, using MRC indices at 3 sites downstream of the dam each dry season |

Source: JEM Programme, MRC (2019)
4.3 Approach and methodology

4.3.1 Sampling stations

The JEM water quality component is designed around the principles of BACI (Before After Control Impact) and statistical replication.

The MRC’s WQMN sampling sites on the Mekong mainstream are located at the following 22 stations shown in Table 4-2. The two stations upstream and downstream of the two JEM pilots are highlighted in bold and the results from routine monitoring at these stations will be especially important as controls for the JEM.

| No. | Name of station | Station ID | River | Countries | Latitude | Longitude |
|-----|-----------------|------------|-------|-----------|----------|-----------|
| 1   | Houa Khong      | H010500    | Mekong| Lao PDR   | 21.5471  | 101.1598  |
| 2   | Chiang Saen     | H010501    | Mekong| Thailand  | 20.2674  | 100.0908  |
| 3   | Luang Prabang   | H011200    | Mekong| Lao PDR   | 19.57430 | 102.14427 |
| 4   | Vientiane       | H011901    | Mekong| Lao PDR   | 17.9281  | 102.62    |
| 5   | Nakhon Phanom   | H013101    | Mekong| Thailand  | 17.425   | 104.7744  |
| 6   | Savannakhet     | H013401    | Mekong| Lao PDR   | 16.5583  | 104.7522  |
| 7   | Khong Chiam     | H013801    | Mekong| Thailand  | 15.3255  | 105.4937  |
| 8   | Pakse           | H013900    | Mekong| Lao PDR   | 15.1206  | 105.7837  |
| 9   | Stung Treng     | H014501    | Mekong| Cambodia  | 13.545   | 106.0164  |
| 10  | Kratie          | H014901    | Mekong| Cambodia  | 12.4777  | 106.015   |
| 11  | Kampong Cham    | H019802    | Mekong| Cambodia  | 11.9942  | 105.4667  |
| 12  | Chrouy Changvar | H019801    | Mekong| Cambodia  | 11.5861  | 104.9407  |
| 13  | Neak Loung      | H019806    | Mekong| Cambodia  | 11.258   | 105.2793  |
| 14  | Kaorm Samnor    | H019807    | Mekong| Cambodia  | 11.0679  | 105.2086  |
| 15  | Tan Chau        | H019803    | Mekong| Viet Nam  | 10.9079  | 105.1835  |
| 16  | My Thuan        | H019804    | Mekong| Viet Nam  | 10.2725  | 105.91    |
| 17  | My Tho          | H019805    | Mekong| Viet Nam  | 10.343   | 106.3505  |
| 18  | Takhmaw         | H033401    | Bassac| Cambodia  | 11.4785  | 104.953   |
| 19  | Koh Khel        | H033402    | Bassac| Cambodia  | 11.2676  | 105.0292  |
| 20  | Koh Thom        | H033403    | Bassac| Cambodia  | 11.1054  | 105.0678  |
| 21  | Chau Doc        | H039801    | Bassac| Viet Nam  | 10.9552  | 105.0867  |
| 22  | Can Tho         | H039803    | Bassac| Viet Nam  | 10.058   | 105.7977  |
4.3.2 Sampling station at Xayaburi

“The JEM documents for the sampling design includes three distinct campaigns for Xayaburi:

1. A high frequency series of measurements of dissolved oxygen (DO), conductivity, turbidity and temperature at a single station within 500 m of the dam discharge point; (now postponed to a future project)
2. Monthly measurements or samples at one station upstream and three stations downstream of the dam of: DO, temperature pH, conductivity, turbidity, temperature, light penetration (PAR), Chlorophyll-a, total P and oxides of nitrogen (NOx);
3. Existing MRC water quality monitoring activities.”

However, the first high frequency campaign will not begin yet because of a lack of a suitable site for installing the fixed equipment within 500 m of the dam. This campaign will therefore be postponed to a future project.

Using the initial identification of the WQ sampling stations from the JEM Pilot description for Xayaburi, the MRC/GIZ team confirmed the following stations for sampling, during the field trip in November 2019, as shown in Table 4-3. These are shown in Figure 4-1.

Table 4-3: Water Quality sampling stations for Xayaburi JEM Pilot.

| Code | Station                                      | River | Latitude         | Longitude        |
|------|----------------------------------------------|-------|------------------|------------------|
| WQ1  | Upstream of Xayaburi around 110-km upstream of the dam. | Mekong | ~20°00’07.2”N | 102°14’06.7”E |
| WQ2  | Within the Xayaburi Impoundment (at Ban Talan, 1-km above the dam wall) | Mekong | 19°15’16.1”N | 101°48’45.5”E |
| WQ3  | Around 1.5-km downstream of the dam          | Mekong | 19°13’49.5”N | 101°49’17.1”E |
| WQ4  | Around 4-5 km downstream of the dam         | Mekong | 19°12’58.3”N | 101°49’25.5”E |
| WQ5  | Downstream at Pakhoung Village, around 10-km downstream of the dam | Mekong | 19°09’28.0”N | 101°48’50.6”E |

The location of the upstream station, WQ1, has been retained, despite the full extent of the upstream inundation area from Xayaburi still being uncertain and that, ideally, the sampling station should not be influenced by impoundment conditions. Ideally, the sampling station should be located at least 500m upstream of the furthest extent of inundation as well as being located downstream of the Nam Ou confluence. However, at times of high flow, it is expected that the impoundment will back-up as far as the Nam Ou confluence. It is therefore not possible to find a location that is upstream of the impoundment and downstream of the Nam Ou confluence. When analysing the results, we will have to be aware of the possible influence of the impoundment conditions and obtain information from the hydrological records of the extent of the backwater.

The first downstream sampling station WQ3 would be the station for the continuous monitoring under campaign 1, and for the monthly monitoring under campaign 2. The station has been chosen as the closest accessible location outside the boundary of the dam site that meets safety requirements.

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1 MRC 2019 Joint Environment Monitoring of Mekong Mainstream Hydropower Projects JEM PILOT PROJECT PROPOSAL – XAYABURI
The third campaign, based upon existing WQMN monitoring stations, focuses on the monthly records of the two sampling stations between Luangprabang and Vientiane (see Figure 1-2) as indicated in Table 4-2.
4.3.3 Sampling stations at Don Sahong

The design of the water quality monitoring at Don Sahong includes two campaigns:

1. Monthly measurements or samples at one station upstream and several stations downstream of the dam for: DO, temperature pH, conductivity, turbidity, temperature, light penetration (PAR), Chlorophyll-a, total P and oxides of nitrogen (NOx);
2. Existing MRC water quality monitoring activities.

![Figure 4-2: Stations for water quality monitoring downstream of Don Sahong dam.](image-url)
The JEM pilots proposal states that “the dam is unlikely to cause large changes in water quality, but sampling from mid channel close to the dam during high flow periods is unlikely to be safe or even possible, while sampling far from the dam is unlikely to detect any impact. Based on Google Earth it seems unlikely that more than two sampling stations will be able to be identified downstream of the dam, both within Lao PDR.

Sampling stations are indicated in Figure 4-2. High frequency sampling should be located at one of the two downstream stations depending on the location of existing hydrological infrastructure. One additional sampling station within the impoundment should be identified if permission is granted by the Government of Lao PDR. Campaign 2 should be carried out there on a monthly basis².

The second campaign based upon existing WQMN monitoring stations would focus on the monthly records of the two sampling stations between Pakse and Siphandone and the station upstream of Stung Treng in Cambodia (see Figure 1-3) as indicated in Table 4-2.

In December 2019 the MRC/GIZ team conducted a field visit to Don Sahong and confirmed the suitability of the following water quality sampling stations around the Don Sahong HPP. These are listed in Table 4-4 and shown in Figure 4-2.

| Code | Station | River | Latitude       | Longitude      |
|------|---------|-------|----------------|----------------|
| WQ6  | Upstream of Don Sahong Dam, at the impoundment inlet point | Mekong | 13°58′41.8″N | 105°57′16.2″E |
| WQ7  | Within the impoundment (around 1.2-km upstream of the dam wall) | Mekong | 13°56′38.8″N | 105°57′42.5″E |
| WQ8  | Downstream of Don Sahong (around 250-m downstream of the dam) | Mekong | 13°56′31.7″N | 105°57′15.8″E |
| WQ9  | Downstream Monitoring #2 of Don Sahong (around 1-km downstream of the dam) | Mekong | 13°56′14.7″N | 105°57′25.7″E |

### 4.3.4 Sampling parameters

Each of the water quality monitoring parameters chosen for the JEM pilots, are aligned with MRC routine monitoring, and reflect potential changes in water quality as a result of hydropower construction and operation. It is important that the teams undertaking the sampling and monitoring understand what each of the WQ parameters indicate. Table 4-1, taken from the JEM documents, illustrates the risks to water quality at different stages of construction and operation and locations within the impoundment, below the dam and downstream. This risk assessment provides the rationale for the locations and types and parameters for the water quality monitoring campaigns designed for the JEM pilots.

The other criterion for the design of the water quality monitoring is that it should be standardised with the MRC’s WQMN that has been long established in the Mekong mainstream and tributaries. The WQxSMN primarily samples 22 mainstream stations in the

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² MRC. (2019). Joint Environment Monitoring of Mekong mainstream hydropower projects: JEM PILOT PROJECT PROPOSAL – DON SAHONG.
The Lower Mekong basin every month to measure as many as 19 parameters (see Figure 1-3). It is designed to allow an assessment of basin wide long-term changes in water quality.

The parameters measured in the WQMN are shown in Table 4-5. Comparing the monitoring requirements of both the risk assessment and present WQN parameters, it is clear that the main gaps identified are in the chlorophyll, turbidity, PAR and the toxic metals such as Mercury and Cadmium as well as Iron and Manganese. As a result of equipment procurement and budget discussions, it has been decided that only Chlorophyll-a and turbidity measurements will be added to the list for JEM. Two methods will be tested for Chlorophyll-a determination, a) sampling and analysis in the lab using a narrow band spectrophotometer, and b) the use of a BBE Algae Torch which can measure Chlorophyll- and Cyanobacteria directly in the field. The PAR measurements would duplicate the turbidity measurements which can then be contained within the one WQ probe. The heavy metals are expensive to analyse, requiring a flame spectrophotometer and cannot be analysed on the Narrowband spectrophotometer to be purchased for Chlorophyll-a analysis.

Table 4-5 Water quality parameters measured in the WQMN

| Parameters monitored monthly throughout the year | Parameters only monitored between April and October | Additional monthly JEM parameters |
|--------------------------------------------------|----------------------------------------------------|----------------------------------|
| Temperature                                      | Calcium (Ca)                                       | Chlorophyll-a                     |
| pH                                               | Magnesium (Mg)                                    | Turbidity                         |
| Conductivity (Salinity)                          | Sodium (Na)                                        | Photosynthetically active radiation (PAR) |
| Alkalinity/ Acidity                              | Potassium (K)                                      | Occasional parameters measured in impoundments |
| Dissolved Oxygen (DO)                            | Sulphate (SO₄)                                     | Mercury (Hg)                      |
| Total phosphorous (TP)                           | Chloride (Cl)                                      | Cadmium (Cd)                      |
| Total Nitrogen (T-N)                             |                                                    | Iron (Fe)                         |
| Ammonium (NH₄-N)                                 |                                                    | Manganese (Mn)                    |
| Nitrite +Nitrate (NO₂⁺³-N)                       |                                                    |                                  |
| Fecal Coliforms                                  |                                                    |                                  |
| Total Suspended Solids (TSS)                     |                                                    |                                  |
| Chemical Oxygen Demand (COD)                     |                                                    |                                  |
| Biochemical Oxygen Demand (BOD)*                 |                                                    |                                  |

*selected stations only

Table 4-6 provides a schedule for the JEM WQ sampling stations and parameters to be measured (in green), together with the adjacent routine WQ monitoring (in blue). It also differentiates between those parameters that can be measured in the field using the probe, and those that require water samples to be taken to the laboratory for analysis. Note that because of difficulties of transport of samples for BOD analysis, this will not be undertaken for the JEM monitoring stations, and similarly faecal coliforms will be measured only for the routine WQ monitoring. Also note that the stations of the WQ1 and the routine Luang Prabang station are almost identical, and only the top up JEM analysis will be done for WQ1.

Also note that the full set of analyses are required on a monthly basis for WQ1 and WQ4, i.e. upstream and downstream of Xayaburi dam, and at WQ6 and WQ9, i.e. upstream and downstream of Don Sahong. These may then be compared directly with the routine water quality sampling which also occurs on a monthly basis.
The sampling in the two impoundments is to be conducted by taking a sample for routine analysis of oxides of Nitrogen and Total Phosphate at 50 cm below the surface. Then the probe measuring the other parameters of DO, temperature, pH, Conductivity, Turbidity and chlorophyll will be lowered to assess the water profile at depths of 1 m intervals. The Algae Torch will be used in the Xayaburi impoundment, while sampling of the water for chlorophyll determination in the laboratory will be carried out in the Don Sahong impoundment.
The sampling in the two impoundments is to be conducted by taking a sample for routine analysis of oxides of Nitrogen and Total Phosphate at 50 cm below the surface. Then the probe measuring the other parameters of DO, temperature, pH, Conductivity, Turbidity and chlorophyll will be lowered to assess the water profile at depths of 1 m intervals. The Algae Torch will be used in the Xayaburi impoundment, while sampling of the water for chlorophyll determination in the laboratory will be carried out in the Don Sahong impoundment.

Blue = routine WQ monitoring, Green = measurement in the laboratory, Yellow = measurement in the field by probe.

### Table 4-6: Schedule of JEM WQ sampling stations and parameters

| Parameter                  | Frequency | Probe | Luang Prabang | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong | Mekong |
|---------------------------|----------|-------|-------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|        |
The JEM water quality monitoring has therefore been designed with three campaign types as shown in Table 4-7. The first is a high frequency campaign designed to monitor changes immediately downstream of each dam site such as potential acute toxic events arising from impoundment stratification, gas supersaturation, algal blooms, chemical spillages, sediment flushing. In Don Sahong the impoundment is very small with a 2-hour storage volume and is not expected to result in these sorts of impacts, and so the high frequency monitoring immediately downstream is not required. For Xayaburi, where these risks are higher, a suitable site for locating a permanent high frequency water logger is currently not available within 500 m of the dam site, and so this campaign has been temporarily postponed from the Xayaburi JEM pilot.

Table 4-7: JEM water quality monitoring campaigns

| Campaign | Frequency | Station | Parameters | Purpose |
|----------|-----------|---------|------------|---------|
| 1        | Every 1-4 hours | Within 500 m downstream of each impoundment | Dissolved oxygen, pH, Conductivity, Turbidity, Temperature | To detect potential acute toxic events arising from impoundment stratification, gas supersaturation, algal blooms, chemical spillages, sediment flushing. |
| 2        | Once per month | Single station within each impoundment | Temperature, Dissolved oxygen, pH, Conductivity, Turbidity, Light | Vertical profile to detect stratification and risks of algal blooms |
|          | Once per month | One station upstream and up to 4 stations downstream of each impoundment to the next substantial tributary | Dissolved oxygen, pH, Conductivity, Turbidity, Temperature, Light, Chlorophyll-a, Total P, NOx, | To detect medium term dam impacts, and extent of dam impacts |
| 3        | At most once per month | Stations selected across the basin by MRC | COD, Conductivity, Dissolved oxygen, pH, temperature NOx, Total P, Chlorophyll, Faecal coliforms. | To detect large scale water quality trends across the basin |
|          | Annually or less often, as required | Stations selected across the basin by MRC | Toxicants (metals, pesticides) | To evaluate risk of specific toxicity issues |

Source: JEM Programme MRC (2019)

The second lower frequency campaign, with sampling approximately monthly, aims to detect medium term impacts. The lower frequency campaign would include sampling at a control station upstream, a station within the pondage and at several stations downstream of the impoundment. For this medium-term campaign within the pondage a profile for temperature, pH, dissolved oxygen and light should be measured, while at the upstream and downstream stations dissolved oxygen, pH, conductivity, turbidity, temperature, light, chlorophyll-a, total phosphorus and NOx should be measured.
The third campaign is based upon the regular monthly WQMN sampling at the established stations as shown in Figure 1-3. It is essential that the results from these regular samplings are linked into the JEM reporting.

4.3.6 Sample collection and laboratory analysis

4.3.6.1 Sample collection

The standardised methods for sample collection are specified in the JEM Programme, (MRC 2019). Water sampling, sample preservation, sample transportation and storage will be carried out in accordance with methods outlined in the 20th Edition of the Standard Methods for the Examination of Water and Wastewater (Clesceri et al., 1998) or in accordance with national standards, complying with the requirements of the method validation under ISO/IEC 17025-2017, which is the update of ISO/IEC 17025-2005.

In accordance with the practice of the MRC, water quality monitoring network procedure, field measurements and samples should be taken at a depth of 30-50 cm below the water surface from approximately midstream where free flowing water is observable. Three grab samples should be collected from places at least 5m apart, or at 5-minute intervals using either specialised equipment such as a Van Dorn sampler, or an appropriate container mounted on a pole. Samples for nutrient analysis should be preserved in the field. At least three field measurements should be taken at each station, using recently calibrated field meters with appropriate probes.

All designated laboratories of the MRC WQMN are required to adhere to the MRC QA/QC procedures that were developed in accordance with ISO/IEC 17025-2005 (now updated as ISO/IEC 17025-2017) and personnel safety procedures when collecting water samples and measuring water quality parameters.

The main methodological addition suggested under JEM is that multiple samples should be collected and analysed, and where field measurements are taken with meters, multiple probe measurements taken on each occasion.

4.3.6.2 Water Quality Analysis Methods

The analysis of water samples at the laboratory will be done in accordance with Standard Methods of JEM (MRC, 2019). Fourteen (14) parameters will be analyzed on a monthly basis for each sample. These parameters, together with their analytical methods, are outlined in Table 4-8. Additionally, six (6) parameters will be analyzed for each sample taken between April and October. These parameters, together with their analytical methods, are outlined in Table 4-9.

In addition to the standard samples and analytical methods specified under the WQMN, JEM monitoring will require analysis for Chlorophyll-a. This will require the sampling of a quantity of water appropriate to extract sufficient algal biomass on which to perform the analysis, with preservation of the samples in the field. Analysis would be carried out by narrow band spectrophotometry in the laboratory where the other water samples are analysed, using standard techniques with extraction of chlorophyll in acetone. These results will be compared to field measurement using the Algae Torch. In the Xayaburi impoundment chlorophyll-a measurements will be done by Algae Torch, while in the Don Sahong impoundment water will be sampled for chlorophyll-a analysis in the laboratory.
The WQ monitoring team will be trained on how to monitor phytoplankton by deploying the specialized Algae Torch. The specific methodology will be developed by the JEM International Expert Team and shared with the team during field training. The JEM Programme as well as these ToR will be updated to reflect the new equipment and methodology. The field algae torch will be purchased by ICEM and handed over to the monitoring team during the training.

Quoting from the manufacturer’s description, “the BBE AlgaeTorch is a lightweight instrument for the simultaneous quantification of the chlorophyll-a content of cyanobacteria and the total chlorophyll content of microalgae in water. The measurement of chlorophyll-a can eliminate laborious sample preparation in the lab. A complete measurement needs less than 20 seconds. No sampling or preparation is necessary.

“The bbe AlgaeTorch uses in vivo fluorescence of algae cells: the algae pigments are selectively excited by coloured LEDs and emit red fluorescence light as a natural phenomenon at high sensitivity. The intensity of the chlorophyll fluorescence is used to calculate the different algae as chlorophyll-a, here blue-green algae (cyanobacteria) and total microalgae. The calculation is carried out internally using an optimised algorithm. The results are shown immediately on the display and stored in the internal memory. An encapsulated USB port enables subsequent data transfer to a PC. The PC software is supplied free of charge.

“The built-in turbidity sensor calculates the results in FTUs (formazine turbidity units). A turbidity measurement is taken with each chlorophyll measurement. The novelty here is the automatic turbidity correction during chlorophyll measurement which makes subsequent correction unnecessary, improves the accuracy and enables the evaluation of the results in the field, at station.

“The instrument is robust and completely sealed. It is operated through the transparent housing using capacity keys. The key actions are confirmed by a vibration signal. In this way it is possible to ensure safe operation of the instrument even in a wet environment. The instrument is deployable down to depth of 10 m. No power cable is needed for operation due to the internal rechargeable batteries.”

### Table 4-8: Analytical methods for WQ parameters

| No | Analytical parameter                  | Analytical method/equipment | Field WQ meter | Laboratory analysis |
|----|--------------------------------------|------------------------------|-----------------|---------------------|
| 1  | Temperature                          | 2550-B                       | Yes             | No                  |
| 2  | pH                                   | 4500-H+                      | Yes             | Yes                 |
| 3  | Conductivity (Salinity)              | 2510-B                       | Yes             | Yes                 |
| 4  | Alkalinity/ Acidity                  | 2320-B                       | No              | Yes                 |
| 5  | Dissolved Oxygen (DO)                | 4500-O                       | Yes             | Yes                 |
| 6  | Chemical Oxygen Demand (COD)         | British Standard BS 6068-2.34:1988 | No             | Yes                 |
| 7  | Total phosphorous (T-P)              | 4500-P                       | No              | Yes                 |
| 8  | Total Nitrogen (T-N)                 | 4500-N                       | No              | Yes                 |
| 9  | Ammonium (NH₄-N)                     | 4500-NH₃                     | No              | Yes                 |
| 10 | Nitrite (NO₂), Nitrate (NO₃)         | 4500-NO₂, 4500-NO₃           | No              | Yes                 |
| 11 | Faecal Coliform                      | 9221-Faecal Coliform group   | No              | Yes                 |
| 12 | Total Suspended Solid                | 2540-D-TSS                   | No              | Yes                 |

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3 https://www.bbe-moldaenke.de/en/products/chlorophyll/details/algaetorch.html
The instrument is deployable down to depth of 10 m. No power cable is needed for operation.

The instrument is robust and completely sealed. It is operated through the transparent display when the monitors would consist of the existing Lao national water quality monitoring team, who are experienced in the application of the field sampling equipment, such as water quality probes and the taking of standardised samples. This is the team that will be trained in the use of the new equipment and sampling techniques. At least two members of each team would undertake each monitoring mission. The training envisages that 6 members of the team would receive training so that there are trained replacements able to undertake different missions.

### Table 4-9: Additional parameters analysed on samples taken between April and October

| No | Analytical parameter          | Analytical method/equipment                  | Field WQ meter | Laboratory analysis |
|----|-------------------------------|----------------------------------------------|----------------|---------------------|
| 13 | Chlorophyll-a                 | 10200H                                       | No             | Yes                 |
| 14 | Turbidity                     | 2130 or commercial meter                     | Yes            | Yes                 |
| 15 | Par (light penetration)       | Radiometer with spherical sensor             | No longer required |                   |
| 16 | Biochemical Oxygen Demand     | 5210-BOD5                                    | Not required for JEM stations      |                     |

### 4.3.7 Data analysis and reporting

During laboratory analysis of water samples, the Quality Assurance and Quality Control (QA/QC) system will be implemented to ensure quality of water quality data.

The following outputs are required by the Mekong River Commission Secretariat from its member Water Quality Monitoring Network Laboratories:

- Water Quality Data stored in a format (as in 2017). The data should be electronically submitted to the MRC Secretariat within ten (10) working days of the month data was collected. The data should be submitted through LNMC.
- Prepare two six monthly report for Water Quality Data Assessment for the two pilot stations, to be submitted to the MRC Secretariat through the Lao National Mekong Committee Secretariat before 30 August 2020 and 30 August 2021. Data for JEM pilots should be submitted to MRCS every 3 months.
- Two Annual Water Quality Data Assessment Report. The participating Water Quality Monitoring Network Laboratories are required to prepare and submit one (1) hard copy and one (1) electronic file of the annual water quality data assessment report with a full water quality data set to the MRCS before 28 February 2021 and 28 February 2022.

