Review of the Decentralisation of Core River Basin Management Function Activities

Undertaken for the Mekong River Commission as part of the Mid-Term review of the Strategic Plan 2016-2020

22 February 2019

Table of Contents

List of Tables

List of Figures

Mid-Term Review Team

The mid-term review of the Mekong River Commission's Strategic Plan 2016-2020 was conducted by Mr Jeremy Bird, Ms Klomjit Chandrapanya, and Dr Benjamin Docker, with the support of Ms Nguyen Thi Phuong Lam and Mr Nguyen Nhan Quang on the decentralisation component that is the focus of this report. A separate Mid-Term Review report covers the full scope of the Strategic Plan 2016-2020 and includes the overall findings and recommendations from this decentralisation component.

Acknowledgements

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Some notes on terminology:

1. The report uses the generally adopted convention of referring to *The Study on the Sustainable Development and Management of the Mekong River* commissioned by the MRC Council in 2011 by the shortened name, '*The Council Study*'.

2. References to 'line agencies' is a generic reference relating to the ministries, departments, institutes and agencies of Member Country governments that have mandates relevant to MRC's work programme. This includes sector, thematic and regulatory agencies and the ministries of foreign affairs. Some Member Countries may also refer to these agencies as 'implementing agencies'.

Executive Summary

This review has examined the status of decentralisation of the Mekong River Commission's Core River Basin Management Functions, as reflected in the monitoring and data collection activities under CRBMF1 (*Data acquisition, exchange and monitoring*). It has sought to identify the key issues and challenges being faced by Member Countries (MCs) and the Mekong River Commission Secretariat (MRCS), and presents some options for addressing the problems that are becoming increasingly evident.

Overall, there has been some good progress in the decentralisation process, and it is commendable the way both Member Countries and the MRCS have taken responsibility in giving effect to the commitments made by Heads of Government in the *2010 Hua Hin Declaration*. This is all the more significant given the disruptions resulting from concurrent organisational reform, Secretariat downsizing and several issues that arose beyond the control of relevant agencies. This progress is evident in the clear and unambiguous acceptance of responsibility for monitoring activities by Member Countries as documented in signed handover agreements, and in the ongoing data collection, transmission and reporting activities. Where issues have presented, the MCs and the MRCS have generally found a way to address them. Often this has resulted in delays to the roll-out of decentralisation by pushing back the handover schedule and sometimes it has meant the MRCS stepping-in to use basket funds to ensure the delivery of critical data continues.

All of this demonstrates a shared commitment and appropriate flexibility to ensure that what needs to get done does get done. However, these stop-gap measures can only continue for so long before the more fundamental issues need to be openly recognised and resolved. Principle among these is the difficulty national agencies face in having activity-by-activity budgets approved while at the same time increasing their overall contributions to the MRC budget. Unsurprisingly, national line agencies have a difficult case to make for additional funds for monitoring when finance ministries point to the national funds already committed to the MRC central budget. This difficulty is hitting the two countries least able to cope, the hardest. In addition to increasing the total value of their contributions, Cambodia and Lao PDR are also seeking to increase their proportional share of the MRC budget and at the same time, by the MTR's estimate, face the highest additional financial burden in implementing the decentralised monitoring activities. Something has got to give.

The availability of high quality data and information is critical to the MRC's capacity to deliver on its CRBMFs. Time and again, through the consultations done for this review, participants identified the MRC's knowledge base and unique record of historical data as one of its most valuable assets. The data underpins the procedures, studies, assessments, scenario testing and planning on which the regional knowledge base is built.

Many activities are already carried out nationally – the modality of funding is the central issue. Changes to the initial plan of the 2014 Road Map and the narrowing down from 26 to nine activities indicates there was already a high degree of decentralised implementation within the operations of the MRC. For most activities the on-ground work was already conducted by Member Countries. Decentralisation mostly means funding for these activities is sourced at a national level rather than through the joint MRC budget.

Delays in the roll-out of decentralisation indicate the timing of the initial plan was too ambitious, neither reflecting sufficiently the different capacities of country systems, nor accounting for the major restructuring upheaval and related lack of continuity of staff. A lack of integration between regional and national monitoring networks has also not helped. Although this is something decentralisation should help improve over time, as national agencies take greater control and responsibility for more efficient operations. As at the end of 2018, three activities had been completely handed over[1]. However, the performance of data collection and transmission for these activities has declined. This has mostly been due to lack of resources for operation and maintenance of HYCOS stations, exacerbated in some cases by factors beyond the control of relevant agencies such as changes in national telecommunications networks (*near real-time hydro-meteorological parameters*), but also due to a lack of handover agreements specifying what is required by whom and by when (*ad-hoc provision of socio-economic data*).