### 4.4 National Monitoring teams

The Natural Resources and Environment Statistics and Research Institute (NRESRI) is the designated Water Quality Monitoring Network Laboratories (WQML) of Lao PDR. The ED national focal point is Mr Khamsone Philavong from the Lao National Mekong Committee Secretariat.

The monitors would consist of the existing Lao national water quality monitoring team, who are experienced in the application of the field sampling equipment, such as water quality probes and the taking of standardised samples. This is the team that will be trained in the use of the new equipment and sampling techniques. At least two members of each team would undertake each monitoring mission. The training envisages that 6 members of the team would receive training so that there are trained replacements able to undertake different missions.
4.5 Workplan: key deliverables and timeframe

The team from the Natural Resources and Environment Statistics and Research Institute of Lao PDR will be contracted to carry out the monitoring of water quality at the proposed sampling stations on a one-day basis between the 13th and 18th of each scheduled month (Table 4-10). Reporting of the JEM data is expected through electronic copy of results before the next month’s monitoring mission. Two semi-annual reports are expected before end of August 2020 and 2021. Data should be submitted to MRCS every 3 months. The annual reports of all the WQMN water quality monitoring are required by February 2021 and 2022.
The team from the Natural Resources and Environment Statistics and Research Institute of Lao PDR will be contracted to carry out the monitoring of water quality at the proposed sampling stations on a one-day basis between the 13th and 18th of each scheduled month (Table 4-10). Reporting of the JEM data is expected through electronic copy of results before the next month’s monitoring mission. Two semi-annual reports are expected before end of August 2020 and 2021. Data should be submitted to MRCS every 3 months. The annual reports of all the WQMN water quality monitoring are required by February 2021 and 2022.

| Activities                                           | Outputs                                      | Deadline                                                                 | 2020 | 2021 | 2022 |
|------------------------------------------------------|----------------------------------------------|--------------------------------------------------------------------------|------|------|------|
| JEM Water Quality Monitoring:                        | Monthly Water Quality Data                  | Monthly between 13th and 18th of each month from Mar 2020 - Feb 2022    |      |      |      |
| Submission of Monthly JEM Water Quality Data         | One electronic copy of monthly water quality data | No later than 10th day of the month after sampling                        |      |      |      |
| Prepare JEM Water Quality Data Assessment Report for the two pilots’ sites | Two Six-monthly reports | Before 30 August 2020 and 30 August 2021. |      |      |      |
| Preparation of Annual Water Quality Data Assessment Report: | Two Annual Water Quality Data Assessment Reports | Following the last day of the monitoring and no later than 28 Feb 2021 and 2022 |      |      |      |
| Submission of Annual Water Quality Data to the MRCS  | Electronic Copy of the Annual Water Quality Data | No later than 28 February 2021 and 2022 |      |      |      |
| Submission of Annual Water Quality Assessment Report to the MRCS | One hard copy and one electronic copy | No later than 28 February 2021 and 2022 |      |      |      |
5 ECOLOGICAL HEALTH MONITORING

5.1 Background and justifications

Aquatic Ecology is one of the main disciplines of concern to Member Countries. While MRC routine monitoring on Ecological Health is carried out every two years, the results cannot differentiate the impacts of hydropower development projects and the impact from other riparian activities. MRC monitoring sites are not located near the current existing hydropower projects on the Mekong mainstream. So, to understand whether changes in the river water quality and hydrology due to the hydropower developments affect fish and other aquatic biodiversity or not, the JEM pilot projects proposed additional ecological health monitoring sites upstream and downstream of the dams, as well as within the Xayaburi and Don Sahong impoundments. It is also noted that the Xayaburi HPP has included ecological health monitoring at several sites downstream of the dam using some similar parameters.

An understanding of the risks to aquatic ecological health from hydropower development is important for the design of the JEM Programme. The consequences and monitoring requirements are shown in Table 5-1. This rationale helps in the interpretation of the changes in ecological health monitoring results which will form part of the QA/QC and reporting of the JEM.

The existing MRC bioassessment activities have been outlined in section 1.2.3. in which monitoring is conducted bi-annually at 41 different sites across the basin. Bioassessment is used to detect long term changes in the ecological condition of the river, which cannot be picked up in the water quality monitoring. The four indicator groups - littoral macroinvertebrates, benthic macroinvertebrates, zooplankton and benthic diatoms – respond to changes in flow and geomorphology and water quality; this may be observed through changes in their species diversity and population numbers or abundance. A Mekong-specific river health index has been developed by the MRC as a means of analyzing these indicators.

5.2 Purpose and Objectives of the JEM Ecological Health monitoring

The objectives of the JEM Ecological Health monitoring are:

- To conduct bio-monitoring and assessments upstream, downstream and within the impoundment of Xayaburi and Don Sahong Hydropower projects using the methodologies and protocols derived from the Bio-monitoring Handbook published in 2010 and JEM Programme (2019).
- To assess the intensity and extent of the ecological impact due to hydropower dam development.
- To disseminate bio-monitoring methodology and ecological health assessment results to hydropower developers, and other riparian countries and allow them to assess the effectiveness of the management and mitigation measures put in place by Projects’ developers.

The JEM documents propose to supplement the MRC’s long-standing bio-assessment record in 4 ways:

1. By the addition of chlorophyll and phytoplankton as an additional indicator;
2. To run regional taxonomic workshops to improve the quality assurance of this monitoring – this will be done at a later date;
3. To add additional monitoring sites upstream and downstream of each hydropower plant; and
4. To collect multiple samples from each site to allow better statistical comparison between potentially impacts and control sites.

The existing MRC sampling protocols will be followed, and the existing MRC indices used as a means of comparing site results. Multivariate statistical analyses will be trialed to compare results between sites and between sampling events.
### Table 5-1: Risks from hydropower development, consequences and monitoring requirements for aquatic ecological health

| Risk | Consequences | Monitoring |
|------|--------------|------------|
| **Within the Impoundment** | | |
| Loss of lotic habitat | Loss of habitat area available to aquatic species reliant on flowing water, and their consumers | |
| Occurrence of toxic algal blooms | May occur if nutrient levels, and especially phosphorus levels become too high | Monitoring of chlorophyll in surface water, with frequency increasing if chlorophyll > 5 μg/L |
| Infestations of invasive plants | Water hyacinth, *Salvinia* and water cabbage all occur in the basin and all have caused major problems in impoundments elsewhere | Inspect impoundment twice a year, increase monitoring if pest species evident |
| Infestations of invasive animals | Golden apple snail and several fish species occur in the basin and have caused problems elsewhere in southeast Asia | Inspect for Apple snail twice per year, increase monitoring if pest species evident |
| Increases in parasite load of local human populations | Malaria and schistosomiasis are not expected to become problems, but fascioliasis (liver fluke, lung worm and heart worm) incidence is likely to increase if people consume raw fish | Annual health checks and, if necessary, treatment for local people. |
| Loss of deep holes/pools | Deep holes/pools along the Mekong mainstream, if inundated within an impoundment, will stratify and eventually fill with sediment, resulting in a loss of habitat to aquatic organisms dependent on the environmental conditions provided by deep holes. | Assessments each 3 years using depth sounding equipment |
| **Downstream of the Impoundment** | | |
| Barrier to movement of nutrients | Water downstream may be nutrient poor, impacting food chains | Combination data from the WQ monitoring programme and longterm EHM programme |
| Barrier to movement of carbon | Water downstream may be depleted in fine particulate carbon, impacting food chains | EHM will reveal a reduction in filter feeding invertebrates |
| Barrier to movement of biota | Migratory crustaceans, molluscs and some insects may be unable to colonise upstream reaches | Use existing EHM data from sites upstream and downstream of dams. |
| Benthic community degraded as far as next substantial tributary | The reasons for benthic community impact are uncertain, but probably a cumulative result from changes in riverbed geomorphology, water quality and flow patterns. | Monitor MRC indicators (littoral invertebrates, benthic invertebrates, zooplankton and benthic diatoms) annually at several sites down to, and one site downstream of, the next tributary contributing at least 2% of the flow. |
| Risk                                      | Consequences                                                                 | Monitoring                                                                 |
|------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Altered river water temperature          | May exceed thermal tolerances of biota, may cause oxygen levels to be reduced | Monitor MRC indicators (littoral invertebrates, benthic invertebrates,      |
| downstream of dam                        | below the tolerances of biota, either of which will cause biota to die or    | zooplankton and benthic diatoms) at a site ~1km downstream of the           |
|                                          | drift away                                                                   | impoundment.                                                               |
| Poor water quality downstream            | May cause death or drift of biota; deposition of iron or manganese may      | Monitor MRC indicators (littoral invertebrates, benthic invertebrates,      |
| of dam                                   | render habitat unsuitable to biota for many years                             | zooplankton and benthic diatoms) at a site ~1km downstream of the           |
|                                          |                                                                              | impoundment.                                                               |
| Changes to Downstream Flows              |                                                                              |                                                                            |
| Increased short-term variation in        | Littoral fauna may be stranded, and littoral algae have insufficient time    | Monitor MRC indicators (littoral invertebrates, benthic invertebrates,      |
| river levels                             | to develop, reducing availability of grazing invertebrates and fish          | zooplankton and benthic diatoms) annually at several sites down to, and    |
|                                          |                                                                              | one site downstream of, the next tributary contributing at least 2% of the |
|                                          |                                                                              | flow.                                                                     |
| Increased dry season flow                | May reduce reproductive success of biota that breed in the dry season and    | Monitor MRC indicators (littoral invertebrates, benthic invertebrates,      |
|                                          | decrease availability of riparian habitat                                    | zooplankton and benthic diatoms) annually at several sites down to, and    |
|                                          |                                                                              | one site downstream of, the next tributary contributing at least 2% of the |
| Decreased wet season flow                | Decreased floodplain contributions (carbon, energy and nutrients) to the    | Monitor MRC indicators (littoral invertebrates, benthic invertebrates,      |
|                                          | river, which in turn impact on biota                                        | zooplankton and benthic diatoms) annually at several sites down to, and    |
|                                          |                                                                              | one site downstream of, the next tributary contributing at least 2% of the |
|                                          |                                                                              | flow.                                                                     |
| Delay to flood season flows              | May interfere with reproduction of species which breed during the flood     | Monitor MRC indicators (littoral invertebrates, benthic invertebrates,      |
|                                          | season.                                                                      | zooplankton and benthic diatoms) annually at several sites down to, and    |
|                                          |                                                                              | one site downstream of, the next tributary contributing at least 2% of the |
| Delay to dry season flows                | May interfere with reproduction of species which breed during the dry       | Monitor MRC indicators (littoral invertebrates, benthic invertebrates,      |
|                                          | season.                                                                      | zooplankton and benthic diatoms) annually at several sites down to, and    |
|                                          |                                                                              | one site downstream of, the next tributary contributing at least 2% of the |
| Downstream geomorphology (habitat) altered | The altered habitat – changes in the proportion of sand, gravel, cobbles    | Monitored under sediment monitoring.                                        |
| as a consequence of changed flow regime  | or boulders - will alter the biota present                                  |                                                                            |
| Changes to Floodplains                   |                                                                              |                                                                            |
| Risk                                           | Consequences                                                                 | Monitoring                                                                                           |
|-----------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| Reduction in area of floodplain inundation    | Reduced floodplain production; reduced reproduction of plants, invertebrates and fish on the floodplain | Use existing hydrological models such as SWAT or MIKE 11 and remote sensing data to establish whether changes occur. Establish permanent vegetation quadrats in potentially impacted sites, reevaluate quadrats annually |
| Reduction in period of floodplain inundation  | Reduced floodplain production; reduced reproduction of plants, invertebrates and fish on the floodplain | Use existing hydrological models and remote sensing data to establish whether changes occur. Establish permanent vegetation quadrats in potentially impacted sites, re-evaluate quadrats annually |
| Change in timing of floodplain inundation     | May lead to reduced reproduction of plants, invertebrates and fish on the floodplain | Use models and remote sensing data to establish whether changes occur. Establish permanent vegetation quadrats in potentially impacted sites, re-evaluate quadrats annually |
| Reduction in nutrient load to the floodplain  | Reduced productivity in both floodplain wetlands and seasonal terrestrial systems. | Use models and remote sensing data to establish whether changes occur. Establish permanent vegetation quadrats in potentially impacted sites, re-evaluate quadrats annually |

Source: JEM Programme MRC (2019)
5.3 Approach and methodology

5.3.1 Sampling sites

The JEM aquatic ecology component is designed around the principles of BACI (Before After Control Impact) and statistical replication. It recommends sampling one site upstream of an impoundment, and at several sites downstream, extending as far as the next substantial downstream tributary.

The choice of sites for sampling is also important, representing a balance between suitable substrates for littoral and benthic invertebrates, access and safety. Littoral macroinvertebrates can be sampled from the bank, but the sampling the zooplankton, diatoms and benthic macroinvertebrates will require a boat. Within the impoundments, bio-assessment monitoring will focus on phytoplankton as measured by cyanobacteria and Chlorophyll-a, using an Algae Torch (measured on a monthly basis by the Water Quality Monitoring team).

The existing aquatic ecological health sites are shown in Table 5-2 and illustrated in brown on Figure 5-1. The sites closest to the two dams are highlighted and include:

1. Upstream of Xayaburi, just below the confluence with the Nam Ou (Don Chor) LPB (106 km above Xayaburi)
2. Downstream of Xayaburi near Vientiane (Ban Houahome) LVT (354 km below Xayaburi)
3. Upstream of Don Sahong, near Pakse (Done Ngiew (LDN) (116 km above Don Sahong)
4. Downstream of Don Sahong, in Cambodia (Au Svay) CMR (2.65 km below Don Sahong)

However, these bio-assessment sites are quite distant from the dam locations and will not be able to pick up changes in the ecological health of the river due to the operation of these two dams.

Table 5-2: Existing bio-assessment sites in Lower Mekong

| No. | Site | Site          | River  | X     | Y     |
|-----|------|---------------|--------|-------|-------|
| 1   | CPT  | Prek Te       | Prek Te| 613899| 1374811|
| 2   | CKT  | Kampi         | Mekong | 609207| 1393544|
| 3   | CMR  | Au Svay       | Mekong | 604976| 1539456|
| 4   | CKM  | Sdao          | Sekong | 615508| 1500632|
| 5   | CSJ  | Kamphun       | Sesan  | 620973| 1499412|
| 6   | CUS  | Au Yadao      | Srepok | 764506| 1526065|
| 7   | CSS  | Veunsai       | Sesan  | 699442| 1546710|
| 8   | CSP  | Srepok        | Srepok | 717424| 1490804|
| 9   | CSN  | Stung Sen     | Stung Sen| 490805| 1401784|
| 10  | CSK  | Prek Toal     | Tonle Sap Lake | 358625 | 1458210|
| 11  | CCK  | Chong Khneas  | Tonle Sap Lake | 371882 | 1469940|
| 12  | CPS  | Stung Pursat  | Pursat River | 378398 | 1385716|
| 13  | CLK  | Kampong Luang | Tonle Sap Lake | 415402 | 1393110|
| 14  | CTU  | Prak Kdam     | Tonle Sap River | 478364 | 1307071|
| 15  | CKK  | Koh Khel      | Bassac  | 503327| 1246641|
| 16  | CNL  | Nak Leung     | Mekong  | 528321| 1250852|
| 17  | CPP  | Chak Tomok    | Mekong Confluence | 492271 | 1279432|
| 18  | LDN  | Done Ngiew    | Mekong  | 596176| 1650505|
| No. | Site | Site | River | X    | Y    |
|-----|------|------|-------|------|------|
| 19  | LSD  | Ban Hae | Se Done | 585939 | 1674638 |
| 20  | LKL  | Ban Xou | Se Kong | 671170 | 1623577 |
| 21  | LBH  | Se Bang Hien bridge | Se Bang Hien | 540132 | 1779968 |
| 22  | LBF  | Se Bang Fai bridge | Se Bang Fai | 454745 | 1959958 |
| 23  | LVT  | Ban Huayhome | Mekong | 239871 | 1988731 |
| 24  | LMX  | Ban Xiengkok | Mekong | 670860 | 2311778 |
| 25  | LPB  | Done Chor | Mekong | 206113 | 2206957 |
| 26  | TNP  | Nakorn Panom | Mekong | 474858 | 1927503 |
| 27  | TSM  | Mekong Junction | Songkhram | 442497 | 1952715 |
| 28  | TNK  | Kong Chiam | Nam Mun | 450492 | 1874363 |
| 29  | TMU  | Kong Chiam | Nam Mun | 552465 | 1673182 |
| 30  | TKC  | Kong Chiam | Nam Mun and Mekong | 552099 | 1694552 |
| 31  | TUN  | Ubon Rachathani | Nam Mun | 495167 | 1685093 |
| 32  | TCS  | Chiang San | Mekong | 614706 | 2240577 |
| 33  | TKO  | Chaing Rai | Nam Kok | 582587 | 2201804 |
| 34  | VCT  | Phu An, Can Tho | Bassac | 588639 | 1107329 |
| 35  | VLX  | Long Xuyen, An Giang | Bassac | 551906 | 1143385 |
| 36  | VDP  | Da Phuoc, An Giang | Bassac | 514688 | 1188055 |
| 37  | VKB  | Khanh Binh, An Giang | Bassac | 509385 | 1210992 |
| 38  | VTP  | Thuong Phuoc, Dong Thap | Mekong | 519878 | 1204905 |
| 39  | VTT  | Thuong Thoi, Dong Thap | Mekong | 529461 | 1194776 |
| 40  | VCL  | Cao Lanh, Dong Thap | Mekong | 563902 | 1153701 |
| 41  | VVL  | My Thuan, Vinh Long | Mekong | 603478 | 1134897 |
Figure 5-1: Existing Ecological health monitoring sites in brown, proposed JEM sites in green
5.3.2 Sampling sites at Xayaburi

The sampling sites for Xayaburi have been confirmed as a result of the field visit by MRC and GIZ with representatives from LNMCS, Ministry of Energy and Mines, DONREs of Xayaboury and Khong Districts and NUoL in November 2019. They are shown in Table 5-3 and illustrated in green in the Figure 5-1.

Table 5-3: Confirmed sites for JEM bio-assessment at Xayaburi

| Site No. | Name of site                      | River  | Latitude N    | Longitude E    |
|---------|----------------------------------|--------|---------------|----------------|
| Xayaburi|                                  |        |               |                |
| EHM1    | Right upstream of Xayaburi Impoundment | Mekong | 20°00'07.2"N  | 102°14'06.7"E |
| EHM2    | Within the impoundment            | Mekong | ~19°26'05.1"N | 101°50'05.1"E |
| EHM3    | Xayaburi downstream around 2 km    | Mekong | 19°13'49.6"N  | 101°49'27.4"E |
| EHM4    | Xayaburi downstream around 5 km    | Mekong | 19°12'07.7"N  | 101°49'28.0"E |
| EHM5    | Xayaburi downstream around 8 km    | Mekong | 19°10'49.5"N  | 101°49'19.5"E |
| EHM6    | Xayaburi downstream around 12 km   | Mekong | 19°09'05.0"N  | 101°48'47.2"E |

There would be one site above the impoundment (EHM1), in the same location as the water quality monitoring station (WQ1), one site within the impoundment (EHM2), and four sites below the dam. These are illustrated on Figure 5-2.

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4 Site selection field visits were attended by representatives from LNMCS, and from Dept. of Energy Business, of Ministry of Energy and Mines, from the District office of Natural Resources and Environment from Xayaboury and Khong Districts and one representative from NUoL.
The sampling sites for Xayaburi have been confirmed as a result of the field visit by MRC and GIZ with representatives from LNMCS, Ministry of Energy and Mines, DONREs of Xayaboury and Khong Districts and NUoL in November 2019. They are shown in Table 5-3 and illustrated in green in the Figure 5-1.

| Site No. | Name of site | River | Latitude N | Longitude E |
|---------|--------------|-------|------------|-------------|
| EHM 1   | Right upstream of Xayaburi Impoundment Mekong | 20°00'07.2"N | 102°14'06.7"E |
| EHM 2   | Within the impoundment Mekong | ~19°26'05.1"N | 101°50'05.1"E |
| EHM 3   | Xayaburi downstream around 2 km Mekong | 19°13'49.6"N | 101°49'27.4"E |
| EHM 4   | Xayaburi downstream around 5 km Mekong | 19°12'07.7"N | 101°49'28.0"E |
| EHM 5   | Xayaburi downstream around 8 km Mekong | 19°10'49.5"N | 101°49'19.5"E |
| EHM 6   | Xayaburi downstream around 12 km Mekong | 19°09'05.0"N | 101°48'47.2"E |

There would be one site above the impoundment (EHM1), in the same location as the water quality monitoring station (WQ1), one site within the impoundment (EHM2), and four sites below the dam. These are illustrated on Figure 5-2.

4 Site selection field visits were attended by representatives from LNMCS, and from Dept. of Energy Business, of Ministry of Energy and Mines, from the District office of Natural Resources and Environment from Xayaboury and Khong Districts and one representative from NUoL.

Figure 5-2: Bioassessment monitoring sites around Xayaburi HPP
5.3.3 Sampling sites at Don Sahong

The bio-assessment sampling sites for Don Sahong have been confirmed as a result of the field visit by MRC and GIZ with representatives from LNMCS, Ministry of Energy and Mines, DONREs of Xayaboury and Khong Districts and NUoL in November 2019. They are shown in Table 5-4 and illustrated in green in Figure 5-1. They include one site above the impoundment, one site within the impoundment and two sites below the dam. More detailed locations of the bio-assessment sites around Don Sahong are shown in Figure 5-3.

Table 5-4: Confirmed EHM sampling sites around Don Sahong

| Site No. | Name of site | River | Latitude N | Longitude E |
|----------|--------------|-------|------------|-------------|
| Don Sahong |               |       |            |             |
| EHM 7    | Don Sahong upstream at inlet of impoundment | Mekong | 13°58'42.6" N | 105°57'07.4" E |
| EHM 8    | Don Sahong impoundment | Mekong | 13°56'40.1"N | 105°57'43.6" E |
| EHM 9    | Downstream Don Sahong at round 2 km | Mekong | 13°56'33.0" N | 105°57'15.2" E |
| EHM 10   | Downstream Don Sahong at around 4 km | Mekong | 13°56'19.1" N | 105°57'19.9" E |


The bio-assessment sampling sites for Don Sahong have been confirmed as a result of the field visit by MRC and GIZ with representatives from LNMCS, Ministry of Energy and Mines, DONREs of Xayaboury and Khong Districts and NUoL in November 2019. They are shown in Table 5-4 and illustrated in green in Figure 5-1. They include one site above the impoundment, one site within the impoundment and two sites below the dam. More detailed locations of the bio-assessment sites around Don Sahong are shown in Figure 5-3.

**Table 5-4: Confirmed Sampling Sites around Don Sahong**

| Site No. | Name of Site                          | River  | Latitude N  | Longitude E |
|----------|--------------------------------------|--------|-------------|-------------|
| EHM 7    | Don Sahong upstream at inlet of impoundment | Mekong | 13°58'42.6" | 105°57'07.4" |
| EHM 8    | Don Sahong impoundment                | Mekong | 13°56'40.1" | 105°57'43.6" |
| EHM 9    | Downstream Don Sahong at round 2 km   | Mekong | 13°56'33.0" | 105°57'15.2" |
| EHM 10   | Downstream Don Sahong at around 4 km  | Mekong | ~13°56'19.1" | 105°57'19.9" |

*Figure 5-3: Bioassessment sites around Don Sahong HPP*
5.3.4 Sampling parameters

The bio-assessment consists of four parameters – Littoral macroinvertebrates, benthic macroinvertebrates, zooplankton and benthic diatoms. The additional parameter of phytoplankton, as measured by Chlorophyll-and blue-green algae had been included in the JEM documents for sampling in the impoundments. However, it has been agreed at the EMEG meeting in February 2020 that the Water Quality team will take monthly measurements of Chlorophyll-a using both the Algae Torch and spectrophotometric analysis of water in the laboratory. The methods for each of these assessments are described below, abstracted from the memorandum of understanding (MOU) with the Lao national bio-assessment team. Three samples are recommended to be collected at each sampling site.

5.3.4.1 Water quality conditions

The physical water quality conditions would be measured in each station, following the Biomonitoring Handbook 2010 and the draft JEM Programme 2019. For the chemical variables such as water turbidity, temperature, dissolved oxygen, electrical conductivity, and pH would be measured with a DO700 meter, calibrated according to the manufacturer’s instructions. Water transparency would be measured by Secchi disc as before.

5.3.4.2 Benthic Diatoms

Locations chosen for sampling of benthic diatoms had a shoreline where the water depth was not greater than 1 m at 5 m from the bank and suitable substrata for sampling extended over 100 m. The most appropriate substrata were cobbles and other stones with a surface area that was greater than 10 cm², but small enough to fit in a sampling bowl of 20-30 cm diameter. At sites that lacked stones but had predominantly muddy or sandy beds, suitable substrata included bamboo sticks, aquatic plants, and artificial substrata.

A random number table is used to select 10 plots of 1 m² within the sampling area of 100 m by 5 m. A single stone was selected in each plot that appeared to contain a high abundance of benthic diatoms, evident as a thin brownish film or a slippery feel. For each plot that had no stones, the nearest hard substratum would be sampled. To sample the diatoms, a plastic sheet with a 10-cm² cut out is placed on the upper surface of the selected stone or other substratum, and benthic diatoms were brushed and washed off into a plastic bowl until the cutout area was clear. Each sample is transferred to a plastic container, and labelled with the site name, location code, date, and replicate number. The collector’s name and substratum type is also recorded. Samples are preserved with Lugol’s solution and kept in plastic bottles.

5.3.4.3 Zooplankton

Three samples are collected at each site. One is taken near the left bank of the river, far away of about 4–5 m from the water’s edge. A separate sample is taken at a similar distance from the right bank, and another in the river. The samples are taken at least 1 m from potentially contaminating substances such as debris and aquatic plants, and at least 2 m from vertical banks. At sites where the water current is too fast to sample exactly in the mid-stream, samples are collected closer to the left or the right bank, but not as close to the bank as where the ‘side samples’ are taken.

Before sampling at each site, the sampling equipment (a net, bucket, and plastic jar) is washed to remove any organisms and other matter left from the previous site. Quantitative samples are collected at a depth of 0 to 0.5 m in a bucket having a volume of 10 L. The 10 L of river water
collected is filtered slowly through a plankton net (mesh size of 20 μm) to avoid any overflow. When the water volume remaining in the net is about 150 mL, the water is transferred to a plastic jar (250 mL volume). The samples are immediately fixed in the field with 4% formaldehyde. The sample jars are labelled with the site name, site code, sampling position, sampling date, and the sample number.

5.3.4.4 Littoral Macro-invertebrates

At each site littoral macro-invertebrate samples usually are taken on only one side of the river. Usually this is the depositional side where sampling is easier because of the gradual shelving of the bottom that occurs in this setting in contrast to the steeper bottom characteristic of the erosional side. In addition, the depositional side supports more aquatic vegetation, which also provides more habitats suitable for invertebrates. Because the study area is large, a wide range of littoral habitat types is sampled. Similar habitats are selected at each site to facilitate comparisons among sites.

In 2020 and 2021, as in most previous years, both sweep and kick sampling methods are to be used. A D-frame net with 30 cm x 20 cm opening and mesh size of 475 μm was used for sweep sampling.

Sweep samples are taken along the shore at intervals of about 20 m. To obtain each sweep sample, the collector stands in the river about 1.5 m from the water’s edge and sweeps the net toward the bank 10 times near the substrate surface. Each sweep is done for about 1 m at right angles to the bank, in water no deeper 1.5 m, and not overlapping the previous sweep.

After sample collection, the net contents are washed to the bottom of the net. The net is inverted, and its contents are emptied into a metal sorting tray, with any material adhering to the net being washed off with clean water. Invertebrates are picked from the tray with forceps and placed in a jar of 90% ethanol. Small samples are kept in 30 ml jars and large samples were kept in 150 ml jars. During the picking process, the tray is shaken occasionally to redistribute the contents and tilted occasionally to look for animals adhering to it. Sorting proceeds by working back and forth across the tray until no more animals are found. A second person then checks the tray to be sure that no animals remain. The sample jars are labeled with the site location code, date, and sample replicate number. The collector’s name, the sampling site, and replicate characteristics (including substrate types sampled) are recorded in a field notebook.

5.3.4.5 Benthic Macroinvertebrates

Sample locations at each site are selected by choosing numbers between 1 and 100 from a table of random numbers. These numbers are used to select five points within 100 m transects in each of the right, middle, and left bank portions of the river. At some sites, the middle of river could not be sampled because of the presence of hard beds or fast currents. Also, sites narrower than 30 m were not sampled in the middle portion.

Before sampling, all equipment to be used is cleaned to remove any material left from the previous sampling site. At each sampling location, a composite of four samples is taken with a Petersen grab sampler, covering a total area of 0.1 m². Grab contents are discarded if the grab did not close properly because material such as wood, bamboo, big water plants, or stones jam the grab’s jaws. In these cases, the sample is retaken. The sampled bed material is washed on a sieve (0.3 mm) with care taken to ensure that animals do not escape. The contents of the sieve are then placed in a white sorting tray and dispersed in water. All animals in the tray are picked out with forceps and pipettes and placed in jars containing a solution of 90% ethanol.

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Samples of less experienced sorters are checked by an experienced sorter. The sample jar is labelled with site name, location code, date, position within the river, and replicate number. The sampling location conditions, collector’s name and sorter’s name are recorded on a field sheet.

5.3.4.6 Phytoplankton

Originally, within the JEM Programme, it was suggested that the bio-assessment team would use a BBE Fluroprobe. However, because of high quoted prices it was decided in consultation with the MRC/GIZ team to follow the suggestion of Dr Ian Campbell to use a BBE Algae Torch that measures Chlorophyll-and Cyanobacteria (blue-green algae) instead of the different algal phyla. Phytoplankton and turbidity will be measured at both riverine and impoundment stations. Within impoundments a depth profile of chlorophyll-a and cyanobacteria will also be measured.

Because phytoplankton populations change rapidly with the season, especially in impoundments, it is appropriate to measure chlorophyll-a more regularly than once a year as scheduled under the EHM team. It has been agreed at the first EMEG meeting, that measurements using the Algae Torch would be carried out monthly by the Water Quality team for those sampling stations in the impoundment and upstream and downstream of Xayaburi. For the sampling stations around Don Sahong, monthly samples of water will be taken by the WQ team for spectrophotometric analysis of chlorophyll-a in the laboratory. Nevertheless the results of the chlorophyll-a sampling nearest the dates of the EHM annual monitoring should be shared with the EHM team.

5.3.5 Sampling frequencies

The bio-assessment monitoring is to be carried out annually in the dry season between March and May. It is important that monitoring is done at this time because river levels are low and the indicator groups will not have been dispersed by rising water levels and flash flows at the beginning of the wet season. It is also safer to access the sampling sites during low flows.

5.3.6 Data analysis

The Terms of Reference (TOR) for the bio-assessment team includes the following tasks:

- Prepare the Ecological Health Monitoring (EHM)/Aquatic Ecology Monitoring programme for two JEM pilot projects for the year 2020 and 2021 that include the sampling sites/stations and procedure, national team preparation, logistic support identification, timeline, laboratory preparation and procedure, budget and contact arrangement.
- Measure environment parameters that include dissolved oxygen, pH, Conductivity and water transparency as required at the selected sites.
- Collect biota samples of four key taxa chosen including Zooplankton, benthic Diatoms, benthic Macroinvertebrates, Phytoplankton (within the impoundment sites only) and littoral Macroinvertebrates at the JEM pilots selected sites according to sampling methodology that described in the Biomonitoring Handbook 2010 and draft JEM documents 2019.
- Habitat assessment and classification based on the experts’ visual assessment and scoring of the surrounding landscape at each selected site according to sampling method that described in Biomonitoring Handbook 2010 and draft JEM Programme 2019.
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- Preserve and transport biota samples according to the guideline that described in the Biomonitoring Handbook 2010 and draft JEM Programme 2019.
- Conduct laboratory work for biota sample procedure according to methodology described in the Biomonitoring Handbook 2010 and draft JEM documents 2019.
- Identify all biota specimens of the collected samples to the four group up to species level as possible,
- Quality Assurance and Quality Control (QA/QC) system must apply for sampling, handling, transport, storage, analytical methods and data reporting.
- Provide water quality and biological data, and habitat assessment and scoring.
- Analysis and interpret all data and information of water quality and biological data of each study site, and site classification.
- Prepare, revise and submit the national report to LNMC and MRCS.
5.3.7 Reporting

The laboratory identification and reporting will be carried out immediately after the annual field visit. The following tasks are planned:

- Water quality, biological data stored at the formatted database submitted to the MRC JEM team.
- Three progress reports, including the first progress report (field survey report), the second progress report (laboratory work report) and the third progress report (data analysis and interpretation report); and the final report should be sent separately and progressively submitted to MRCS by electronic and hard copies. The submission of reports is detailed in the Table 5-6.
- The photos representative of each species requested recording and submitting to MRCS by electronic file with full label information, that include scientific name of species, key characteristic of taxonomy, and the coordinates of the sampling site(s).
- All EHM datasets of two pilot sites, including raw and processed data must be sent to MRCS office at the end of the assignment on 30 December 2020 and 30 December 2021, respectively. However, to support the ICEM periodically reporting and analyzing, the national team is encouraged to submit the raw data to MRCS every 3 months.
- Complete a final EHM for two JEM pilot sites report in Lao PDR of 2020 and 2021;
- Datasets of 2020 and 2021 would be used for further site evaluations, site classification of EHM programme for whole Lower Mekong Basin.

5.4 Monitoring team

The monitors will be the existing Laos national ecological health monitoring team – covering littoral and benthic macroinvertebrates, benthic diatoms and zooplankton specialists. These teams are experienced in the collection of samples and in the identification of the different genera and species. This is the team that would be trained in the use of the new equipment and sampling techniques. At least two members of each team will undertake each monitoring mission. The JEM pilots training programme will provide training for all five members of the team, so that there are trained replacements able to undertake different missions.

The names and responsibilities of the Lao national bio-assessment team are in Table 5-5 as suggested in the MOU. Mr Khamsone Philavong of Lao National Mekong Committee Secretariat is currently the National ED Focal Point.

| No. | Study Team | Roles and Responsibilities |
|-----|------------|-----------------------------|
| 1   | Niane Sivongxay | Team leader: Organize the team members to implement the EHM activities at two JEM pilot sites for the year 2020 and 2021. Prepare the proposal for the pilot years (2020-2021) that includes the sampling sites/stations and procedures, national team preparation, logistic support identification, timeline, laboratory preparation and procedures, budget and contact arrangement. Ensure that the EHM is carried out in accordance to the requirements set out in Section 4 of this Terms of Reference. Zooplankton: Zooplankton sampling at the study sites, sample preservation and transportation. Laboratory work QA/QC procedures, Zooplankton species identification, database and data analysis and report on Zooplankton section. Samples preservation and protection procedures for the long-term use purposes |
The following tasks are planned:

1. The laboratory identification and reporting will be carried out immediately after the annual field mission. The JEM pilots training programme will provide training for all five members of the genera and species. This is the team that would be trained in the use of the new equipment.

2. The monitors will be the existing Laos national ecological health monitoring team – covering water quality, biological data stored at the formatted database.

3. Three progress reports, including the first progress report (field survey report), the second progress report (laboratory work report) and the third progress report (data analysis and interpretation report); and the final report should be sent separately and progressively submitted to MRCS by electronic and hard copies. The submission of datasets of 2020 and 2021 would be used for further site evaluations, site classification and protection procedures, national team preparation, logistic support identification, timeline, laboratory preparation and procedures, budget and contact arrangement.

4. Ensure that the EHM is carried out in accordance to the requirements set out in Section 4 of this Terms of Reference.

5. Quality Assurance and Quality Control (QA/QC) system must apply for Measure water quality parameters that include DO, pH, Conductivity and water transparency as required at the sampling sites.

6. Overall data analysis and reporting of the package of team works.

### Roles and Responsibilities

| No. | Study Team       | Roles and Responsibilities                                                                                                                                                                                                 |
|-----|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2   | Chanda Vongsombath | Benthic macro-invertebrates: Benthic macroinvertebrate sampling at the study sites, sample preservation and transportation: Laboratory work QA/QC procedures benthic macroinvertebrate species identification, database and data analysis and report on benthic macroinvertebrates: Samples preservation and protection procedures for the long-term use purposes. |
| 3   | Sopha Keoinpeng  | Environmental water test: Measure water quality parameters that include DO, pH, Conductivity and water transparency as required at the sampling sites. Quality Assurance and Quality Control (QA/QC) system must apply for Measure water quality. |
| 4   | Chanthima Pothalith | Benthic Diatoms: Diatom sampling at the study sites, sample preservation and transportation. Laboratory work QA/QC procedures diatom species identification, database and data analysis and report on Diatom. Samples preservation and protection procedures for the long-term use purposes. Overall data analysis and reporting of the package of team works. |
| 5   | Viengkhone Vannachack | Littoral macro-invertebrate: Littoral macroinvertebrate sampling at the study sites, sample preservation and transportation: Laboratory work QA/QC procedures Littoral macroinvertebrate species identification, database and data analysis and report on Littoral macroinvertebrates. Samples preservation and protection procedures for the long-term use purposes. |
| 6   | To be determined  | Phytoplankton: Phytoplankton sampling at the study sites, record results from BBE AlgaeTorch measurements on given form (will be provided in March); QA/QC procedures; Turbidity, Chlorophyll-a measurements from total microalgae and from blue-green algae/cyanobacteria, database and data analysis and report on phytoplankton. |
5.5 Workplan: key deliverables and timeframe

The work plan and key deliverables for the EHM monitoring is shown in Table 5-6.

| Activities                                      | Outputs                                                                 | 2020 campaign          | 2021 campaign          |
|------------------------------------------------|-------------------------------------------------------------------------|-------------------------|-------------------------|
| **Preparation of EHM fieldwork plan**          | Final EHM Fieldwork Plan at Two Pilot Sites in 2020 and 2021           | 20 January 2020        | 20 January 2021        |
| **Conduct field survey and sample collection** | First Progress report – Field survey and sample collection report for two pilot sites | 30 April 2020          | 30 April 2021          |
| **Conducting laboratory work:**                | Second Progress report – Laboratory work report and database submission, including: | 31 July 2020           | 31 July 2021           |
| • Water quality parameter analysis             | • Data by parameter and site/station                                   |                          |                         |
| • Sorting the samples                          | • List of species with abundance per sample and site                  |                          |                         |
| • Identify all samples up to species level as possible | • Keep samples in safe place for QA/QC and cross references purpose |                          |                         |
| **Data analysis and interpretation:**          | Third Progress report – Data analysis and interpretation report, including: | 30 September 2020       | 30 September 2021       |
| • Water quality and biological data analyses   | • All data analyzed and interpreted.                                  |                          |                         |
| • Compilation including cross reference with existing information | • Figures, tables in the report                                        |                          |                         |
| **Writing final reports:**                     | Final report                                                           | 30 December 2020        | 30 December 2021        |
| • A comprehensive national report compiles all water quality, biological data, and habitat assessment/classification | Submission of a national report to MRC and LNMC with annex of list of taxa and other relevant data and information. |                          |                         |
6  FISHERIES AND FISH PASSAGE MONITORING

6.1 Background and justifications

Multiple studies have flagged the risks inherent to dam development on the sustainability of fisheries resources. These risks are diverse and include:

- barrier effects on upstream and downstream fish migrations;
- mortality at hydropower structures (over spillways, in turbines);
- impoundment impacts (habitat changing from running river to impoundment, with loss of rapids and deep pools and seasonal and daily water level fluctuations);
- downstream impacts on water and fish resources (hydrological and hydrodynamic alterations, change in sediment load, change in water temperature and water quality);
- transboundary impacts (impact on floodplains, on the coastal zone).

For these reasons it was important to design a monitoring programme that would document:

- changes in fish catches by local fishers (monitoring of the fisheries);
- changes in the fisheries resources itself (monitoring of fish, through a standardized assessment of i) adults and ii) larvae and juveniles);
- changes in fish passage at dam sites and assessment of the effectiveness of mitigation measures.

6.2 Purpose and Objectives of the JEM in fisheries

The JEM Programme states that “The overall objective of fisheries monitoring is to measure indicators contributing to the interpretation of the status and trends of local, regional and basin-wide capture fisheries as well as providing an effective means of monitoring and assessing the effects of water management and basin development activities, specifically hydropower development. Particularly, it should also answer some basic questions regarding issues such as the impact of the hydropower development on abundance, diversity and catches of fisheries and OAAs, including disruption to life cycles, recruitment and productivity of species, shifts in contribution of fisheries to rural livelihoods and food security, status of giant and endangered (especially International Union for Conservation of Nature (IUCN) listed) species and disruption of habitats impacting on aquatic ecosystem functioning.”

6.2.1 Focused objectives and protocols

Overall, the objectives of the JEM Programme in relation to fisheries are multiple and broad. These objectives can be grouped into six different categories: (i) Biodiversity assessment, (ii) Fish stock assessments; (iii) Fish catch monitoring; (iv) Ecological knowledge and species-habitat relationship; (v) Socio-economics of the fisheries sector; and (vi) Dam impact assessment.

These multiple angles imply several different approaches (e.g. species-habitat relationships require a solid characterization of variable habitats, whereas socioeconomic assessments...
focusing on people require specific social and economic approaches and tools). The multiple angles therefore imply a major data gathering effort (i.e. budget) and subsequent data analysis effort.

In order to cover all these objectives, the JEM monitoring activities may require more than the four protocols currently considered. Thus, assessing the location of spawning grounds in space and time\textsuperscript{6} or the impact of dams on spawning by guild\textsuperscript{7} may require, in addition to drifting larvae studies, specific studies of spawning among adults; socioeconomic assessments should involve specific research questions on sales, income or nutrition and a clear integration with the whole economic and nutritional environment.

The four sampling protocols detailed in the draft JEM Programme, and in the Standard sampling guidelines for fish abundance diversity monitoring (FADM), focus on trends in fish catches, relative fish abundance or stock and fish diversity and on dam impacts. They are relevant for these four purposes. However, also assessing the role of habitats or the contribution of fisheries to socioeconomics and nutrition would require more specific protocols. The habitat quality or quantity assessment should be linked with other MRC environmental monitoring programmes, i.e. HYCOS, DSM, WQM and EHM. The existing and JEM fisheries monitoring programme should focus on the above four purposes only.

Programme - Following discussions during the inception phase and feedback received, the focus of the present Pilots in Fisheries monitoring should be on:

- adjustments to the current fish abundance and diversity (FADM) protocol based on the monitoring of fishers’ gears in sites selected by Member Countries;
- final definition of a monitoring based on multiple panel gillnets in the same sites,
- proposal of a simple methodology for fish migration study around dams;
- adjustments to the existing fish larvae drift monitoring (FLDM) protocols in sites selected, and
- definition and feasibility design and analysis of a fish passage monitoring programme using different types of tags and tagging techniques at DSH dam in the Khone Falls area.

The other sampling protocols mentioned in the draft JEM Programme (seine net sampling, electrofishing, sampling of various habitats) will not be considered here.

\textsuperscript{6} JEM programme v.3 page 139 para. 4
\textsuperscript{7} JEM programme v.3 pages 148-149
6.3 Approach and methodology

The JEM fisheries monitoring activities developed cover the above points, through three sub-components:

- Fish Abundance and Diversity Monitoring Programme (FADM) including i) sampling of artisanal catch, ii) standardised gillnet surveys and iii) frame surveys;
- Fish Larvae Drift Monitoring Programme (FLDM); and
- Monitoring fish passages at dam sites

We present below three sub-sections covering these different components. We review their description in the JEM workplan, identify challenges, indicate how the methodology can be tested, improved or implemented, detail sampling sites/stations, parameters and frequencies, and propose ways forward when adjustments are needed.

Ultimately, two main products will be developed in the Fisheries component:

- a report, with different technical notes of the above three components, with approaches and methodologies/protocols, recommending how to update of fisheries monitoring sections of the JEM Programme. Each technical note should mentioned in the below relevant section;
- a proposal for the selection and testing of fish passage monitoring options, including selection on appropriate fish tags and testing of the tools recommended; and
- In collaboration with CSU, approach and methodology/protocol for a fish pass monitoring programme using acoustic and PIT tags developed and tested at DSH dam site for the incooperation into the final JEM programme.

6.4 Fish Abundance and Diversity Monitoring (FADM)

6.4.1 Approach and methodology of the monitoring of fishers

The practical aspects of this activity are familiar to MRC and national teams, have been consolidated during training, and should not be subject to any implementation problem.

The FADM protocol consists in monitoring the gear and catch of 3 fishers in each site. This monitoring will use log books and fishers use any gear and target any fish they decide, at the frequency they decide.

Fisher catch monitoring forms

In logbook forms, species caught are identified using flipcharts and codes. Experience from field surveys, flipcharts developed for recent projects in Cambodia (see Fisheries Administration, 2019), and MRC’s new publications (see Ngor, et al. 2016) in fish identification indicate that it is desirable and possible to produce new fish identification flipcharts for each country. These flipcharts would integrate other small species becoming frequent in catches, and could combine the best of existing manuals, i.e. large good photos (Laos), criteria to distinguish species (Fisheries Administration, 2019) and local names in all riparian languages (Ngor et al., 2016), plus roman script of local names to be added.

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8 JEM programme document v.3 page 239
More generally, it would be useful for the MRC to consider a systematic, clean, peer-reviewed and commonly accepted table of equivalences between local names and the latest scientific names (example from Cambodia in Table 6-1).

### Table 6-1: Example of system for cross-referencing scientific and local names of fish species

| SPECIES NAME | REFERENCE LATIN NAME in So et al. 2018 | ORDER, FAMILY | LOCAL NAME | ROMAN SCRIPT OF LOCAL NAMES | KHMER NAME MEANING | REMARK |
|--------------|----------------------------------------|---------------|------------|-----------------------------|---------------------|--------|
| Pangasius kunytt | Pangasius kunytt | Siluriformes, Pangasidae | Pr. hea | Fig fruit | The name “Pr. hea” covers both Pangasius kunytt and P. akoult |
| Pangasius larroudé | Pangasius larroudé | Siluriformes, Pangasidae | Po |  | No meaning |
| Pangasius macroema | Pangasius macroema | Siluriformes, Pangasidae | Chhevat chnout | Striped |  |

| Roman script of local names | Meaning of Khmer name | Local name | Reference Latin name in photo guidebook (FIA 2011b) | Guidebook code | Remark |
|-----------------------------|-----------------------|------------|---------------------------------|----------------|--------|
| Changvar pika chouk | Lotus flower (pink) Changvar |  |  |  |  |
| Changvar sowe | White Changvar |  |  |  |  |
| Chik tum khinaw | Black ripe banana |  |  |  |  |
| Chik tum luang | Yellow ripe banana |  |  |  |  |
| Chhok | No meaning |  |  |  |  |

6.4.2  Sampling sites of the monitoring of fishers

After several rounds of consultation, the following sites were identified for FADM:

**Don Sahong**

*Upstream:* Muang Saen Nua in Laos (14° 5’51.11”N, 105°47’2.18”E; new site)

*Downstream:* Ban Hang Khone in Laos (13°56’15.59”N, 105°56’54.32”E; new site)
Plus two existing sites in Laos in which the FADM protocol will be continued: Ban Hat and Ban Hang Sadam in Laos (upstream of Don Sahong), and one site in Cambodia downstream of Don Sahong: Ou Run in Stung Treng Province.

**Xayaburi**

*Upstream:* Pha O (19°56′4.39″N, 102°12′21.97″E; new site)

*In the impoundment:* Tha Deua (19°27′12.80″N, 101°49′14.38″E; new site)

*Downstream:* Pak Houng (19°09′46.6″N 105°57′42.49″E; new site)

![Figure 6.1: Sites for FADM monitoring a) Don Sahong and b) Xayaburi](image)

In Cambodia, IFReDI is implementing the World Bank funded IWRM project component 1 (Fisheries and Aquatic Resources Management in Northern Cambodia). This project includes ongoing monitoring of fish resources, using a protocol very close to the the FADM one, in five Mekong mainstream sites. Four fishers in each site record their catches one day per week, and two of these sites (Anlong Svay 2 and Koh Sneng) are less than 8 km downstream of Don Sahong Dam; see Fisheries Administration 2019⁹).

→ In order to better cover transboundary impacts and build on synergy opportunities, it is recommended to set a formal agreement with IFReDI for a collaboration around at least two sites. The practical aspects of this collaboration (e.g. specific funding of a strict JEM protocol in these sites or use of the local data for partial integration to the JEM database) need to be discussed during the inception meeting.

### 6.4.3 Sampling parameters of the monitoring of fishers

The parameters sampled will be those defined in the draft JEM, as the latter also reflect the Standard Sampling Guidelines for FADM and the protocol that has been in operation for many years. The procedure for sub-sampling will be simplified, as it is currently far too complex for routine operation by fishers, and national teams have already developed an alternative.

### 6.4.4 Sampling frequencies of the monitoring of fishers

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⁹ Fisheries Administration (2019). Scientific monitoring of the fish resource with community fishers. Report for the project “Support for Fisheries and Aquatic Resources Management in Northern Cambodia”. Fisheries Administration and Inland Fisheries Research and Development Institute, Phnom Penh, Cambodia. 42 pages.
The catch of the 3 fishers in each site will be monitored each time they use their gear, i.e. each day.

### 6.4.5 Data analysis and reporting

Data will be entered in the existing FADM database, and the new sites only consist in additional records in an existing structure. Data analysis will follow the procedures used to date by national teams and updated during the training to be provided in March 2020 in Cambodia. Reporting will follow the formats already established by the MRC.

**Box 6-1: Summary for FADM: 1) selection and training of fishers**

| WHAT |
|--------------------------------|
| 1) Selection of 3 candidate fishers in each site as per criteria of Standard sampling guidelines for FADM section 6.2 and JEM documents v.3 Annex 19 |
| 2) Training of three fishers to monitor their own catch. |

| WHO |
|--------------------------------|
| National teams train fishers to record their catch (continuation of the MRC FADM process) |

| WHEN |
|--------------------------------|
| In March 2020 |

| WHERE |
|--------------------------------|
| In Pha O village (Xayaburi) |
| In Tha Deua village (Xayaburi) |
| In Pak Houng village (Xayaburi) |
| In Muang Saeng Nua village (Khone Falls) |
| In Ban Hang Khone village (Khone Falls) |

| HOW |
|--------------------------------|
| Following instruction of Standard sampling guidelines for FADM section 7.2, national agency staff will replicate the training of fishers previously undertaken for FADM in other sites, while using the updated recording sheet provided by JEM |

| HOW OFTEN |
|--------------------------------|
| Training is done once in each site, and is redone in case fishers drop out. |
Box 6-2: Summary for FADM: 2) data collection

FADM #2: data collection

WHAT Data gathering by fishers

WHO By three fishers in each site

WHEN Starting in March 2020

WHERE
- In Pha O village (Xayaburi)
- In Tha Deua village (Xayaburi)
- In Pak Houng village (Xayaburi)
- In Muang Saeng Nua village (Khone Falls)
- In Ban Hang Khone village (Khone Falls)
- In Ou Run (Cambodia)

HOW
The procedure based on logbooks should follow instructions in Standard sampling guidelines for FADM section 6.2 and JEM documents v.3 Annex 19

HOW OFTEN
Each fisher records his catch daily

DATA MANAGEMENT & CLEANING Data sheets are compiled weekly by a key fisher at each site, and are collected quarterly by national agency staff. During the month following data sheet collection, data are cleaned and entered in the database by IFReDI and LARREC staff

6.4.6 Approach and methodology of standardized multiple panel gillnets sampling

A new protocol using standardized multi-mesh gillnets is proposed for the JEM Programme. The purpose is to get data about fish species diversity (rather than about fish catch, as old FADM does). This protocol is also proposed for standardization purposes: in the old FADM, gears vary from fisher to fisher, from site to site, from season to season; for accurate comparison between sites or years, it is necessary to have the same sampling in all sites, all the time. Last, the multiple panel gillnets protocol allows calculating a precise catch per unit effort (CPUE), in grams of fish per square meter of net per hour.

The multiple panel gillnets protocol consists in sampling fish by three local fishers using a standardized set of multiple panel gillnets of different mesh sizes.

The range of information gillnet sampling provides includes the fish species composition, relative abundance, population structure, and distribution of fish. The proposed protocol will not provide information on catchability coefficient, food and feeding habits, reproductive biology or mapping of critical habitats. Assessing these aspects would require additional observations not included in the methodology (e.g. stomach content, gonad observation) - but this information is not primarily needed for impact assessment.

Setting the multiple panel gillnets

We consider that in each site fishers are the local experts and always adapt fishing to local conditions to maximize the catch; therefore, they should decide of the best place to set the nets (e.g. along the bank in Veunkham because the current is strong, and across the channel in Ban...
Hang Sadam as the current is slow there). Net setting may also vary seasonally (e.g. depending on algae density).

Guidance currently recommend sampling different habitats in each site, without being specific about the number of samples to be collected from each habitat. However, in their methodology for impact assessment of Lower Sesan 2 dam, Gotzek and Johnstone 2019 are of the opinion that “if specific habitats are targeted in one location at a given time point, that habitat type may not be present at other locations and may not exist at other timepoints, making it difficult to make comparison between the species caught at the different locations”.

→ Following discussions during the inception phase, it was agreed that in a site characterized by several types of habitat, different fishers usually operate in different habitats, and that they change their target habitat depending on the season (e.g. deep pools in the dry season, floodplains in the flood season). For this reason, a sub-sampling by habitat will not be explicitly required.

Mesh sizes of the gillnets

The mesh sizes recommended in the JEM Programme (12, 16, 22, 35, 45, 57, 73, 93, 115, 118, 150 mm) include sizes that are not found on markets (e.g. 12, 57, 73 or 93 mm). An alternative set of mesh sizes was considered, based on local availability (25, 35, 45, 70, 90, 115, 120, 145, 160, 185, 200 mm). However, a review of the legislation in the four riparian countries also indicated that using a mesh size superior to 150 mm is forbidden in Cambodia (for protection of large breeders) and that mesh size inferior to 20 mm is forbidden in Laos (other countries have smaller minimal mesh sizes). Furthermore, the distribution currently proposed does not follow an explicit pattern:

| 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 | 110 | 115 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 120| 125| 130| 135| 140| 145| 150| 155| 160| 165| 170| 175| 180| 185| 190| 195| 200 |

→ For these reasons, and following consultations during the inception phase, it was decided to opt for the following distribution of 14 mesh sizes - to be officially confirmed:

| 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 90 | 95 | 100| 105| 110| 115| 120| 125| 130| 135| 140| 145| 150|

Another constraint was integrated: 14 panels of 10m width result in a total multi-mesh net of 140m, which is too long for use in most places with rocks and current.

→ As a consequence, it was agreed to reduce the width of each panel to 8 meters (8 x 14 = 112m total length). The total number of multi-mesh panels per site remains three.

10 JEM programme v. 3, page 256: “It is possible that the position of the netting could vary between surveys because of flow conditions in the river and the need to select the optimal position for obtaining the best catch”.

11 Gotzek D., Johnston S. 2019. Monitoring system for fisheries management and evaluation of the LSS2 Dam. Lower Sesan Srepok II Dam Monitoring Final Report, NIRAS Project No. 210387 in connection with Programme ‘Promotion of Inclusive and Sustainable Growth in the Agricultural Sector: Fisheries and Livestock in Cambodia’. Inland Fisheries Research and Development Institute (IFReDi), Phnom Penh, Cambodia. 43 pp.

12 In JEM and in the region, sizes correspond to the dimension of a stretched mesh, i.e. 20 mm corresponds to 10 mm between two knots.
6.4.7 Sampling sites of the standardized multiple panel gillnet surveys

The sites are the same as FADM:

**Don Sahong**

*Upstream:* Muang Saen Nua in Laos  
*Downstream:* Ban Hang Khone in Laos

Plus Ban Hat and Ban Hang Sadam in Laos (upstream), and Ou Run in Cambodia (downstream)

**Xayaburi**

*Upstream:* Pha O  
*In the impoundment:* Tha Deua  
*Downstream:* Pak Houng

6.4.8 Sampling parameters of the standardized multiple panel gillnet surveys

The parameters are detailed in Annex 20 of the JEM Programme; no change is proposed. Two remarks:

⇒ *Training participants agreed that the form required for data recording could be simplified, while keeping the same information.*  
⇒ *Like in FADM, the subsampling procedure will be simplified.*

6.4.9 Sampling frequencies of the standardized gillnet surveys

The catch of 3 fishers in each site will be monitored. Each fisher will use the gillnet set one day a week, all year round.

6.4.10 Data analysis and reporting

Data will be entered in a database to be created. As almost all parameters are similar to those of gillnets in FADM, the format for that database will be very similar to that of the FADM database, and compatible with it. Data analysis will follow the procedures used to date by national teams. Reporting will follow the formats already established by the MRC.
Box 6-3: Summary for standardized gill net sampling: 1) selection and training of fishers

**Standardized multiple panel gillnet sampling #1: selection and training of fishers**

**WHAT**
1) Selection of 3 candidate fishers in each site as per criteria of Standard sampling guidelines for section 6.5.2 and JEM Programme v.3 Annex 20
2) Training fishers to monitor their own catch.

**WHO**
National teams train fishers to record their catch using a standardized gillnet protocol

**WHEN** From March 2020 onwards

**WHERE**
- In Muang Saeng Nua village (Khone Falls)
- In Ban Hang Khone village (Khone Falls)
- In Ou Run (Cambodia)
- In Pha O village (Xayaburi)
- In Tha Deua village (Xayaburi)
- In Pak Houng village (Xayaburi)

**HOW** Following instruction of Standard sampling guidelines for FADM section 7.2

**HOW OFTEN** Training is done once in each site, and is redone in case fishers drop out.

---

Box 6-4: Summary for standardized gill net sampling: 2) data collection

**Standardized multile panel gill sampling #2: data collection**

**WHAT** Data gathering by fishers

**WHO** By three fishers in each site, as previously identified by national agency staff

**WHEN** From March 2020 onwards

**WHERE**
- In Pha O village (Xayaburi)
- In Tha Deua village (Xayaburi)
- In Pak Houng village (Xayaburi)
- In Muang Saeng Nua village (Khone Falls)
- In Ban Hang Khone village (Khone Falls)
- In Ou Run (Cambodia)

**HOW** Following instruction of Standard sampling guidelines for FADM section 7.2, i.e. each fisher using each time one set of 14 panel gillnets provided by the project. Gillnets are set in the evening (16:00-18:00) and retrieved the following morning (06:00-08:00). Catches are recorded using forms 1 and 2 in Annex 5 of the Standard sampling guidelines for FADM

**HOW OFTEN** Each fisher uses the panel and records catches once a week

**DATA MANAGEMENT & CLEANING** Data sheets are compiled weekly by a key fisher in each sites, and collected quarterly by national agency staff. The following months, data are entered and cleaned in the database by national agency staff
6.4.11 Approach, sites/stations, parameters and frequency of frame surveys

The JEM Proragmme and Standard sampling guidelines for FADM (as well as pilot project proposals for both dam sites) make reference to the implementation of frame surveys, in order to determine the number and diversity of fishing gear, the local fish catch, the fishing effort, CPUE, fish price and value of fish13.

Frame surveys do allow inferring from individual fishers monitored to larger figures at a given level. However, the number of objectives determines the nature of the frame survey to be undertaken (questions to be asked, secondary data to be gathered) and the survey strategy (sampling fishing households only or random households representing an average population, sampling fishers for fish value at first sale or markets for fish value in trade, etc.). Thus, the breadth of objectives determines the field deployment effort - and cost- of each frame survey.

Similarly, the scale of the area to be covered by frame surveys for the inference of monitoring results to local situations is important. The minimal scale is that of dam sites, but if answers about catches, trends or livelihoods are expected at the provincial, regional or basinwide scale, then frame surveys would have to be designed accordingly. Thus, the guidance provided in the JEM documents could be made more operational by a specification the objective(s) and scale(s) of the frame surveys considered.

It should be noted that designing and implementing frame surveys is a complex task and has resulted in the development of multiple guidelines and dedicated tools, for instance the FAO ARTFISH software (Approaches, Rules and Techniques for Fisheries Statistical Monitoring) that includes an ARTPLAN component for planning frame surveys, including required sample sizes and various scenarios for cost-effectiveness. Overall, the design of reliable and representative fisher and market frame surveys is a sizeable activity (village and household questionnaire design, secondary data collection for sampling, village and household selection, interview guidelines, database design, etc.). Such surveys require substantial time, human resources and budget (examples of district and province scale frame surveys in fisheries in Laos point to about 2 months of work by 4-6 surveyors)

If the objectives are mainly on monitoring trends in fish abundance, catch composition or CPUE at dam sites, without trying to infer from FADM survey results to figures at a larger geographical scale nor assessing changes in fish prices or larger socioeconomic aspects, then these objectives can be reached without a frame survey, through the monitoring of a number of selected fishers. In other words, frame surveys are not essential to assessing trends in catches (monitoring fishers is enough); Frame surveys are required only for the assessment of total production and its value at different management levels. Conversely, assessing dam impacts on catches and livelihoods in the vicinity of the dam through a local frame survey does not allow covering large scale impacts, and tends to minimize the perceived consequences of that dam (i.e. quantified impact on fish production limited to the villages surrounding the dam).

⇒ Following discussions during the inception phase, feedback from the MRC Environmental Management Division and integration of budget and logistical constraints, it was decided that:

- the theme of the frame survey should be limited to fisheries
- each frame survey should be kept simple, without major logistical requirements;

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13 JEM pilot project proposal – Don Sahong p. 40; JEM pilot project proposal –Xayaburi p. 44
• the indicators of the frame survey should focus on Resource status, Income from fish, Labor in fisheries, Fish in nutrition, and Management;
• the target sites should be the villages of the JEM FADM sites, in order to document conclusions about changes in villages near dam site;
• there should be no extensive household interviews, but a focus instead on i) key informants (village heads, heads of fishery organizations, fisheries officers, etc.), and ii) group discussions with fishers for fishery issues, and with groups of random households for other generic issues
• questions on species should focus on about 30 species carefully selected;
• the approach should include reconnaissance surveys in each village, design of a questionnaire building on the one tested during the February training, and presentation of the final methodology to the Member Countries in October 2020 for implementation in 2021.

6.4.12 Establishing a baseline

In Don Sahong, baseline studies can integrate:

• MRC data about the Lee trap fishery in Khone Falls (Halls et al. 2013; fish catches in pre-dam conditions).
• Ian Baird’s Khone Falls fishery data set14 (6 years of data between 1993 and 1999; 32 gear categories used by 20 fishers in all Khone Falls channels)
• The CESVI’s characterization of local fishery activities and catches in Khong District15
• More than 15 publications documenting extensively local knowledge on fish migrations, species behavior and fishing practices at Khone Falls.

The latter background echoes the JEM recommendation to collect local knowledge on catch and fish species through semi-structured questionnaires.

In Xayaburi, the pre-dam baseline can build on a number of existing analyses and data sets a. These include:

• The MRC FADM data in the province
• Species point distribution compiled by the MRC (MDF 200316; species point distribution),
• The 2000 MRC socioeconomic survey for the frame survey (Sjorslev et al. 2000; data in 27 villages during 4 months in 1999).

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14 Baran E., Baird I. G., Cans G. 2005. Fisheries bioecology at the Khone Falls (Mekong River, Southern Laos). WorldFish Center, Penang, Malaysia. 84 pp.
15 Baird I. G., Vixay Inthaphaysi, Bounpheng Phylaivanh, Phongsavath Kisouvannalat 1998. A rapid fisheries survey in Khong District, Champasak Province, Southern Lao PDR. Technical Report. CESVI, LAO/B7-6200/IB/96/012. 31 pp.
16 MFD (Mekong Fish Database) 2003. Mekong River Commission: Mekong Fish Database. A taxonomic fish database for the Mekong Basin. Mekong River Commission, Vientiane, Lao PDR. CD-Rom.
6.5 Fish Larvae Drift Monitoring (FLDM)

6.5.1 Approach and methodology of the FLDM

There is a confusion in different documents between the terms “bongo net” (cylindrical by design in the region) and “conical net”. Only Cowx et al. 2015 state that MRC programs have been using conical nets; the various studies reported in Cambodia and Viet Nam before 2015 all report using bongo nets – and this kind of net is still used for regular monitoring in Cambodia, Laos and Viet Nam.

All studies done by national teams since 2002 have been using 1 mm mesh size nets; only Cowx et al. 2015 report using a 0.5 mm mesh size in their study. The JEM draft programme document seems to mistakenly refer to Cowx et al. 2015 in recommending a 1 mm mesh size gear type, as that study used a 0.5 mm mesh size. The use of a smaller mesh size for the cod end of the net (either 250 or 330 microns) is aimed at collecting the youngest and smallest larvae, usually for specific ichthyoplanktonic studies. However, identification of these tiny larvae is very difficult, time-consuming and doable by specialized larvae taxonomists only. In a context of routine monitoring generating a lot of weekly samples analysed by various teams throughout the basin, it is not necessary to use a mesh size inferior to 1mm in the design of fish larvae sampling nets.

Terminology and shape aside, the JEM draft Programme confirms that larvae nets of 1m diameter, 5m length and 1 mm mesh size should be used for regular sampling – in agreement with the team of larvae scientists in Cambodia and the conclusions of the MRCS and GIZ team.

⇒ For the JEM pilot project and further monitoring of larvae in rivers as part of the JEM program, we recommend the (continued) use of 1m diameter, 5m length and 1mm mesh size nets, cylindrical by design, that have been called “bongo nets” (although they are not formally bongo nets, the latter coming normally two by two).

The twin bongo nets are smaller conical nets set two by two like bongo drums. Clarifications during the procurement phase indicated that the diameter of each net should at the mouth should be 60 cm and the length of the net should be 1.80 meters (in the turbid waters like the Mekong mainstream the ratio diameter to length should be 1:5, but in clearer waters like in impoundments the ratio should be 1:3). Based on previous trials in the region, the mesh size at the mouth should be 1mm but (2/3 of the length = 120 cm long) and the mesh size at the cod end (1/3 of the length = last 60 cm) should be 330 micron.

⇒ Given the complication and standardization issues inherent to sampling larvae with different gears and methods in rivers and in impoundments, sampling impoundments with a single river-type bongo net was discussed among larvae scientists during the

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17 Cowx I. G., Kamonrat W., Sukumasavin N., Sirimongkothawon R., Suksri S., Phila N. 2015. Larval and juvenile fish communities of the Lower Mekong Basin. MRC Technical Paper No. 49. Mekong River Commission, Phnom Penh, Cambodia. 100 pp.
inception meeting and training, and it was decided to use the same 1m diameter, 5m length and 1mm mesh size net for both river and impoundment. Further testing will confirm this choice.

The JEM Programme does not give details, but in each site 1 m diameter bongo nets should be anchored and operated with a buoy. The JEM Programme indicate one sampling per site, at 2 m depth. This is in agreement with the existing protocols\(^{18}\), but in past years the national teams have also sampled larvae at 1m below the surface\(^ {19}\).

⇒ *We recommend sampling larvae once in each site, 2m below the surface, in places at least 3m deep.*

Current meter: record the number of rotations of a propeller; multiply the rotations by the cross-sectional area of the mouth of the net (0.785 m\(^2\)) ⇒ estimate of the volume of water flowing through the net.

### 6.5.2 Sampling sites

The sites selected after consultation of all partners are very close to those of the FADM protocol; they have only been adapted only adapted to sampling conditions and research questions specific to larvae.

**Don Sahong**

*Upstream:* Leuad Kuey in Laos (14°22’0.98”N, 105°51’58.10”E); existing FLDM site  
*Mouth of the impoundment:* Hoo Sahong in Laos (13°58’35.77”N, 105°57’21.61”E);  
*Downstream:* Veunkham (13°55’25.77”N, 105°59’17.67”E); new site  
Preah Romkel in Cambodia (13°54’4.63”N, 105°57’52.34”E).

**Xayaburi**

Same sites as those of the FADM sites  
*Upstream:* Pha O  
*In the impoundment:* Tha Deu  
*Downstream:* Pak Houng

Sampling in Leuad Keuy, north of Don Khong, allows picturing larvae distribution upstream of the falls in the non-branched mainstream. Sampling is also done upstream, in the mouth of Hoo Sadam to assess the drift into the impoundment. Downstream, Sampling in Veun Kham and in Preah Romkel allows covering almost all of the Mekong downstream of the falls (i.e. comparable with Leuad Keuy and with Hoo Sahong inlet)

⇒ *Sampling larvae in Don Tolathi was proposed given its important role, claimed by local fishers, as a breeding site, and its contribution to the larval drift through unobstructed channels. Sampling in this site was considered impossible given the budget available.*

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\(^{18}\) Halls A. S., Paxton B. R., Hall N., Hortle K. G., So N., Chea T., Chheng P., Putrea S., Lieng S., Peng Bun N., Pengby N., Chan S., Vu V. A., Nguyen Nguyen D., Doan V. T., Sinthavong V., Douangkham S., Vannaxay S., Renu S., Suntornratana U., Tiwarat T., Boonsong S. 2013. Integrated Analysis of Data from MRC Fisheries Monitoring Programmes in the Lower Mekong Basin. MRC Technical Paper No. 33. Mekong River Commission, Phnom Penh, Cambodia. 130 pp.

\(^{19}\) Chea Tharith, Lek Sophat, Thach Phanara. 2003. Fish larvae and juvenile drift at the confluence of four rivers near Phnom Penh: the Mekong upstream and downstream, the Tonle Sap and the Bassac River June-September 2002. Pp. 21-28 in Poulsen A. (ed.) Proceedings of the 5th Technical Symposium on the Mekong Fisheries, 11th-12th December 2002, MRC Conference Series No. 4. Mekong River Commission, Phnom Penh, Cambodia. 358 pp.
However, we still recommend to consider larvae sampling in Don Tholathi when the programme expands and budget allows.

6.5.3 Sampling parameters

Overall, the parameters of sampling larvae and juvenile fish remain similar to those of the previous FLDM programme (see Halls et al. 2013), with the following adjustments or clarifications:

- In each sampling site, samples should be collected in two locations, in order to better integrate the variability in larvae distribution;
- Wherever possible, the two samples should be collected along the two river banks. This allows reflecting distribution variability resulting for instance from tributaries joining the mainstream on opposite banks.

When only one sample is possible, sampling should be done along the external bank characterized by stronger current and erosion. For safety reasons, sampling should not be done in the middle of the river

⇒ In each site, we recommend sampling in two locations, one along each river bank

6.5.4 Sampling frequencies

The current JEM recommendation to collect 3x4x2=24 larvae samples per month in the “low” season and 3x4x2x4=96 samples per month in the “high” season may be unmanageable at the field level and even more so in the lab.
Discussion with national teams led to the recommendation to sample each week of the year, one day per week from August to April (low larvae density season) and two days per week from May to July (high larvae density season). Each site should be sampled along each bank (i.e. in 2 locations per site), 4 times per 24-hour period (6am, 12am, 6pm, 12pm), during 30 mn each time. Thus, sampling in each site would generate \[1\text{ day} \times 2\text{ banks} \times 4\text{ daily samples}\] = 8 samples per week between August and April, and \[2\text{ days} \times 2\text{ banks} \times 4\text{ daily samples}\] = 16 samples per week between May and July. These sampling frequencies will be reviewed in relation to the ability of the team to gather and process samples.

⇒ Larvae sampling should be done one day per week from August to April and two days per week from May to July. In each site, two banks should be sampled. Samples should be collected 4 times a day: at 6:00, 12:00, 18:00 and 24:00, during 30 minutes each time. This will produce 8 samples per week between August and April and 16 samples per week between May and July.

Once a sample is collected by fishers, it should be rinsed and quickly cleaned so that algae and wood debris are removed.

### 6.5.5 Fish larvae identification

Once samples are collected by fishers and collected for analysis and identification, the national teams trained in March 2020 will start sorting samples to remove debris, sort fishes by taxa, identify taxa, measure fish lengths and relate fish counts to water volumes sampled. This will provide data about larvae density, dominance among taxa and lengths of individuals (as a way to assess proximity of breeding sites).

Experience from training sessions indicates that about 30 taxa can be routinely identified (least common denominator between all teams, identification ranging from family to species level depending on the taxon).

In order to make this identification equally possible among all teams involved, the project will procure laboratory equipment for the Laos fisheries team in LARReC, in particular a high resolution microscope, lab glassware, tweezers, and consumable such as formaldehyde or alcohol. Copies of larvae identification manuals have already been shared during field training, and data entry in Access was covered by training in Phnom Penh in March 2020.
Discussion with national teams led to the recommendation to sample each week of the year, one day per week from August to April (low larvae density season) and two days per week from May to July (high larvae density season). Each site should be sampled along each bank (i.e. in 2 locations per site), 4 times per 24-hour period (6am, 12am, 6pm, 12pm), during 30 mn each time. Thus, sampling in each site would generate [1 day x 2 banks x 4 daily samples] = 8 samples per week between August and April, and [2 days x 2 banks x 4 daily samples] = 16 samples per week between May and July. These sampling frequencies will be reviewed in relation to the ability of the team to gather and process samples.

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**Box 6-5: Summary for FLDM sampling: 1) selection and training of fishers**

| WHAT | 1) Selection of candidate fishers in each site as per the first five criteria of Standard sampling guidelines for FADM section 6.2  
2) Training fishers to operate the bongo net. |
| WHO | National teams train fishers to operate the bongo net |
| WHEN | From May 2020 on |
| WHERE |  
• In Pha O village (Xayaburi, Laos)  
• In Tha Deua village (Xayaburi, Laos)  
• In Pak Houng village (Xayaburi, Laos)  
• In Hoo Sadam village (Khone Falls Laos)  
• In Veun Kham village (Khone Falls Laos)  
• In Preah Romkel (Cambodia) |
| HOW | Following instruction of JEM procedures v.3 Annex 22, using only a 1m diameter, 5m length, 1mm mesh size net. Actually national agency staff will teach fishers how to operate the bongo nets the way they used to (continuation of a previous protocol). The role of fishers is limited to collecting fish larvae samples and recording flow meter data. |
| HOW OFTEN | Training is done once in each site, and is redone in case of drop out. |
6.6 Fish passage studies at Don Sahong

6.6.1 Approach and methodology of the fish passage studies

Mapping the area, naming places

In order to be explicit about the sites and places discussed in the various sections, we provide below two maps of islands and waterfalls in Khone Falls, Figure 6-4, Figure 6-5) and of the channels improved by Don Sahong Power Company (DSPC) (Figure 6-6, Figure 6-7).

To date, Don Sahong Power Company has developed activities to improve fish passage in 9 channels; from East to West:

- Hoo Som Noi and Hoo Som Pa Dai next to Khone Phapheng waterfall
- Hoo Sadam in Don Sadam
- Hoo Xang Peuak Noi, Nuay Khoun, Koum Tao Hang, Hoo Wai and Luong Pi Teng (?) between Don Ee Som and Don Sahong
- Hoo Don Dai next to Lee Pee waterfall

Works at two additional channels are planned:
- Hoo Nok Gasoom noi between Don Ee Som and Don Nok Gasoom
- Hoo Ta Sang next to Don Pa Soi.

**Box 6-6: Summary for FLDM sampling: 1) data collection**

| WHAT  | Data gathering by fishers |
|-------|---------------------------|
| WHO   | By one fisher in each site, as identified by national agency staff. |
| WHEN  | From May 2020 on |
| WHERE | In Hoo Sadam village (Khone Falls Laos) |
|       | In Veun Kham village (Khone Falls Laos) |
|       | In Preah Romkel (Cambodia) |
|       | In Pha O village (Xayaburi, Laos) |
|       | In Tha Deua village (Xayaburi, Laos) |
|       | In Pak Houng village (Xayaburi, Laos) |
| HOW   | Following the above instructions, using a 1m diameter, 5m length, 1mm mesh size net. One day per week from August to April and two days per week from May to July. Two banks per site, 2m below the surface, during 30 minutes each time, at 6:00, 12:00, 18:00 and 24:00. |
| HOW OFTEN | Every week of the year |
| DATA MANAGEMENT & CLEANING | Larvae bottles are collected monthly by national agency staff. The following months, data are entered and cleaned in the database by LARREC and IFReDI staff. |
Fish passage studies at Don Sahong

Approach and methodology of fish passage studies

In order to be explicit about the sites and places discussed in the various sections, we provide below two maps of islands and waterfalls in Khone Falls, Figure 6-4, Figure 6-5) and of the channels improved by Don Sahong Power Company (DSPC) (Figure 6-6, Figure 6-7).

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- Hoo Don Dai next to Lee Pee waterfall

Works at two additional channels are planned:

- Hoo Nok Gasoom noi between Don Ee Som and Don Nok Gasoom
- Hoo Ta Sang next to Don Pa Soi.

Fish larvae sampling #2: data collection

WHAT

Data gathering by fishers

WHO

By one fisher in each site, as identified by national agency staff.

WHEN

From May 2020 on

WHERE

- In Hoo Sadam village (Khone Falls Laos)
- In Veun Kham village (Khone Falls Laos)
- In Preah Romkel (Cambodia)
- In Pha O village (Xayaburi, Laos)
- In Tha Deua village (Xayaburi, Laos)
- In Pak Houng village (Xayaburi, Laos)

HOW

Following the above instructions, using a 1m diameter, 5m length, 1mm mesh size net. One day per week from August to April and two days per week from May to July. Two banks per site, 2m below the surface, during 30 minutes each time, at 6:00, 12:00, 18:00 and 24:00.

HOW OFTEN

Every week of the year

DATA MANAGEMENT & CLEANING

Larvae bottles are collected monthly by national agency staff. The following months, data are entered and cleaned in the database by LARREC and IFReDI staff.

Figure 6-4: Map of islands in the western part of Khone Falls
Figure 6-5: Map of islands in the eastern part of Khone Falls
Figure 6-6: Map of channels and waterfalls islands in the western part of Khone Falls (improved DSPC channels in orange)
Figure 6-7. Map of channels and waterfalls islands in the eastern part of Khone Falls (improved DSPC channels in orange)
Notes on fish ecology at Khone Falls

Local ecological knowledge indicates that during the main upstream migration pulses, fish tend to follow the line of deepest water levels (and possibly strongest current) and move first towards western Khone Fang area. Then “those fish using this migration route that cannot ascend through channels in the Khone Fang area apparently then fall back downstream and seek other possible passage routes” (Williams 2015[20]) - while some fish also move directly up to eastern channels.

⇒ In terms of mitigation, this indicates that the waterfalls around Khone Fang (west of Khone Falls) could play an important role as an area naturally attracting fish but not passable despite the relatively low height of the falls, i.e. a good candidate for the creation of fish passage[21]. The current proposed distribution of fish tagging study locations (figure 7-2 of DSHPP pilot) does not reflect that option.

We also hypothesize that the outflow from the Don Sahong power plant (diversion of 15% of the Mekong flow on average, design station discharge of 1600 m3/s in a 260m wide channel) is creating a large hydrodynamic and sediment perturbation at the entrance of the channel leading to five of the nine fish passes. The extent of that perturbation should be assessed before a fish tag detection location accurately reflecting the downstream density of migratory fish can be identified.

⇒ The release of an average 1300 m3.s-1 outflow just downstream of the plant and its influence on fish movements deserves further analysis - in particular in relation to the hydrological component of the pilot study- and should be integrated to the design of the fish tagging and fish passage study.

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[20] Williams, J. G. 2014 Fish migration features and environmental parameters at Khone Falls that can inform the design of fish passes in the Mekong. Report for the project “Informing the design of fish passes in the Mekong”. WorldFish, Phnom Penh, Cambodia. 20 pp.

[21] DSPC biologists indicated that the reason why no fish passage improvement was considered there is only distance from the plant
These different points are summarized in the figure below (Figure 6-9).
Comments on the Terms of Reference for the JEM Pilots

According to the terms of reference (DSHPP pilot, page 33), the objectives of the fish migration and fish passage studies in Don Sahong are to:

- assess the effectiveness of the two natural fish passages channels (Hou Sadam and Hou Xang Pueak, in particular in dry season)
- generate reliable fisheries data and information on trans-boundary fish species, their migration patterns,
- fish catch/yield and value in Hou Sadam, Hou Sahong and Hou Xangpueak channels.

The second and third point are will be largely covered by FADM and frame surveys/fish migration study, while:

- noting that Hou Sahong is not a functional channel any longer
- underlining that fishing in Hou Sadam and Hou Xangpueak channels is constrained by DSPC regulations.

More generally, the primary focus of the fish passage study should be on migratory patterns of fish and the impact of the dam and of its operational procedures on upstream and downstream migration.

The Don Sahong hydropower project presents a unique feature: the creation of nature-like bypass channels for fish to swim upstream despite the loss of Hoo Sahong, the deepest channel formerly used by fish during dry season migrations. The company has, over the years, removed obstacles to passage and flow and created bypasses. Although the study of attraction flows in the whole area is relevant (see below), the DSPC fish passage improvements measures do not include “attraction flows” per se.

Assessing the effectiveness of the fish passages channels, in particular attraction efficiency and passage efficiency as required, implies specific studies discussed below. Before developing these, some background information can be useful.
In the above context, the proposed distribution of fish tag detection locations (figure 7-2 of DSHPP pilot) does not reflect existing knowledge of fish migration channels (e.g. role of the channel to Khone Fang, no passage upstream of Khone Fang area), may have to be extended to integrate the possible influence of the plant outflow, and includes arguable locations (e.g. in Hoo Sahong just downstream and upstream of the dam). For these reasons, an in-depth analysis of the local conditions underpinning fish tag detection locations is recommended before a full-scale implementation is initiated.
In the above context, the proposed distribution of fish tag detection locations (figure 7-2 of DSHPP pilot) does not reflect existing knowledge of fish migration channels (e.g. role of the channel to Khone Fang, no passage upstream of Khone Fang area), may have to be extended to integrate the possible influence of the plant outflow, and includes arguable locations (e.g. in Hoosahong just downstream and upstream of the dam). For these reasons, an in-depth analysis of the local conditions underpinning fish tag detection locations is recommended before a full-scale implementation is initiated.

Last, the TORs of the pilot study recommend that for the fish migration and passage study, 1200 acoustic/radio tags at USD 200 and 30 acoustic/radio receivers are purchased, for a total cost of USD 315,000. The high cost of the study and the need to procure a specific type of tag (unspecified in the ToRs) requires a thorough analysis of the option and of its alternatives.

6.6.2 Review of the different tagging methods considered

There is a diversity of tagging methods depending on fish species (size, body form), environment, objectives, fish being recaptured or not, duration of the study (short or long term) and staff and budget available. For instance, one commercial company surveyed proposes 92 different types of tags for fish.

Traditional external tags

These tags are mentioned here as they have been used by Don Sahong Power Company for two years of tagging experiments (with 7% recapture rate overall).
This category of tags depends on recapture of the tagged fish to obtain data. Results are highly influenced by the distribution and intensity of the fishing effort. No information is provided for the fish not recaptured (lost) and no information is generated between tagging and recapture. Given the high loss rate, the study requires a large number of fish to be tagged. Last, these tags only provide snapshot information, and limited info on long-term fish behaviour, dispersal and habitat use.

A new type of tag consists in paint or Visible Implant Elastomere (VIE); the success rate with these methods is not known for Mekong fish species.

**Electronic tracking (telemetry)**

Five types of tags exist: radio, acoustic, data storage, satellite or PIT. They pertain to two main categories:

1. Tags with batteries = active tags. These large tags include radio transmitters, acoustic transmitters, data storage tags (DST or archival tags), and pop-up satellite archival tags (PSAT)
2. Tags with no batteries = passive tags. These smaller tags are called passive integrated transponders (PIT-tags). They provide repeated information from the same individuals and for most methods the fish do not need to be recaptured. Longer term data on fish movements can therefore be collected, and the number of tagged fishes needed is more limited. These tags can also collect information on fish physiology and/or environmental parameters.
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Pop-up Satellite Archival Tags (PSAT) are designed for the study of oceanic migration of large fish and cost about USD 5000/tag; they are not relevant here. Data Storage Tags (DST) are large (i.e. restricted to very large fish), collect a lot of information but need to be recaptured to retrieve data (usually no transmission of signal in the field). They are not relevant to our study.

Among active tags, radio transmitters attached to the fish can, via their antenna, transmit radio signals to a receiver at a distance. They work best for fish swimming in the upper 5-10 meters of the water column. Tagged fish distributed over a large study area can be tracked with a portable receiver and aerial antenna or by stationary receivers/loggers. This method is widely used for river migration study of large fish, and transmitters are usually clipped to the muscles of fishes (external attachment).

Among active tags, acoustic (= sonic) transmitters are recorded by hydrophones in water (i.e. by boat). They are relevant to “real time” fine-scale studies of fish movements, e.g. fish behavior through a barrier. These tags transmit signals to a receiver, from tens of meters to a few kilometers (gas bubbles e.g. downstream of dams and turbid water reduce their range). They can be monitored by using stationary automatic data loggers or automatic listening stations (ALS).
Passive Integrated Transponder Tags (PIT-Tags) are the smallest of all tags (9-22 mm long, less than 0.1 gram) as they do not require a battery (they consist in an integrated circuit chip encased in glass). They are read when fish pass near or through an active antenna; the antenna can be held by hand, be anchored or consist in a wiring across the stream (larger streams). Unlike the previous ones, they do not affect fish behavior, and fish down to 5 cm in length can be tagged. Their main drawback is the short detection distance of the readers (<1 m).

Acoustic and PIT tags need to be inserted in the body of fishes with a syringe or with a scalpel. The intervention generates a mortality (shock, infection, handicap), depending on the experience of the practitioner (importance of the training and practicing phase).

Pros and cons of each tag type

The review of pros and cons of the different types of tags below - in particular practical aspects - is largely based on a discussion with scientists of the Fish-Pass company specialised in fish tagging and passage monitoring in France (www.fish-pass.fr/uk/index.php)

Radio tags are the largest ones and their use is restricted to large fishes. They are mainly used for precise behavioral studies such as response to attraction flows. They have a large detection range and can be monitored using a hand antenna. Receptors have a short battery life (about 6 hours).

Like radio tags, acoustic tags have a large detection range (500 m to 1 km) and are suited for use in deep and wide rivers or channels (>10m deep, > 50m wide) because of the cone-shaped field in which the detectors can "see" the tags. For example, as per Figure 6-17, in a narrow 6-m wide channel several detectors may still leave blind spots where fish could travel undetected. Acoustic receptors (= hydrophones) are also sensitive to noise; they are not suitable for turbulent areas, in particular downstream of dams. Implanting each radio tag requires ± 10-15 mn and surgery skills (water irrigation, anesthesia, 2-3 surgical stitches). Survival depends on water temperature (higher temperature, like in tropical rivers implies lower survival); therefore the survival rate must be assessed before calculating any fish passage rate (trial tagging of about 50 fish, and monitoring survival in a cage over 2-3 weeks). An acoustic tag can emit one bip per minute, each 2 minutes, each 5 minutes, etc. Higher frequencies facilitate identification but reduce the tag battery life (1 bip/mn corresponds to about 6 months of battery life). The weight of the tag should also be inferior to 2% of fish weight. Therefore, the life span of the tag depends on the frequency of bips but also on the size of the fish tagged. In addition to the cost of tags (USD 200 for older larger models, USD 300 for more recent models), signal receptors are also costly: one hydrophone costs more than USD 1500. For an area as complex as Khone Falls, a minimum of 10 hydrophones are required.

![Figure 6-17: Use of acoustic hydrophones in a river. Crosses indicate uncovered areas and ste strike a signal overlap area.](image-url)
Pit tags have a very limited detection range (70 cm to 1 m). They are suitable for small fish and require minimal surgical intervention (implantation with a syringe). They are also suitable for small and shallow steams only, when the antenna is set in a river (it is then sensitive to current and debris), but receptors can also be put on a container receiving captured fish (Figure 6-18). Receptors also require sizeable batteries and access to 220 V power to recharge these batteries on a frequent basis.

*Figure 6-18: PIT tag detectors. Left: antenna to be put in a stream; right: detector around a fish container*

Power supply is one of the main field constraints. Radio and PIT tag receptors in particular require a set of batteries to be recharged every 6 hours by an electric cable or by solar panels, but both batteries and solar panels are subject to stealing. Hydrophones, on the contrary, can stay underwater for 12 months.

For all tags, the software and statistical analysis of data is a complex point. For instance data downloaded from one hydrophone correspond to 200,000 - 1.6 million records. These records include multiple fish but also environmental noise. Idle fish emitting repeatedly without moving and overlap between signals received by different hydrophones complicate the analysis. These aspects require statistical routines to clean data, and specific software to synchronize reception between different receptors.

6.6.3 Additional elements to be considered for a fish tagging study

Once the tag type is selected for a given species and location, it is necessary to catch live fish to be tagged. The dominant gears used at Khone Falls (gill nets and long lines) do not guarantee live and valid fish; yet they represent 82% of all fishing operations. Fish supply will therefore be dependent on other, less common and more specialized gears and methods. This implies identifying compatible combinations of [guild x species x gear x migration season].

Radio tags with an antenna sticking out of the fish are the most traumatic ones, as the antenna maintains a wound open. Acoustic tags are also large and require, like radio tags, surgical procedures: anesthesia of the fish, aseptic conditions, oxygenated water flow through gills, stitching of the opening and recovery of the fish for several days in quiet conditions. This know-
how requires a special training usually gained from veterinarians, during a few days (in lab and in field conditions).

Survival of the fish after tagging is essential: conclusions about passage success are faulty when fish die, in a large part, from the tagging itself. For these reasons, it is essential to trial tags and test mortality in cages, by species (50 fish over 15 days minimum).

A licence of ethical handling of fish is required to be able to publish results about tagging in international journals. In Laos, special permissions are also required to do fish tagging at dam locations. Getting such permissions imply consulting DoF, MONRE, LNMC, MEM and NAFRI, and the process can take several months.
6.6.4 Conclusions and the way forward

In conclusion, four types of tags can be considered: i) traditional external tags are very cheap and “easy” to set but require recapture. The DSPC experience shows a 7% recapture rate only; ii) radio tags are limited to large fish (e.g. catfishes), allow monitoring in large streams, but are single-use and very expensive ($200/tag), which is not compatible or financially feasible in terms of long-term annual monitoring conducted by MRC, but feasible for dam developers, if later on the dam developers use the methods; iii) acoustic tags are suitable for large and medium-size fish but require risky surgical interventions and highly trained operators; and iv) PIT tags are cheap and suitable for small fish such as the dominant Henicorhynchus, but their detection range is very limited (use in small streams only).

⇒ The diversity of species and stream sizes to be monitored clearly requires the use of more than one kind of tag and receiver. The lack of specification about the tags to be used in the DSHPP pilot TORs does not allow starting the fish tagging study immediately.

Our review highlights the complexity of selecting relevant fish tags for the JEM monitoring. That selection will depend on the size of fish species considered, on the size of the channel considered, on the biological questions being asked (assessing passage attractiveness = characterizing fish behavior vs. assessing passage efficiency = counting the proportion of fish passing the obstacle), on costs (all costs, i.e. tags + receptors + maintenance + data analysis), on fish survival for each tag type and on location-specific practical aspects (power supply, turbulence, etc.).

⇒ A thorough analysis of the specific constraints and requirements for pit tags, depending on local stream features conditions and target species, is required. A detailed desk study for tag selection, possibly involving Fish-Pass company scientists, will be undertaken. Clarifying and finalizing the fish tagging protocol should be done before October 2020, so that conclusions can be presented to the Members Countries at the end of that month.

During the inception period, a collaboration with Charles Sturt University (CSU), Lee Baumgartner’s team, already doing tagging at Xayaburi Dam) was discussed, in relation to possible additional funding from the Australian Water Partnership (AWP)/Department of Foreign Affairs and Trade (DFAT). At this stage, it was concluded that:

⇒ the study of fish passage at Khone Falls is extremely complex; the methodology is not operational and requires a substantial selection and testing phase before fish passage itself can be assessed. This selection and testing phase will be the focus of activities in 2020 (need to establish the methodology first; monitoring will come later);
⇒ testing fish survival rates and effectiveness of antennas of PIT tag is the first priority. The focus of testing will be on PIT tags, but testing of acoustic tags will also be undertaken by CSU;
⇒ testing capture-recapture options (external marks, PIT tags for fish to be recaptured by fishers) will also be considered;
⇒ a report documenting the methodological approach and next steps is expected by October 2020;
⇒ the testing phase will be complemented as much as possible with training of national partners in tagging methods; this training will be done to the extent possible by CSU, around November-December 2020.
⇒ When testing is done in the field, Hoo Sadam and Hoo Xang Pueak channels with be the priority options.
⇒ Collection of local knowledge on catch and fish species in three channels, as recommended in the Don Sahong pilot, will also be done. Specific questionnaires for surveys of local knowledge (Poulsen and Jorgensen 1999\textsuperscript{22}, Baran et al. 2015\textsuperscript{23}) and specific approaches based on local experience (Baird 2007\textsuperscript{24}) can be used to strengthen the questions given in Annex 7 of the Standard sampling guidelines for FADM.

⇒ The study of fish passage or fish migration at Khone Falls will also be addressed through a survey of local ecological knowledge, to be undertaken with the contribution of a national consultant, before October 2020.

\textsuperscript{22} Poulsen A.F., Jorgensen J.V. 1999. Survey manual for the use of local fishers’ knowledge in the study of fish migrations and spawning in the Mekong River Basin. (Basin wide) Assessment of Mekong Fisheries – AMFP Technical Report 1/99 version 1.0. Mekong River Commission, Vientiane, Lao PDR. 30 pp.

\textsuperscript{23} Baran E., Win Ko Ko, Zi Za Wah, Estepa N., Saray S., Tezzo X., Khin Myat Nwe, Maningo E. 2015. Distribution, migrations and breeding of Hilsa (*Tenualosa ilisha*) in the Ayeyarwady system in Myanmar. BOBLME-2015-Ecology-39. Bay of Bengal Large Marine Ecosystem project, Phuket, Thailand. 120 pp.

\textsuperscript{24} Baird I. G. 2007. Local ecological knowledge and small-scale freshwater fisheries management in the Mekong River in Southern Laos. Pp. 227-266. In. Haggan N., Neis B., and Baird I. G. (eds.): Fishers’ knowledge in fisheries science and management. Coastal Management Sourcebooks 4. United Nations Educational, Scientific and Cultural Organization, Paris, France. 437 pp.
7 DATABASE, DATA MANAGEMENT AND ANALYSIS

7.1 Aims and Objectives

The aims of the database and data management component of the JEM include:

- To have a common database or databases of the different disciplines that can be linked, queries and used to conduct integrated analysis and assessment;
- Organization of data in file formats that are directly compatible with the MRC Master Catalogue system;
- Development of a relational database to allow the JEM team (MRC and International consultants) to interrogate the JEM results and integrate the findings between disciplines and with historic results from routine monitoring sites/stations to provide insights into changes related to the development of mainstream hydropower or other developments in the LMB. This database will also be useful as a guide for the ongoing development of the MRC Master Catalogue and data bases;
- Provide recommendations to the MRC for future data reporting and management strategies that are applicable to the long-term ongoing monitoring, and will streamline data reporting without compromising on data QA/QC procedures.

The JEM monitoring is based around the themes of hydrology and hydraulics, Sediment Transport and Geomorphology, Water Quality, Aquatic Ecology, and Fisheries and Fish Passages. The monitoring parameters, and derived parameters based on the monitoring results include the following for each discipline:

- **Hydrology**: Measured parameters include: (i) water level (ii) water velocity (iii) river discharge.
- **Sediment Transport and Geomorphology**: measured parameters include (i) Discharge, (ii) Suspended Sediment Concentration (SSC), (iii) Bedload transport (BL), (iv) Suspended Sediment Grain Size Analysis (SGSA) (v) Bedload grain-size (vi) Repeat photo monitoring of river banks (vii) Repeat survey cross-sections of alluvial river sections.
- **Water Quality** parameters include in all stations: (i) Dissolved Oxygen (DO), (ii) Conductivity, (iii) Turbidity, (iv) Temperature, (v) pH, (vi) Chlorophyll a, (vii) Cyanobacteria, (viii) Total phosphorous and (ix) Oxides of nitrogen (NOx); and in four stations, Alkalinity/Acidity, Total Nitrogen (T-N), Ammonium (NH4+-N), Faecal Coliforms, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD) and four seven months during the wet season Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Sulphate (SO42-), Chloride (Cl-).
- **Ecological Health** parameters include: (i) littoral macroinvertebrates, (ii) benthic macroinvertebrates, (iii) zooplankton, (iv) benthic diatoms and (v) phytoplankton (taken from readings by Water Quality team);
- **Fishery and Fish Passage monitoring** parameters include: (i) Catch assessment, (ii) Fish monitoring, (iii) Larval drift and juvenile fish monitoring, (iv) Fish migration study, and (v) monitoring of the use of fish passages.

Each of the key parameters among the 5 disciplines will be used in preparing the database structure. However, the key point for the database design is that it will be fully compatible with the existing MRC database that is currently being upgraded. In order to achieve this compatibility, the ICEM database specialist will work with MRC database personnel and consult with the MRC discipline specialists, who will be direct users of the system, on the design of both
the data input and product application. On completion of the JEM pilots project and the operationalisation of the future MRC database, all the data and information within will be transferred to MRC Master Database System (Figure 7-1).

Source: MRC guideline for Project Joint Environment Monitoring of Mekong Mainstream Hydropower Project.

*Figure 7-1: Schematic for MRC Master Data Information system*

### 7.2 Database development process

The process for the database development is shown in the Figure 7-2. The first step in the database formation and development processes is to collect all relevant necessary information as a raw input, and the later step it needs to be analysed, categorized and synthesized. The needed input information for database development depends on:

- data collection objectives for each monitoring parameter,
- data collection form format,
- data report format for each observation parameter,
- data analysis and visualization format for each of the 5 project monitoring disciplines Hydrology, Sedimentation, Water Quality Monitoring, Aquatic Ecology, and Fishery and Fish Passage.

*Figure 7-2: Database development process*
Clear data collection objectives and direction are considered critical to the direction of database development. An important point is all data collection form formats across five disciplines of JEM project should be standardized with the with MRC’s five relevant disciplines to ensure that they will be compatible and consistent with each other. The preparation of data collection, data analysis, and information visualization under the JEM project must also be in line with the standardized format of Mekong River Commission.

The data collection forms from each parameter of the monitoring disciplines will categorized and transformed into database tables. The conceptual design will be based upon data collection objectives, data collection forms, data reports, data analysis and visualization format. The main tables and loop-up tables will be created in respect of each monitoring parameter’s objective of among 5 disciplines.

The database also needs to be able to bring in the historic and basin-wide monitoring data from the MRC for comparison and analysis. It also needs to have a function to upload and store data from the monitoring carried out by developers, although this will not necessarily be in a directly compatible format and may not be immediately available.

The database will allow users to bring information in and out the system with a user-friendly interface, where the data export function will be to able export data for further migration to other systems, especially the MRCs central master database system. In order to ensure usability and operability, the data base visualisation, export, basic analysis, information filtering, and data reporting functions will be developed in collaboration with each discipline expert from both sides project service provider and owner as well. A manual will be prepared to provide instructions for use of the database (see Annex 4.C)

7.3 Approach to data management and interpretation

The database will therefore be an independent, stand-alone database to store and manage the monitoring results from the JEM pilot. The database system will be developed by using Microsoft Access which will be able to input and export data in excel format for the further in-depth analysis by each discipline.

Time-series of the monitoring results will be formatted to be compatible with the Aquarius data management system, which is being used by the MRC to organize and store all time-series data sets held by the organization. In addition to the monitoring time-series the JEM team will derive integrated indicators that will also be stored in the database that can be used as a template for future data base development by the MRC. Many of these indicators will have a hydrologic component (e.g. incorporate discharge), which will allow future calculations to be automatically completed within the “Aquarius” environment for the MRC long-term monitoring sets. Indicators will align with the MRC BDP indicator list to allow the automatic calculation, tracking and reporting of these indicators by the organization. Indicators will also focus on processes known to be potentially affected by hydropower development and operations. Examples of calculated indicators include the following:

- **Sediment loads**: The suspended sediment concentrations will be integrated with discharge volumes to generate time-series of sediment loads at each of the monitoring. The time-series can be used to derive monthly, seasonal or annual sediment loads at each station. This information will assist with understanding how sediment loads are changing due to sediment trapping in impoundments, and how the Mekong mainstream is responding to reduced sediment loads;
- **Water quality loads**: water quality concentrations will be integrated with discharge volumes to establish time-series of nutrients loads and other parameters in the river. The time-series can be used to derive monthly, seasonal or annual nutrient (or other parameter) loads. Nutrient trapping in impoundments is an important process to understand. Nutrients are not trapped in the same proportions of sediment because they tend to be associated with very fine sediment sizes which tend to have a lower trapping rate as compared to the total sediment load. Directly measuring concentrations and calculated loads entering and exiting an impoundment is the best way to determine hydropower related changes to nutrient dispersion in a river system;

- **Environmental Health Monitoring**: From the results for each site collected on an annual basis Species abundance, Average species richness and the Average Tolerance score would be calculated for each of the biological groups. These are then used to estimate the Ecological Health Class for the site. The changes in the ecological health class may be related to upstream changes in flow, sediment and water quality occurring during the previous 12 months.

**Fisheries**: The JEM fisheries data will be compiled and analyzed to provide summary statistics about i) total biomass caught per fisher, per site and per year (i.e. trend in fishers’ individual catches); ii) number of species caught at each site (i.e. trend in diversity); iii) total catch, on standard basis, of a few selected long-distance migratory species (i.e. trend in migratory species); iv) dominant species in catches (i.e. identification of possible changes among the abundance of key commercial species), and v) average annual CPUE for gillnets (i.e. standardized comparison of fish catches). For larvae, analyses will focus on i) density (per m$^3$ of water), ii) number of taxa identified, and iii) length of larvae.

In analyses, biomass caught, CPUE and larvae density can be related to discharge, sediment load, water quality index, benthic biodiversity and algae density. Similarly, fish diversity can be compared to sediment load, water quality and benthic biodiversity. These parameters would be compared between fish sampling sites and the closest upstream or downstream sampling stations in hydrology, water quality and aquatic fauna.

The JEM team will also develop a set of graphical representations to display the monitoring and calculated results. These can be used as templates for future data visualization tools in the Aquarius system. Examples of how data might be presented are shown in Figure 7-3 to Figure 7-6.

![Figure 7-3. Examples of data presentation (left) time series of total phosphorus at numerous monitoring stations over one-year (right) Water column profiles collected from within hydropower impoundments of electrical conductivity with depth (example not from the Mekong).](image-url)
Figure 7-4: Example of data presentation: sediment loads over the wet season at one monitoring station.

| Parameter | Estimated inflow (tonnes/yr) | Estimated Outflow (tonnes/yr) |
|-----------|-----------------------------|-----------------------------|
| TP        | 14,080                      | 3,300                       |
| TN        | 91,520                      | 21,450                      |
| NO$_{3+2}$ | 27,520                     | 6,450                       |
| NH$_4$    | 5,088                       | 3,935                       |

Figure 7-5: Example of data presentation: nutrient loads entering and exiting an impoundment (example is not from hydropower – example is of inflow and outflow from the Tonle Sap).

Figure 7-6: Example of changes in Ecological Health Class over time at sites in Cambodia and Lao PDR (from MRC Aquatic Ecological Health report card)
7.4 Correlation within the database

One of the contributions the JEM team can make to the development of an MRC-wide data management system is the development of a relational or correspondence table that would promote and enhance the integration of information between disciplines. One of the hinderances to integrating different thematic data sets is that the results for each theme are stored in a theme-specific data base that cannot be easily integrated. JEM proposes to enhance linkages between the themes by identifying how sites/stations are inter-related.

To do this, data sets need to be connected spatially, e.g. which sites/stations are relevant to which other sites/stations for each discipline and between disciplines, and temporally, e.g. which measurements should be logically correlated or integrated between disciplines and sites/stations.

An example of spatial linking is provided in Figure 7-7, which shows an aerial photo of the Don Sahong region and hypothetical monitoring places for different disciplines. The JEM project proposes to develop a table of 'correspondence' or linkage that would allow a user to automatically query relevant data from other monitoring disciplines. In the example shown, the fish catch at site 'A' could be analyzed with respect to the discharge measured at nearby station 'B' and the sediment loads or concentrations recorded at station 'C'.

![Figure 7-7. Example of how monitoring sites/station from different disciplines are spatially related](image)

Similarly, datasets could be linked temporally, with linkages established between datasets from different themes collected over different time scales (Figure 7-8). For example, monitoring results from one discipline could be analysed with respect to the hydrology on the day of monitoring to provide loads (e.g. for sediments or water quality). The results from fisheries monitoring that might be completed a few days later, could be linked back to the most recent water quality and sediment results. This allows the integration of data sets collected at different monitoring frequency. This is important for the JEM and the MRC in general because monitoring frequency ranges from 'continuous' for water level at HYCOS stations, to annually for Ecological Health Monitoring. EHM monitoring reflects the longer-term changes upstream in flow and water quality and could pick up an extreme flow or water quality event, which would tend to depress the populations of indicator species.
7.5 Identification of change using JEM database system

The JEM monitoring pilots will have collected one full year of monitoring results prior to the start of data analysis by the JEM team. With such a short data set, identifying changes associated with hydropower operations will be difficult unless the longer-term datasets from ongoing MRC monitoring projects are also available for analysis. This will be achieved by incorporating monitoring results from the past 10-years from the MRC Master Catalogue for each discipline into the JEM database.

This larger dataset will be analyzed by each theme leader to identify changes within themes, and a collaborative analysis will identify linkages between disciplines. Examples of approaches to be used include:

- **Hydrology at Xayaburi**: Comparison of flow rates, rates of water level change, and flow duration upstream and downstream of Xayaburi to identify whether storage within the impoundment is altering the timing, magnitude or frequency of flow downstream. The results from Pak Huong upstream of Luang Prabang will be analyzed to better understand the extent and duration of the backwater from Xayaburi;
- **Hydrology at Don Sahong**: Discharge volumes and patterns at Pakse will be compared to the Koh Kel hydrology to understand hydrologic changes through the Si Phan Don at a large scale;
- **Sediment analysis at Xayaburi**: Determination of sediment loads entering and exiting Xayaburi to estimate sediment trapping. The grain-size distribution of material entering and exiting the impoundment will be compared to identify the proportion of each grain-sizes being trapped. These results can be interpreted with respect to potential downstream impacts. Comparison of results with Chiang Khan will inform about what additional sediment loads and grain-sizes are being eroded from the river downstream of the dam;
- **Sediment analysis at Don Sahong** will focus on understanding how sediment loads are changing at a large scale, with the results from Pakse, Koh Kel and Stung Treng...
analysed to document what loads are being transported in the Mekong mainstream, and what loads are entering from the 3S system, and whether these is a large loss or addition of sediment through Si Phan Don area. These results are important at a basin wide scale as they will provide estimates of the sediment loads entering the Cambodian floodplain and eventually the delta.

- **Water quality analysis** will focus on comparisons between upstream and downstream monitoring stations, and in particular the changes in water quality parameters within each of the impoundments. Dissolved oxygen and temperature will be very important measures downstream of the dams, and the analysis will look at any recovery downstream if the water passing through the dam is deoxygenated or at a lower temperature. The new JEM parameter of Chlorophyll-and cyanobacteria will follow the development of algal blooms within the impoundments, especially if information on these parameters in the water entering the impoundment is also measured. The nutrient and turbidity analysis will also inform the growth of phytoplankton in the impoundments.

- **Ecological Health results** will first be converted to the Ecological Health Class for each site, which will be used for comparison on a year-by-year basis. Any changes between sites upstream and downstream would be related to trends in water quality, e.g. pH, COD, conductivity etc. that may be observed in the monthly records of the nearest upstream water quality monitoring sites. Detailed analysis of the species composition and abundance of the bio-assessment taxa would be available to investigate these changes more closely, but would only be used if a major change has been detected.

- **In fisheries**, analyses will focus on three main indicators: species richness, overall abundance distribution between species, and CPUE for a given gear.

- **In Khone Falls**, fisheries analyses will focus on upstream/downstream comparisons, in particular between two long-standing FADM sites: Ban Hat upstream and Ou Run downstream of the dam. Since Khone Falls are a natural ecological barrier regardless of the dam, analyses will also focus, upstream, on any possible difference in catches between pre-dam and post-dam period.

- **In Xayaburi**, analyses will be focused on Pha O village, as this is an upstream site that has been monitored for many years, and that will allow comparisons before and after dam construction. JEM data will allow comparisons between Pha O and Pak Houng villages, i.e. upstream and downstream of the dam, in standardized conditions.

### 7.6 Data input and QA/QC

The line agencies completing the JEM pilot work will report results using the existing or slightly modified reporting forms for each of the monitoring themes. The MCs will complete preliminary QA/QC on the data sets, and the results will be forwarded to the relevant MRC specialist. The MRC and JEM International specialists will collaboratively complete any additional QA/QC checks on the data set before the results are entered into the JEM database.

During this process the JEM team will identify and recommend ways to stream-line the data reporting process. Discussions with the MCs indicate that a web-based or app-based reporting system would be preferable to the present systems. The JEM team will explore existing options for these types of systems, make recommendations about how these systems could be developed and implemented, and provide a demonstration system for one or more of the disciplines. One initial approach could be the development of forms with Access that allow the direct input of field or laboratory results into the system, with QA/QC completed prior to final ‘acceptance’ of the results into the data system. The data entry forms would be accompanied with data validation functions, in order to minimize error data input and ensuring its quality.
7.7 Relationship between JEM and Aquarius databases

The JEM database is required to be a stand-alone system because the MRC does not want external databases linked to its Master hydrologic data base or Master Catalogue. This is a very reasonable and sound approach to data integrity and security, but will require the MRC to extract hydrologic data from Aquarius and provide it to the JEM data base on a regular basis.

An area that the JEM team should work collaboratively with the MRC is the derivation of rating curves in Aquarius for the new JEM stations and checking and updating rating curves at existing stations. The Aquarius data management system has advanced rating curve tools that allow the development and maintenance of high-quality, reliable discharge rating curves. Ideally, in the future, all discharge should be calculated from water level data within Aquarius to ensure curves are maintained and updated in a timely manner.

The discharge and water level results obtained during the JEM pilots at the new stations should be entered into Aquarius as soon as possible following collection to allow for the derivation of preliminary curves for these stations. Time-series of discharge values from these stations would then need to be exported from Aquarius and entered into the JEM data base for use in data integration and analysis. It is proposed that the ICEM database expert works collaboratively with the MRC data management team to achieve these outcomes.
8 REPORTING, GOVERNANCE AND COMMUNICATION

8.1 Reporting and governance

8.1.1 Short term

This project will be overseen by the JEM coordination group, made up of experts from MRC. In particular, the following MRC environmental monitoring experts make up the JEM coordination group:

- Mr Hak Socheat
- Dr So Nam
- Dr Janejira Chuthong
- Dr Prayooth Yaowakhan
- Dr Ly Sarann
- Mr Vanna Nuon
- Mr Palakorn Chanbanyong

The ICEM team will coordination with both the JEM coordination group and with three key staff from GIZ: Dr. Bertrand Meinier, Ms Erinda Pubill Panen, and Ms Mayvong Sayatham.

It is envisaged that during the course of the JEM pilots a mechanism for long-term governance of the full JEM Programme will be developed for discussion at the final EMEG meeting.

The reporting time-lines for the project are detailed in the project workplan (Annex 3), and are also described in section 6 of this inception report. In summary, the reports for the project are detailed in Table 8-1.

| No. | Report                                                                 | Due Date                             |
|-----|------------------------------------------------------------------------|--------------------------------------|
| 1   | Inception report                                                      | Tuesday 28th January, 2020           |
| 2   | Report on equipment procurement, specification checking, installation, calibration and operationalisation | Friday 29th May, 2020                |
| 3   | Proposal on fish passage and fish tagging methodology                  | October, 2020                        |
| 4   | Report on technical training sessions with the JMG in the five disciplines | Friday 31st July, 2020               |
| 5   | Half-year progress reports for Don Sahong Monitoring                    | 1. Friday 31st September, 2020       |
|     |                                                                       | 2. Friday 29th March, 2021           |
| 6   | Half-year progress reports for Xayaburi Monitoring                      | 1. Friday 31st September, 2020       |
|     |                                                                       | 2. Friday 29th March, 2021           |
| 7   | Combined annual report                                                 | 1. Friday 11th March, 2021           |
| 8   | Project final report, including updating of JEM Programme              | 1. Friday 25th November, 2021         |
8.1.2 **Medium and longer-term governance**

Governance is one of the more challenging aspects of transboundary environmental monitoring relating to operation of hydropower dams. There are many different stakeholders involved, including:

- The JEM Joint Monitoring Group
- National monitoring teams for the five JEM disciplines
- The Mekong River Commission
- National decision-makers in river and environmental management
- Xayaburi and Don Sahong hydropower project developers
- National and international environmental/river focused civil society groups/NGOs
- Residents in areas that may be affected by hydropower projects
- Fishermen and women in impoundment and downstream areas
- General public in Lower Mekong Basin

All of these groups have an interest in environmental outcomes, and particularly those near the top of the list have a high level of influence on how monitoring is conducted as well as how the results of monitoring programs will be used to improve environmental outcomes.

In this pilot of the JEM Programme, the governance arrangements that affect monitoring, analysis and sharing of monitoring data, as well as decision-making based on these will be assessed and evaluated. The pilot project reports will include recommendations for involving the different stakeholders, including strengthening communications and data sharing with government agencies and project developers. In particular, current communications and governance mechanisms included in the JEM Programme will be tested, evaluated and recommendations will be provided for where and how these could be adjusted for improved outcomes. The ideas for governance arrangements will be presented and discussed at EMEG meetings as the pilots progress. As the Joint Action Plans for Pak Lay and Pak Beng start to be implemented some of the lessons learnt from the JEM Pilots would be shared and JEM-type monitoring started around these developments.

In the longer term, it is expected that the JEM monitoring will be integrated into the overall monitoring programme of the MRC, and the results reported in the usual way through to the JC and the Council. The EMEG meetings provide the technical oversight of the JEM, and then EMEG reports to the JC and the PDISS. These ideas for long-term governance will be developed and discussed at the data sharing workshop and EMEG meetings, with recommendations forming part of the final report.

8.2 **Communication materials**

In order for the JEM pilots project to be as effective as possibly in achieving its goals, including enhancing transboundary environmental monitoring, there is a substantial requirement for communications materials and outputs. The communications materials are intended to support advocacy to highlight the JEM model as an important contributor to the goal of increasing sustainable development through transboundary cooperation of riverine health in the Mekong. Communication materials are intended to include: i) a promotional video, ii) training materials, and iii) a set of policy briefs.

The following sections of the communications plan outline the main stakeholders in relation to communications products, as well as the three types of communications outputs and the time
inputs required. However, the contract for the implementation of the JEM pilots project does not include any specialist communications position. Within the budget arrangement as outlined in the TOR, ICEM would only be able to provide modest communications inputs through technical backstopping arrangements. The communications materials outputs required for the success of the project, as detailed below, require significantly more input that technical backstopping can provide. As detailed in Table 8-3, the proposed communications outputs require 22 days of specialist communications input from ICEM, as well as specialist input from MRC communications. The 22 days of inputs from ICEM communications specialists is dependent on savings related to equipment procurement.

8.2.1 Promotional video

A short video of around five minutes in length will be produced in the early stages of the project with an anticipated delivery date of May 2020. The main objectives of the video are to (i) introduce JEM and its application in the pilot project sites/stations of Xayaburi and Don Sahong, and (ii) emphasize the JEM’s potential value in enhancing riverine health and transboundary water cooperation across the five key discipline areas in relation to hydropower development in the Mekong basin. The emphasis will be on engaging material presented in an easy to understand format, that will be suitable for a non-technical audience.

The key target groups for the promotional video will be:

i) National decision-makers in river and environmental management
ii) The MRC and
iii) Xayaburi and Don Sahong project developers.
iv) Civil society groups/NGOs and the general public (shared via social media)

The MRC-GIZ team will provide a short text introducing JEM as well as a question to elicit stakeholder views on JEM’s value. Based on this, ICEM will develop a base script/storyboard for the promotional video. The video is intended to be mainly based on an interview format, with material to be collected by the MRC-GIZ JEM team during the February 2020 EMEG workshop and JEM training sessions. Film footage will be edited and the final video produced by MRC-GIZ.

8.2.2 Stakeholders

The main stakeholder groups which have been identified as of key relevance to this project and to which communications products will be directed are shown in Table 8-2. The assessment of the influence that each group has upon the success in achieving project goals is based upon the involvement that each group would have in implementation and using the results of the monitoring.

Table 8-2: Main stakeholder groups for JEM

| Stakeholder groups                                              | Influence over success of project goals |
|-----------------------------------------------------------------|----------------------------------------|
| JEM Joint Monitoring Group                                      | High                                   |
| National monitoring teams for the five JEM disciplines           | High                                   |
| Mekong River Commission                                         | High                                   |
| National decision-makers in river and environmental management  | High                                   |
| Xayaburi and Don Sahong hydropower project developers           | High                                   |
| National and international environmental/river focused civil society groups/NGOs | Medium                                |
Residents in areas of the hydropower projects | Medium  
General public in Lower Mekong Basin | Low

Each communication product required for the project is described in further detail below, including a description of product objective, specific stakeholder group targeted, and team members involved.

### 8.2.3 Policy briefs and factsheets

Assuming budget availability, ICEM will produce two (2) short policy briefs and two (2) factsheets about the project during its second half. The planned delivery date for these is April 2021. These policy briefs and factsheets will focus on distilling main project findings and policy implications for each key area and provide future-oriented recommendations.

**Two policy briefs on the JEM pilots (main target group will be decision-makers):**

- One policy brief on the process of the JEM pilots in 2020 (learning process, objectives of JEM, how the pilots project will feed into and inform the final JEM Programme, and what this means for MCs);
- One policy brief on the outcomes of the JEM pilots in 2021 (Provisional recommendations for adjustments to the JEM Programme, as well as initial findings and achievements in relation to joint work between MRC, MCs and Developers).

**Two fact sheets on the JEM pilots (main target group will be civil society):**

- One factsheet on the process of the JEM pilots in 2020 (learning process, objectives of JEM, how the pilots project will feed into and inform the final JEM Programme, and what this means for MCs);
- One factsheet on the outcomes of the JEM pilots in 2021 (Provisional recommendations for adjustments to the JEM Programme, as well as initial findings and achievements in relation to joint work between MRC, MCs and Developers).

Despite the wording above for factsheets and policy briefs mirroring each other, the content and language in the policy briefs and factsheets will be adjusted to ensure appropriateness for each target group.

All four products (two policy briefs and two factsheets will be translated into the 4 MC languages (Khmer, Lao, Thai and Viet Namese).

The briefs will be produced by ICEM in accordance with MRC branding guidelines, and with support from the MRC-GIZ team. They will be made available in both online and ready-to-print format, using contemporary designs.

### 8.2.4 Training materials

As the revisions to the JEM Programme are being finalised, they will be accompanied by a training package that is intended to support scaling up of the JEM Programme for use on other hydropower project locations, as well as more broadly. The planned delivery date for these training materials is September 2021.
The training materials to be prepared (assuming sufficient budget) will focus on ensuring sustainability of the JEM model. Using the JEM documents as a base, backed up with on-the-ground experience of implementing the JEM documents at Xayaburi and Don Sahong, the training materials will be an engaging and stimulating resource to assist MRC and Member Countries with scaling up the use of the JEM Programme guidance that will be revised under this project.

It is anticipated that ICEM will lead on the development of the package, in close consultation with MRC-GIZ and adhering to MRC branding guidelines. Modules will be designed using elements such as animation and infographics to enhance engagement with the materials and elucidate complex concepts in an accessible manner. These are all design techniques that ICEM’s communications team are familiar with, having developed similar packages for both national governments and multi-lateral donors in the Southeast Asian region.

The training module will be designed for use by national JEM teams and MRC both as part of this project, and for ongoing training and capacity building after project completion.
9 PROCUREMENT AND LOGISTICS

Logistics and procurement for an important aspect of the JEM project, particularly in the early months of the project. The project requires a significant amount of equipment that national monitoring teams will be trained on during the first half of 2020, and which will then be used by the national teams to conduct the monitoring itself.

9.1 Equipment Procurement

Equipment procurement has followed three separate phases.

i) OTT Hydromet was included as a subcontractor in ICEM's successful bid for the project, and for this reason there is no requirement for a competitive tender for equipment being provided by OTT.

ii) All the remaining equipment, except for that relating to fish pass monitoring, was sourced through a tender process, allowing costs to be compared.

iii) Due to the time required to prepare, and assess, a plan for the fish pass monitoring that would satisfactorily achieve the project goals, the fish pass monitoring related equipment has been put temporarily on hold.

During the project inception phase, the equipment requirements were examined and rationalised. This resulted in a number of items being removed from the procurement process, and a number of changes to other equipment items. The following items were removed from the equipment list, or had their quantities reduced, prior to the procurement process beginning:

i) The two shelters for Hycos equipment (as advised by GIZ on the 15th November, 2019). Because MRC has contracted a company to construct the Hycos shelters, there was no longer a need to procure these.

ii) The high frequency water logger. While this item may be required in the future, currently it is not needed. This is because there is nowhere to install the high frequency water logger within 500m on the downstream side of Don Sahong dam (as advised by GIZ following site visit in November 2019).

iii) One of the three Hycos stations has been removed (reduction from three (3) to two (2) Hycos stations). This is because the existing Hycos station in Luang Prabang is subject to flooding as a result of the Xayaburi dam, and the new Ban Sang Hai location appears as though it may be affected by backwater flooding as well. For this reason, a manual station will be used to assess the appropriateness or not of Ban Sang Hai for a new Hycos station, prior to installation of a permanent Hycos station at this location.

During the procurement process the following changes in equipment were made:

i) Following the initial request for quotations, the BBE fluoroprobe was removed from the equipment list for reasons of cost. An Algal Torch was added to the procurement list to replace the functionality of the BBE fluoroprobe;

ii) Twin bongo nets were removed from the procurement list following Training Event 1 in Luang Prabang, where it was determined that the single bongo nets being procured for use in flowing water would also be suitable for use in the impoundment;

iii) Changes in the scope of the project (including the use of single 5m bongo nets in the impoundment) mean that the number of single bongo nets was increased from two (2) to fifteen (15);
iv) The increase in requirements for single bongo nets was accompanied by an increase in flow meter requirements from two (2) to nine (9).

OTT Hydromet is being contracted to supply the equipment for the automatic hydrological monitoring (HYCOS) stations.

The full list of OTT supplied equipment is provided on Table 9-1:

| Table 9-1: Equipment from OTT |
|-----------------------------|
| **Item**                    | **Specifications**         | **No. required** |
|-----------------------------|----------------------------|-----------------|
| HYCOS station               | netDL500 IP data logger    | 2               |
| (automatic hydrological     |                            |                 |
| monitoring station)         | Solar controller: Solar   | 2               |
|                             | PR1205, 12V/5A, IP32       |                 |
|                             | GSM antenna external 5dB, | 2               |
|                             | 5m cable SMA (m)           |                 |
|                             | Schaltschrank AE 1013.600 | 2               |
|                             | B500xH500xT300 VA 1.4301   |                 |
|                             | Solar panel 12V/30W with   | 2               |
|                             | boom 1" and 10m cable      |                 |
|                             | Rechargeable battery      | 2               |
|                             | 12V/24 Ah, with cable      |                 |
|                             | CBS Bubble sensor for      | 2               |
|                             | water level measurement    |                 |
|                             | Measuring tube, 100 m ID   | 2               |
|                             | 2 mm / OD 4 mm             |                 |
|                             | Bubble chamber EPS 50 for  | 2               |
|                             | tube 2/4 mm dia. (i/o)     |                 |
|                             | ADCON Raingauge RG Pro 02 | 2               |
|                             | 5m cable                   |                 |
|                             | Pole 1m for RG Pro,        | 2               |
|                             | galvanized steel           |                 |

All other equipment will be procured from non-OTT suppliers. Non-OTT supplied equipment is being sourced through a variety of suppliers who responded to an open Request for Quotation process. For each piece of equipment offered through the tender process, the technical specifications and price of the offered equipment were considered. In general, for equipment that met the project specifications, the equipment with the most competitive price was selected and purchased. However, in some cases based on the judgement of team experts, equipment other than the cheapest offering was selected. For example, a number of firms offered ADCP units that the team experts considered to be of inferior quality (and did not match the equipment currently in use by national monitoring teams). The list of equipment (excluding equipment related to fish pass monitoring) procured through the tender process is included in Table 9-2.

| Table 9-2: Non-OTT equipment |
|-----------------------------|
| **No** | **Equipment** | **Required Technical specifications** | **No. required** | **Selected supplier** |
|-------|---------------|--------------------------------------|-----------------|----------------------|
| 1     | Boat          | • Around 6 feet x 20 feet x 2 feet,  | 1               | VGS (Lao PDR)        |
|       |               | • Body made of aluminium             |                 |                      |
|       |               | • Flat workspace in the boat’s bottom (e.g. for ease of storing equipment) and with roof. | | |
|       |               | • Must be able to operate in water as shallow as 0.7m | | |
|       |               | • Must have mounting point for outboard motor | | |
|       |               | • Sides of the boat have to be strong enough to mount a crane and winch capable of lifting 60 kg | | |
| 2     | Boat engine   | • 80 or 85 HP                        | 1               | VGS (Lao PDR)        |
|       |               | • Minimum fuel capacity 80 litres    |                 |                      |
| No | Equipment | Required Technical specifications | No. required | Selected supplier |
|----|-----------|-----------------------------------|--------------|------------------|
| 3  | Crane/winch | • Able to raise and lower 60kg at 1m/s  
• Powered by an electric motor  
• To be mounted on a 20’ x 6’ aluminium hull boat | 2 | Currently working with VGS on this |
| 4  | Handheld GPS unit | • Waterproof.  
• Touchscreen  
• 2 AA batteries.  
• Screen **“**160 x 240 pixels Resolution.  
• Memory: Internal (at least 4 GB).  
• Interface: high-speed USB and/or NMEA 0183 compatible.  
• Waypoints/favorites/locations: at least 2000.  
• Routes: at least xs200.  
• Track log: “**10,000 points, 200 saved tracks.  
• Languages: Thai/ English.  
• Accessories: USB cable  
• Includes map of Lao downloaded onto device | 2 | Úniqtek (Lao PDR) |
| 5  | Horizontal Van Dorn Bottle | • Horizontal Van Dorn Bottles:  
• Designed for trace metal sampling.  
• May be used for organic sampling to concentrations of mg/L.  
• Include bottle, carried case, messenger (45-B10)&100 ft. Lie(62-C15).  
• 5 litre capacity and a minimum of a 30 metre line. | 1 | HYMETCO (Viet Nam) |
| 6  | Logging WQ meter | • Manual Water Quality Logger  
• Capable of recording a set of measurements every 5 minutes for 24 hours, with:  
• Probes for Dissolved Oxygen, pH, Turbidity, temperature (0°-50°), conductivity and ORP (oxidation reduction potential)  
• Each probe with 20m cables. | 1 | Hanna (Viet Nam) |
| 7  | Narrow band spectrophoto meter | • Laboratory spectrophotometer  
• With narrow band (pass) width (0.5 to 20 nm)  
• Capable of reading absorbance at 750, 665, 664, 647 and 630 nm.  
• For measuring chlorophyll | 1 | Hanna (Viet Nam) |
| 8  | Algal Torch | For measuring chlorophyll in water:  
• measures cyanobacteria and total chlorophyll content  
• 0-200 µg chlorophyll-a/l  
• resolution 0.2 µg/l  
• can be deployed to at least 10m below water surface  
• includes internal data logger | 1 | Reeco Tech (Viet Nam) |
| 9  | Camera and tripod | • Waterproof  
• GPS  
• Preferably at least 12 mega pixels  
• Fits tripod with minimum 1.2metre height  
• Accessories: USB cable, manual, tripod (that can extend to at least 1.2metres height) | 3 | Úniqtek (Lao PDR) |
### Required Technical specifications

| No | Equipment                                | Required Technical specifications                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | No. required | Selected supplier          |
|----|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------------------|
| 10 | ADCP unit                                | • 9 (transducers) - Dual 4-beam 3.0 MHz/1.0 MHz  
• Echosounder  
• Depth range: at least 60 metres  
• Bottom tracking: Yes  
• software and specific instrument details That software can collect a loop test and post process the run to establish bed load movement                                                                                                                                                                                                                                                                                           | 2           | VGS (Lao PDR)               |
| 11 | US D-96 Suspended Sediment Sampler       | • Depth-integrated collapsible-bag suspended-sediment/water-quality sampler capable of collecting a 3-liter sample                                                                                                                                                                                                                                                                                                                                                                                                         | 2           | Uniqtak (Lao PDR)           |
| 12 | Bed Grab (scoop) sampler                 | • Can be deployed in 30 metres of water that is flowing at 2 or more metres/second.                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1           | To be manufactured in Lao PDR |
| 13 | 2030 mechanical flow meter               | • Can measure flow rates of 0.1 – 7 metres per second  
• Is suitable for attaching to bongo and impoundment nets                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 9           | Uniqtak (Lao PDR)           |
| 14 | Microscope                               | • Fish larvae microscope with light source  
• Large objective lenses to maximise light intake  
• Stereozoom microscope with zoom 0.7 - 7x  
• Camera port  
• Connectable to computer                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2           | HYMETCO (Viet Nam)          |
| 15 | Bongo nets                               | • mouth opening 100cm diameter  
• net length 5 metres  
• mesh size 1mm  
• shape of the net is cylindrical, however the end of the net should be tied to a collecting bottle, and this makes it a conical shape when in use                                                                                                                                                                                                                                                                                                                                                  | 15          | IFReDI (Cambodia)           |

As a joint environmental monitoring programme, the equipment was not all procured for delivery to Lao PDR, although most of the equipment was delivered there. Table 9-3 shows the delivery country for each piece of equipment procured.

### Table 9-3: Delivery country for equipment procured

| LAO PDR                                      | No. Required |
|----------------------------------------------|--------------|
| HYCOS station (automatic hydrological monitoring station) | 2            |
| Boat                                         | 1            |
| Boat engine                                  | 1            |
| Crane/winch                                  | 1            |
| Handheld GPS                                 | 2            |
| Horizontal Van Dorn Bottle                   | 1            |
| Logging WQ Meter                             | 1            |
| Narrowband spectrophotometer                 | 1            |
| Camera and tripod                            | 2            |
The procurement of equipment is an important component of the project that has implications for later parts of the project. For example, some of the training in March will focus on use of new equipment that the national monitoring and analysis teams do not currently have access to. This includes a narrowband spectrophotometer and an algal torch that will help with field and lab-based Chlorophyll-analysis. To ensure that training is able to proceed as planned, ICEM has been working with suppliers to speed up delivery schedules. For example, Hanna instruments has committed to delivering the spectrophotometer and water quality meter within 35 days of the purchase order being supplied. Similarly, ReecoTech has confirmed they can supply an algal torch within 6 weeks.

### 9.2 Installation of fixed equipment

This section of the report is just concerned with equipment that is designed to be installed in location (i.e. fixed in location for at least the period of the JEM pilot projects). Use of equipment that is mobile (e.g. the boat and the equipment that will be operated from the boat, including the Van Dorn bottle, the USGS D-96 Sediment Sampler and the winch to operate the sediment sampler), is described in Section 2 (Approach to technical issues adopted by ICEM team).
9.2.1 Don Sahong

There are limitations in the existing network of automatic hydrological monitoring stations (HYCOS stations) upstream and downstream from the Don Sahong hydropower plant (DSHPP). In particular, the existing stations, at Pakse (145km upstream from the DSHPP) and at Stung Treng (45km downstream from the DHSPP), provide little information on the local hydrological impact of the combined hydropower developments upstream of Cambodia including the DHSPP because the existing station records flow downstream of the 3S river inflow.

To address this issue, the JEM pilots project will install a HYCOS station approximately halfway between the DSHPP and Stung Treng, ensuring that it is located far enough upstream of the confluence of the Mekong with the 3S system that backwater influences from the 3S system can be discounted. Additionally, this HYCOS station should be located in an area where the Mekong is confined to a single channel.

The location for this station has been identified, and the shelter for the equipment is well advanced. The station is located at Koh Key (Figure 9-2), and locations for discharge measurements has been identified at ADCP1. During periods of very low flow, it navigation to ADCP1 is not possible, measurements will be completed ad ADCP 3, upstream of the 3S backwater.

*Figure 9-1: HYCOS monitoring station locations downstream of DSHPP*
9.2.2 Xayaburi

1. **High Frequency Water Quality Logger:** The design for the JEM pilot project included installation of a high frequency water quality logger on the downstream side of Xayaburi Hydropower Plan (HPP), and within 500 metres of the dam. However, in November 2019, MRC, LNMCS, DMH and GIZ conducted a site visit to Xayaburi and determined that there is no suitable location for installing the high frequency water logger in the specified area. For this reason, as at the time of drafting this inception report, the high frequency water logger is not planned to be used. The decision not to install this water logger may be reviewed later in the project.

2. **HYCOS stations:** There is an existing HYCOS station upstream of Xayaburi HPP, located at Luang Prabang, this station may be complemented by a new station upstream once
the extent of backwater flooding from Xayaburi is ascertained through establishment of a manual site.

3. A HYCOS station will be established downstream of Xayaburi, with an appropriate location identified by MRC, LNMCS, DMH and GIZ in November 2019. This place may ultimately be flooded out by the backwater of the Pak Lay HPP, but in the short-term will provide information about the impact of Xayaburi operations on the flow and water levels downstream of the place. The civil works for this HYCOS station will be contracted to DMH under MTC budget, with instruments provide by GIZ through this project.

9.3 Training arrangements

Since the original TOR, the training requirements for the project have evolved in discussion between MRC, GIZ and ICEM. The revised training schedule, including dates, locations, as well as numbers of trainees and where they will come from are shown in Figure 9-3.

| Event 1 | Event 2 | Event 3 | Event 4 | Event 5 | Event 6 |
|---------|---------|---------|---------|---------|---------|
| Training Thaddeus & LPS (Lao) 20-27 Feb 2020 | Training in-field FF (Cam) 2-6 Mar 2020 | In-situ Review of Reporting requirements and In-field Review of Fisheries and Larvae Data Forms and QA/QC for Data Collection and Reporting of Results to the MRC | Training LPS (Lao) 20-27 Mar 2020 | Training LPS (Lao) 30 Mar-1 Apr 2020 | Workshop VTC (Lao) 6-8 Apr 2020 |
| 4 days | 3 days | (3 days) | (3 days) | (3 days) | (2.5 days) |
| JEM—Fish-Abundance and Diversity Monitoring (JAM) and JEM Technical Training | First Part: JEM Laboratory Training on Larvae Monitoring and Taxonomic Identification of Fish Larvae and Juveniles | JEM Water Quality Training both Field and In-house Training | JEM Aquatic Ecology Training both Field and In-house Training | Workshop on Chlorophyll Analysis using narrow band spectrophotometer lab analysis training |
| (5 Loa lease from Vientiane & 5 pax from PMO) | 5 Loa lease from Vientiane & 5 pax from PMO | 5 Loa lease from Vientiane & 5 pax from PMO | 5 Loa lease from Vientiane & 5 pax from PMO | 5 Loa lease from Vientiane & 5 pax from PMO |
| Aphant & Eric | Aphant & Eric | Aphant & Eric | Aphant & Eric | Aphant & Eric |

| Event 7 | Event 8 | Event 9 | Event 10 & 10b |
|---------|---------|---------|---------------|
| Training Chiang Khan (Thailand) 20-25 Apr 2020 | Training Pakse (Lao) 4-13 May 2020 | Training VTE (Lao) 23-27 July 2020 | HYCOS Training: Dth Xayaburi, 10th Stung Treng (Only HYCOS stations are installed) |
| (5 days) | (10 days) | (5 days) | (3 days) |
| Technical Training for Sediment Transport and Discharges Measurements and JEM—In-situ Review of Reporting Requirements and JEM Review of Laboratory Techniques for Determination of Sediment Masses in Samples | JEM—Fish Passage Monitoring Training both in House and Field Training | Second Part: JEM Laboratory Training on Larvae Monitoring and Taxonomic Identification of Fish Larvae and Juveniles | HYCOS maintenance training provided by GIZ |
| Hydrology and Sediment | Fisheries | Hydrology and Sediment | GIZ |
| 5 Loa lease—2 from Vientiane, 3 from Luang Prabang, 2 from Pakse | 5 Loa lease—2 from Vientiane, 3 from Luang Prabang, 2 from Pakse | (2 Loa lease from Vientiane & 5 pax from PMO) | 5 Loa lease from Luang Prabang & 2 pax from Stung Treng |
| Aphant & Eric | Aphant & Eric | Aphant & Eric | GIZ |

Figure 9-3: Training schedule for JEM pilots project
9.3.1 Training logistics

ICEM will contract a Training Events Manager to manage the training events in all three JEM countries (Lao PDR, Cambodia and Thailand). The Training Events Manager will be responsible for all the logistical arrangements for the training events, including booking venues and catering, facilitating transport and accommodation arrangements, organising interpretation services, and paying DSAs to participants. The person filling this role will be responsible for the areas detailed in Table 9-5.

The Training Events Manager will be supported ICEM technical backstopping staff, and under this position, ICEM will also provide events coordinators in each of the three countries as necessary to support the logistics and administration aspects.

Table 9-5: Responsibilities for events coordinators & ICEM support staff in each country

| Tasks                                    | Events Coordinator Tasks                                                                 |
|------------------------------------------|------------------------------------------------------------------------------------------|
| General duties                           | Support to the Project Manager (PM) and the team with overall administrative and financial matters, especially for admin and financial matters relating to logistic arrangements for workshops/meetings/field mission |
| Workshops and meetings organization      | ▪ Collect quotations for various services such as workshop/meeting venue; lunch and tea break (if event is not organized at a hotel); workshop facilities (translation equipment if required, LCD projector, etc); translation service, car rental etc. Make comparison of quotations for contract; ▪ Review the quotations, prepare the cost estimate... before sending to PM the final package to submit to GIZ; ▪ Prepare logistic guidance for participants; ▪ Contact, sending the invitation letter with logistic guidance and follow up with participants on their participation; ▪ Travel arrangements for participants and project team members: Arrange land transportation, domestic flight and hotel accommodation based on the final Mission Plans ▪ Prepare workshop folders for participants including printing of handouts/materials; ▪ Prepare package for using in the workshop: forms... ▪ Provide support during workshop in addition to facilitation as needed; ▪ Make payments to participants (if applicable) and service suppliers based on the approved cost estimate. ▪ Perform other work in connection with the workshop as may be reasonably requested by the team. |
| Consolidation of workshop/meeting expenses| ▪ Consolidate all the training associated expenses with a full package of receipts/supporting documents to Finance for preparation of claim for submission to GIZ |

In addition to the specific training sessions, ICEM will be responsible for managing and running the Regional Data Sharing and Analysis Workshop that will be held in July 2021. The Training Events Manager, supported by ICEM staff, will directly manage and coordinate the logistics for this workshop, with particular responsibilities including:

i. Concept development,
ii. Preparation of workshop inputs,
iii. Co-facilitate the workshop and documenting outputs and discussions,
iv. Arranging the venue,
v. Inviting participants, including managing travel, accommodation and DSA arrangements, and
vi. Organising interpreters, and catering.
10 DESIGN OF TRAININGS

The different trainings in each of the disciplines are discussed below with summary training module descriptions provided in Annex 2.

10.1 Hydrology

The hydrology training will have two components. One related to the installation and commissioning of the new HYCOS stations which will be provided by OTT, and the other to the field-based measurement of discharge using the ADCP. The operating procedures for the HYCOS system are consistent with IS) 4373 and WMO 2010. In addition, Standard Operating Procedures have been developed for field-based discharge measurements.

10.1.1 Installation of HYCOS stations

ICEM’s partner OTT will be responsible for the installation and training associated with the new HYCOS stations. OTT was involved in the initial installation of the HYCOS system and therefore has direct experience in the implementation of new hardware and integration with the existing telemetry data system. At each station, installation will include a bubble sensor to measure water level, a rain gauge, a power source and solar panel, telemetry equipment, housing, and an external staff gauge to be used for calibrating the pressure sensor.

No detail on this training is available yet, but training provided by OTT will include:

- Calibration procedures for the bubble sensor based on staff gauge readings for the MC teams;
- Maintenance procedures to ensure the accuracy and consistency of results for the MC teams

The OTT team will also liaise with the MRCS HYCOS manager to ensure that the new stations are communicating with the system and that the received data is in the required format.

The timing of the installation of equipment and training is dependant on when the new equipment can be procured. It is envisaged that training will occur on a station by station basis during the installation and commissioning of the new stations.

The approach and method are not new to any of the MC teams, and the training by OTT will focus on ensuring compliance with the existing and accepted methodology and harmonisation between stations.

10.1.2 Field based discharge monitoring using ADCP

The field teams involved in the JEM (DSMP teams from Luang Prabang, Chiang Khan, Pakse and Stung Treng) and additional participants from Viet Nam will receive theoretical and practical training in the use of ADCP to measure discharge in the river, and to complete a 'loop-test' to measure bedload transport.

To execute the training in an efficient and cost-effective manner, the ADCP field teams involved in the JEM will meet in a central location. This will ensure uniformity between the MCs and teams, and allow the experienced field team from existing stations, such as Luang Prabang, to provide assistance to the Pakse team who do not have experience with ADCP. Similarly, if the
budget allows, it would be advantageous to include one or more ADCP operators from Nong Khai to join and assist the Chiang Khan team. Inclusion of teams from Cambodia and Viet Nam will ensure uniformity and standardization of ADCP methods. Topics to be covered include:

- Physical setup and deployment of the new equipment, as well as maintenance and calibration procedures relevant to the new and existing equipment
- General theory behind ADCP
- Field considerations for completing a discharge measurement (cross-section and flow characteristics)
- Collecting reliable discharge measurements (percent difference between measurements, percent bad bins, etc.)
- Completing a loop-test using bottom reference
- Establishing repeat photo monitoring stations and guidelines for obtaining repeat photos
- Reporting results including the development of a new form for reporting ADCP loop-test results

Day 1: Morning: Set up and calibration of ADCP, including overview of software, Afternoon: Introduction to hydrology and ADCP, including discharge measurements, station considerations when choosing monitoring locations, loop-tests and flow analysis for depth integrated suspended sediment sampling

Day 2: Morning: Field based set-up and calibration of ADCP and field considerations, including boat speed, number of transects, post-processing of transects for SSC measurements, and general station considerations. Afternoon: Repeated discharge measurements and comparison between instruments and gauging station (if possible), and completion of field based loop-tests

Day 3: Morning: Classroom based review of data collection, post-processing of ADCP profiles to obtain summary discharge measurement, including QA/QC, and reporting of results to the MRC. Afternoon: General review and discussion, additional discussion of data analysis if time permits

The location of the training will depend on the timing of delivery of the new equipment, and availability to use existing ADCP and depth integrating equipment. It is likely that the depth integrated samplers will not be delivered until considerably later than the ADCP units, so the training will likely need to be held at a location where a D-96 sediment sampler is available (Luang Prabang, Nong Khai, Stung Treng).

The timing of training is dependant on the procurement of equipment, availability of the MCS and whether the hydrology training will be completed prior to or combined with the sediment training. Designs for this training module are summarised in Annex 2.

Following the February 2020 EMEG workshop, it is proposed to conduct the hydrology and sediment training as a combined activity, to be held in Chiang Khan in April 2020 (April 20 – 24). If the new D-96 and winch / crane for Chiang Khan has not yet arrived, then Thailand will be requested to bring this equipment from Nong Khai. Thailand will be requested to bring the Nong Khai ADCP so there can be two boats operating on the river during the training.

10.2 Sediment

Sediment training will cover the following areas:
• Field collection of depth integrated suspended sediment samples;
• Field collection of large volume depth integrated suspended sediment samples for the determination of suspended sediment grain-size distribution
• Field collection of bed material samples for subsequent grain-size analysis
• Discussion of field considerations associated with identifying appropriate cross-sections for measurements, or cross-sections for repeat cross-sectional surveys

Designs for this training module are summarised in Annex 2.

A tentative training schedule is:

Day 1: Classroom based theory of sediment transport, including suspended load and bed load. Theory behind depth integrated suspended sediment sampling and its link with discharge measurements; theory behind bedload sampling using ADCP (brief) and collection of bed material, and field considerations when choosing a monitoring site.

Day 2: Field based practice in the collection of depth integrated suspended sediment samples, including review of ADCP discharge measurements to determine sampling locations and field-based practice in the collection of bed materials for grain-size determination. Exercises to include set-up of equipment, field sheet completion, physical collection of samples, storage and labelling of samples and associated documentation.

If laboratory-based training is required, it will need to be completed at an alternative time and involve the laboratory technicians rather than the field hydrographers. This will be discussed with the JEM MRC team. If laboratory training is provided, the following processes and procedures will be covered:

• Laboratory analysis of depth integrated suspended sediment concentration;
• Laboratory analysis of grain-size distribution of suspended sediment;
• Laboratory analysis of grain-size distribution of bed material.

As stated in the hydrology section, the training is scheduled for April 2020. It is unlikely that the new D-96 will be available by this date, and it is proposed to request Thailand to bring the D-96 and DSM boat to Chiang Khan for the training. Although existing equipment could be used to train the new teams, it is preferable to complete the training following acquisition of the equipment so the teams can immediately use the equipment after the training. This will also allow for a review of ADCP methodology which will be useful for the teams using new equipment (Chiang Khan and Pakse). One consideration for the JEM may be to discuss with Thailand the potential to share the D96 at Nong Khai with the Chiang Khan team from the beginning of JEM until the CK team has received the new equipment. This would provide a more coherent data set.

10.3 Water quality and Ecological Health monitoring

Three training modules are envisaged for the Water Quality and Ecological Health monitoring, including:

1. JEM Water Quality monitoring, including use of Algae Torch and chlorophyll sampling
2. JEM Aquatic Ecology Training with use of AlgaeTorch for phytoplankton sampling
3. Laboratory-based training on Chlorophyll-analysis using narrow band spectrophotometry.

Designs for these three trainings are summarised in Annex 2.

Both modules will be focused upon the Lao national teams undertaking the regular water quality samples and the once yearly ecological health monitoring. All of the participants will have been involved in this routine monitoring so will be familiar with the procedures for both disciplines, and so the focus for the trainings will be upon the use of new equipment and procedures required for the additional tests, especially for chlorophyll, algal-based turbidity measurements and AlgaeTorch measurements.

The objectives of the WQ and EHM trainings in Luangprabang are that trainees should:

1. Be familiar with the JEM monitoring components for WQ and/or EH, including sampling locations, timing etc.
2. Be refreshed on the current WQ and/or EH measurements and samples
3. Be proficient with new equipment for water sampling, including a) Horizontal Van Dorn Bottle, b) Handheld GPS unit, c) Logging WQ meter, d) sample preservation solutions, e) BBE AlgaeTorch (for WQ and EHM training).
4. Be familiar with QA/QC and reporting requirements and database entry

The field-based WQ and EHM modules will cover the sampling protocols, and sampling locations and timing requirements of the JEM pilots, including sampling and preservation of algal samples from river and impoundment water, which is the main focus of additional tests.

However, it will be important also to start the training with a refresher of the other sampling and field measurements that are required, together with a briefing on why the different parameters are important and what impacts from hydropower the changes in the results may indicate. An understanding of these reasons assists with the QA/QC process so that abnormal results can be spotted and cross-checked.

It is anticipated that after the first day discussing the JEM monitoring requirements and familiarising the trainees with the equipment, the second day would consist of a one-day field trip to carry out the full set of monitoring and sampling for each discipline at the JEM monitoring sites upstream upstream of Xayaburi, both in and upstream of the impoundment.

The third day would focus on QA/QC and reporting.

The timing of the training course is important, because the Ecological health monitoring must be conducted before the river starts to rise at the start of the wet season. Thus, the EHM training should take place during March or early April, so that the teams can be prepared for EH monitoring missions immediately following the training. However, delivery of the BBE AlgaeTorch may be a limiting factor.

The Objectives for the WQ Laboratory-based training are for trainees to:

1. Have an understanding of the different methods of Chlorophyll-analysis in water
2. Be proficient in the use of narrow band spectrophotometer for analysing chlorophyll
3. Know how to report and QA/QC results
This training course is laboratory-based and would focus on application of the narrow-band spectrophotometer to measure chlorophyll. It is important that the trainees of this course represent both the laboratory staff who will do the analysis and the team members that will collect and preserve the algal samples.

10.4 Fisheries and fish passage monitoring

The four modules presented in Annex 2 reflect the requirements of the TORs.

1. JEM- FADM technical field sampling training
2. JEM-FLDM technical field sampling training
3. JEM-FLDM laboratory training on fish larvae identification
4. QA/QC, presenting results, reporting

The training on Fish Passage monitoring and fish tagging will be developed after the pilot study proposal has been agreed and trialed.

An additional theme - training in data management and simple data analysis is proposed after data entry and QA/QC as part of the capacity building of the national JEM teams.

Experience shows that line agency officers often lack basic knowledge in data handling (full data matrices, labelling, coding, referencing), simple data processing (error checking, outliers, Excel dynamic pivot table) and framing analyses through research questions (questions to be answered). The JEM documents and Sampling guidelines for fish immediately jump to more complex calculations such as Shannon-Wiener or Margalef’s indices, Pielou’s evenness, advanced tools such as Bray-Curtis similarity matrix or multivariate statistics, or even very complex processes such as the creation of dendrograms using hierarchical agglomerative clustering or permutations using specialised packages (SIMPROF, PRIMER). However, i) these tools are not usable if data are not organized, cleaned and reliable; ii) many simple questions (e.g. trends in abundance, in species richness) can be answered with simple tools, and iii) the sophisticated methods mentioned above correspond to PhD level with a solid background in statistics - something most national officers do not have.

For this reason, and in order to set a first step towards local analysis of JEM monitoring data, we propose an initial training in data handling and data analysis. Based on the feedback provided at the end of that first training, more complex tools can be proposed for training later in the course of the project.

Note: The TORs for Don Sahong HPP list a series of expected training courses. These include specific training courses reflected above (FADM and JEM methodologies; elements about data analysis and quality control) but also a long list of generic topics (status and trend in Mekong fisheries; how hydropower impacts environment, fish and fisheries; indicators for fisheries assessment; interpretation and integration of monitoring results from different disciplines) that:

- is not reflected in Annex 5 (list of trainings) of the ToR of the present study;
- is largely covered by the May 2019 training provided to MRC staff in Luang Prabang;
- is not necessarily reflected in the time allocation in the region to provide such training.

For these reasons, these latter modules have not been developed here, since they were not included in the TOR for the present study.
11 WORKPLAN AND SCHEDULING

11.1 Timing constraints

The project has a number of timing-related constraints that fit into ecological, procurement, and logistical preparation for training workshops.

Ecologically, fish pass monitoring is most effective during certain times of the year when there are large numbers of the target species of fish migrating. At Don Sahong, for example, the period over May and June will be most effective for fish pass monitoring, with another window in January to February. There are similar ecological constraints at Xayaburi, however because the dam is further upriver, the timings of the windows are not the same. Since this JEM pilots project is not undertaking fish pass monitoring at Xayaburi dam, the timing constraints for this section of the river have not been investigated.

Procurement related timing constraints relate primarily to the time needed for preparing and signing contracts with suppliers, shipping times, and customs clearance times. In terms of preparing and signing contracts, the time required is to ensure that bids have been transparently assessed, that technical specifications have been met, that there is agreement between ICEM and the supplier about transport and insurance arrangements, and that GIZ/MRC have had time to review and approve contracts. Most suppliers have indicated two to three months shipping time, and in addition the ICEM logistics and administration officer recommends allowing up to one month for customs clearance processes.

Training workshops require time for development, including ensuring that training programs have been prepared and approved by GIZ/MRC, that participants have been invited and are available (which requires that training sessions are organised well in advance).

11.2 Work plan phases and activities

The project work plan has four phases (Annex 3): (i) Inception, (ii) Equipment installation, data collection and training, (iii) Data analysis and reporting, and (iv) Knowledge consolidation and dissemination. There is some overlap between the different phases. For example, the project plan will be presented in the second half of February at a regional meeting as part of the inception phase, however procurement processes such as customs clearance, under phase two, should already have begun by this time.

The inception phase of the project will be finalised in February 2020. The main activities and outputs of the inception are to ensure governance arrangements are clear to everyone involved in the project and that the project plan (as per the inception report) has agreement from stakeholders. In particular, the JEM Coordination Team from MRC and GIZ, but also probably involving some outside experts with experience and licenses in fish tagging.

Phase two of the project will run through until July 2020. The main activities under this phase will be: (i) equipment installation, calibration, and operationalisation, (ii) development of the fish tagging methodology, including means to compare different tagging systems, (iii) Refining the training concepts and developing the logistics arrangements for the training sessions, (iv) Deliver training, (vi) Begin fish tagging and monitoring, and (vii) Prepare a training report that will be included in the project mid-2020 report.
The project’s third phase will focus on continuing data collection, as well as its analysis and reporting. This phase is the heart of the project, with the national monitoring teams conducting data collection activities, and being supported by the ICEM team for data analysis and reporting. The ICEM team will provide oversight of monitoring activities for quality control purposes. The primary outputs of this phase will be documentation of, and reporting on, environmental monitoring findings, (ii) Revision of monitoring procedures following initial data analysis, in order to improve the quality and comparability of data that is collected, (iii) Begin developing mitigation recommendations for factors where negative environmental impacts are being observed, and (iv) Report on the findings in a basin-wide context.

The fourth phase of the project will focus on consolidating and disseminating project findings. This will be done through preparation of communications materials, two workshops and through reporting processes. The communications materials section of this report details the communications outputs and their anticipated delivery dates. In summary, there will be three communications products prepared during the project comprising (i) a short promotional video, (ii) several policy briefs, and (iii) a set of training modules for the JEM process. The video will be prepared early in the project, during the technical training programme and the policy briefs will be prepared for early 2021. The training modules will be prepared in parallel with recommendations for adjustments and improvements to the JEM documents, with expected delivery in September 2021. The dates indicated for the communications materials are guides, as exact timings will be determined for maximum communicative effect.

The two workshops that will be conducted in the fourth phase will be the regional data sharing and analysis workshop in July 2021, and the regional EMEG meeting that will be held in October 2021. The final components of the fourth phase of the project will be preparation and submission of a final project report, which will occur at the end of 2021.

11.3 Milestones and reports

The project has nine key milestone reporting requirements, as follows. The proposed contents of each report are outlined in Annex 4:

1. The inception report: this report details the proposed workplan for the project, and ensures that ICEM and other project stakeholders have a common understanding of project objectives, timelines, reporting requirements and challenges;
2. Report on equipment procurement: this report will detail equipment procurement process, describe any major challenges and how they were dealt with, as well as confirming equipment installation and operationalisation;
3. Proposal on fish passage and fish tagging: this is an additional milestone report that has been incorporated into the project subsequent to contract signing. The purpose of this proposal is to outline a methodology for comparing both the effectiveness, and the sustainability of, different fish tagging methods including plastic, acoustic and radio tagging.
4. Development of a database for data storage and sharing: this database will be developed by July/August 2020 in order that it can be used for storing environmental data collected during the project. The database will be developed in collaboration with MRC database specialists to ensure that it can be migrated into the MRC database at a later date. The database design will also support the data storage and accessibility and comparison from the five different disciplines of monitoring that this JEM pilots project focuses on (hydrology, sediment/river morphology, aquatic ecology, water quality, and fisheries);
5. Training report: Reports on each training session will be prepared immediately after the completion of the training. A consolidated training report will pull all these together and will be submitted in July 2020. Its purpose will be to detail the progress achieved through the training, including reporting on discussions and other outputs from each training session; it will make recommendations for future training needs.

6. Half yearly pilot sites/stations progress reports: These progress reports will be submitted at six monthly intervals during the first year, with reports for each pilot site/station (i.e. in September 2020 and March 2021 there will be two progress reports submitted for the Xayaburi monitoring, and two progress reports submitted for the Don Sahong monitoring;

7. Communications materials: These materials will add value to the project by making the environmental monitoring information, analysis and mitigation and adaptive management measures, more widely available in easily digestible formats. The details of what the communication materials are suggested in section 7.5;

8. Annual combined report for first year of project: In addition to the pilot site/station half-yearly reporting, there will be an annual combined report developed for the whole project. This will be submitted by March 2021;

9. Final report: The final report will consolidate the learnings of the project, including the training, monitoring, findings and mitigation recommendations, as well as final recommendations for improvements to the monitoring and data sharing and analysis processes. This includes the finalisation of the JEM Programme.

11.4 Deployment of team members

The ICEM expert team consists of four international experts, one national database specialist, and one logistics and administration support specialist, who will manage logistics related to the training events and the regional data sharing workshop. The international experts will conduct the initial training sessions on location in Thailand, Lao PDR and Cambodia, and following this will provide oversight and quality control through regular assessment of the data collected by the national monitoring teams. Thus, the international experts will primarily be deployed in the early stages of the project over the period January through July 2020. Three of the international experts (the hydrologist, fisheries expert, and the water quality and ecology expert) will also be deployed two times in the final stages of the project, during July and October 2021.

The planned number of deployed days for each expert over the course of the project is detailed in Table 11-1.

| Expert                                | Number of Field days |
|---------------------------------------|----------------------|
| Hydrologist                           | 45                   |
| Fisheries & Fish Passage Specialist    | 64                   |
| Water Quality & Aquatic Ecology Specialist | 45               |
| Fish Larvae and Taxonomist Specialist  | 21                   |
| Database Specialist                   | 0                    |
| Logistics and administration specialist| 44                   |
12 CONCLUSIONS AND CLARIFICATIONS

This inception report has presented the development of the monitoring approaches and requirements of the JEM pilots at Don Sahong and Xayaburi hydropower plants. It has developed the training programme and its different discipline modules, and identified the need for a proposal for the pilot fish passage monitoring to be developed. It has explained the logistic and governance arrangements and established a schedule for implementation, especially for the trainings.

However, in the development of the inception report a number of issues requiring clarification and decision have been identified – these have been expressed in italics throughout the report and they are pulled together in this section by discipline. They will form the basis for discussion at the inception meetings.

12.1 Hydrology and Geomorphology

There are several issues that require discussion and decision before finalization of the training packages. These include:

- What location is best for the field based ADCP and depth integrated suspended sediment sampling training? Chiang Khan is recommended
- Is it feasible to have multiple boats equipment with suitable equipment available for the training? This may be complicated, but with only one boat and so many trainees, practical training may be limited.
- A supplementary training following delivery of the D-96 sediment samplers would be desirable, but has not been budgeted for. If so, where should it be located and who should attend?
- Is it possible to schedule a supplementary training for the laboratory training. This training would need to be completed at a location with a sediment laboratory (Chiang Saen, Vientiane, Phnom Penh, Chau Doc). The laboratory training will take place in Chiang Khan where there is a laboratory equipped for sediment analysis.

12.2 Water Quality and Ecological Health Monitoring

The water quality and ecological health monitorings of the JEM sites/stations are rather straightforward since they are an extension of the existing MRC programmes with national teams who are already experienced with appropriate equipment. Training will need to focus upon the requirements of new equipment and the sampling and analytical protocols associated with the additional parameters, especially for chorophyll, PAR and phytoplankton.

12.3 Fisheries and fish passage monitoring

Following discussions during the inception phase and feedback received, the focus of the present Pilots in Fisheries should be on:

- adjustments to the current fish abundance and diversity (FADM) protocol based on the monitoring of fishers’ gears in locations selected by Member Countries;
- final definition of a monitoring based on gillnets in the same locations,
- proposal of a simple methodology for rapid frame surveys;
- adjustments to the existing fish larvae sampling (FLDM) protocol in locations selected, and
• definition and feasibility analysis of a fish passage study in Khone Falls.

The other sampling protocols mentioned in the draft JEM documents (seine net sampling, electrofishing, sampling of various habitats) will not be considered here.

**Study sites (FADM and FLDM)**

*Upstream of Don Sahong:* Muang Saen Nua in Laos (14° 5'51.11"N, 105°47'2.18"E; new site)

*Downstream of Don Sahong:* Ban Hang Khone in Laos (13°56'15.59"N, 105°56'54.32"E; new site)

plus Ban Hat and Ban Hang Sadam in Laos (upstream of Don Sahong), and Ou Run in Cambodia.

*Upstream of Xayaburi:* Pha O (19°56'4.39"N, 102°12'21.97"E; new site)

*In the Xayaburi impoundment:* Tha Deua (19°27'12.80"N, 101°49'14.38"E; new site)

*Downstream of Xayaburi:* Pak Houng (19°09'46.6"N 105°57'42.49"E; new site)

**Monitoring of fishers**

The protocol consists in monitoring the gear and catch of 3 fishers in each site. This monitoring will use log books. The parameters of the sampling will be those defined in the draft JEM documents. The catch of the 3 fishers will be recorded each day. Data will be entered in the existing FADM database.

We recommend updating identification manuals for fishers (and scientists), and developing systematic tables of equivalence tables between local common names and scientific names. However, these activities will not be part of the pilot project.

In order to better cover transboundary impacts and build on synergy opportunities, it is recommended to set a formal agreement with IFReDI for a collaboration around at least two sites.

**Standardized gill nets**

The protocol consists in sampling fish by three local fishers using a standardized set of gillnets of different mesh sizes, once a week, each week of the year. A sub-sampling by habitat is not required.

It was decided to opt for the following distribution of 14 mesh sizes (14 panels of 8m width and 2.5m height)- to be officially confirmed:

| 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 90 | 95 | 100 | 105 | 110 | 115 | 120 | 125 | 130 | 135 | 140 | 145 | 150 |

The parameters are detailed in JEM documents Annex 20. Data will be entered in a database to be created.

**Frame surveys**

The theme of the frame survey should be limited to fisheries. The objective is to assess the status and trend of fisheries in target sites.
Each frame survey should be kept simple, without major logistical requirements. The indicators of the frame survey will focus on Resource status, Income from fish, Labor in fisheries, Fish in nutrition, and Management.

The target sites will be the villages of the FADM sites.

There will be no extensive household interviews, but a focus instead on i) key informants, and ii) group discussions with fishers for fishery issues, and with groups of random households for other generic issues. Questions on species will focus on about 30 species carefully selected;

The approach will include reconnaissance surveys in each village, design of a questionnaire building on the one tested during the February training, and presentation of the final methodology to the Member Countries in October 2020 for implementation in 2021.

FLDM

The protocol will use the same 1 m diameter, 5 m length and 1 mm mesh size net for both river and impoundment. Further testing will confirm this choice.

Larvae will be sampled once in each site, 2m below the surface, in places at least 3m deep. Two station in each location: one on the right bank and one on the left bank. Sampling each week, and twice a week if budget and resource allow. The parameters of sampling larvae and juvenile fish remain the same as those of the previous FLDM programme (see Halls et al. 2013).

FLDM sampling sites:

*Upstream of Don Sahong*: Leuad Kuey (14°22’0.98”N, 105°51’58.10”E)
*Mouth of the Don Sahong impoundment*: Hoo Sahong (13°58’35.77”N, 105°57’21.61”E);
*Downstream of Don Sahong*: Veunkham (13°55’25.77”N, 105°59’17.67”E) and Preah Romkel in Cambodia (13°54’4.63”N, 105°57’52.34”E)
*Upstream of Xayaburi*: Pha O
*In the Xayaburi impoundment*: Tha Deua
*Downstream of Xayaburi*: Pak Houng

Fish passage

The diversity of species and stream sizes to be monitored clearly requires the use of more than one kind of tag and receiver. The lack of specification about the tags to be used in the DSHPP pilot TORs does not allow starting the fish tagging study immediately.

A thorough analysis of the specific constraints and requirements for pit tags, depending on local stream features and target species, is required. A detailed desk study for tag selection, possibly involving Fish-Pass company scientists, will be undertaken. Clarifying and finalizing the fish tagging protocol should be done before October 2020.

During the inception period, a collaboration with Charles Sturt University (CTU, Lee Baumgartner’s team, already doing tagging at Xayaburi Dam) was discussed, in relation to possible additional funding from AWP/DFAT.

The study of fish passage at Khone Falls is extremely complex; the methodology is not operational and requires a substantial selection and testing phase before fish passage itself can be assessed. This selection and testing phase will be the focus of activities in 2020.
Testing fish survival rates and effectiveness of antennas is the first priority. The focus of testing will be on PIT tags, but testing of acoustic tags will also be undertaken by CTU. Testing capture-recapture options (external marks, PIT tags for fish to be recaptured by fishers) will also be considered. A report documenting the methodological approach and next steps is expected by October 2020.

The testing phase will be complemented as much as possible with training of national partners in tagging methods; this training will be done to the extent possible by CTU, around November-December 2020. When testing is done in the field, Hoo Sadam and Hoo Xang Pueak channels with be the priority options.

The study of fish passage at Khone Falls will also be addressed through a survey of local ecological knowledge, to be undertaken with the contribution of a national consultant, before October 2020.
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The study of fish passage at Khone Falls will also be addressed through a survey of local ecological knowledge, to be undertaken with the contribution of a national consultant, before October 2020.

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