Funding directly through line agencies can help crystallise the value national governments place on the work. However, risks include competing national priorities for funding and the need for greater coordination effort to ensure funds available for regional activities across multiple ministries continue to go toward the highest regional priorities. The coordination role of the NMCs throughout the budget process is critical in this regard. In any case a challenge for countries arguing for budget allocation is that despite some exceptions they often do not use the data from their component of MRC monitoring directly. Its primary value to individual countries is through the full regional dataset and in the regional products and services, i.e. the value-added work, produced by the MRC.

2019 is an important year for decentralisation. It will be the first year Member Countries are expected to make a financial contribution to both fisheries monitoring and ecological health monitoring. The MTR is certain this will not happen in all cases, as some countries have indicated they do not have sufficient budget given other national priorities. Two activities proceeding reasonably well are the manual monitoring of rainfall and water levels and water quality monitoring. Both of these are activities for which countries already have well established national programmes and monitoring networks. Nevertheless, even for water quality some important components are still funded through the MRC regional budget (e.g. Proficiency Testing of laboratories) and some countries report they are struggling to purchase basic consumables such as chemicals and glassware. In essence, where the additional costs are of personnel, countries are mostly able to absorb these within their existing budgets. For additional capital and consumables or for procuring specific external expertise where new budget lines may be required, budget submissions are more challenging.

There has been insufficient regional support to the decentralisation process. The 2014 Road Map identified a number of risks associated with the handover of responsibilities. Principle among these was the level of readiness of the countries given gaps in both human and financial capabilities. Recognising this, one of the recommendations of the Road Map was to establish a 'kick-start' fund to support the transition. Ultimately, this fund was not established due to a lack of financial commitments. Perhaps due in part, there has been insufficient focus on regional capacity building

[1] The three activities completely handed over to Member Countries as of December 2018 are: (i) near real-time monitoring of hydro-meteorological parameters (HYCOS stations); (ii) manual rainfall and water level monitoring (other hydro-met stations); and (iii) ad-hoc provision of socio-economic data for basin planning.

and transitional support, not only in relation to the MRCS's coordination and technical leadership role but also in terms of joint country-to-country efforts. A lack of regular basic training, manuals and supporting tools in local languages, mechanisms to manage staff turnover and encourage compliance with operations and maintenance procedures have all been a feature.

While the basket fund could have been used for joint efforts in this regard, there are no specific outputs identified in the Strategic Plan as supporting the decentralisation of CRBMF activities. Instead, each division is responsible for overseeing relevant monitoring activities under Output 6.1 of the Strategic Plan. Having a dedicated Output in the Strategic Plan may have enabled greater regional focus on the transition support and capacity building that was identified as necessary in the 2014 Regional and National Road Maps.

This review identifies there are two key issues that although not strictly related to decentralisation, it is becoming increasingly apparent will need to be confronted as resources decline. These are: (i) the overall scope of the monitoring effort and the way in which it is integrated with national systems; and (ii) the supporting information and data management systems that enable more effective use of the outputs. The MTR believes that some prioritisation of monitoring effort is required, both in terms of activities and methodology design. Based on the results of the Council Study and the need to further consider trade-offs in support of water diplomacy, the MTR suggests the focus should be on the following disciplines: (i) hydro-meteorology; (ii) sediment transport; (iii) water quality; (iv) fisheries; and (v) regular provision of socio-economic data. There is also an urgent need to accelerate and appropriately resource the upgrade of the MRC Information System and its links to national agency data and information management systems.

It is apparent to the MTR that the implementation of monitoring activities for regional needs will require joint efforts to resolve, recognising the differing capacities between countries and the degree of readiness to take on complete responsibility for financing. The nature of these integrated monitoring activities is that if one country fails to secure sufficient budgetary resources it has the potential to undermine the whole regional effort – the value is in the whole, not the constituent parts. Recognising the substantial commitment Member Countries have made to self-financing of the MRC and that some activities are more efficiently delivered through joint arrangements, the MTR recommends:

- a more gradual transition process for decentralisation between now and 2030;
- greater emphasis on transitional support through a dedicated joint funding facility;
- a systematic and focused capacity building effort in support of decentralisation; and
- hard choices are made about monitoring activities that could cease, be scaled-back or re-designed as informed by a comprehensive audit of monitoring activity across the LMB.

In addition to these overarching recommendations, the MTR also provides some specific actions for MRCS and the MCs to consider for each individual activity. These are provided in the tables below.

The MTR does not consider that any individual activities, monitoring stations or parameters should be re-classified for centralised delivery at this stage. The recommendations do, however, propose the use of regional funds (MRC basket funding) for support to activity implementation over a longer transition period. While the MTR proposes the focus of this funding is on technical and human

capacity building and common procurement needs where a single process would be more efficient, temporarily cross-financing the collection of critical data (when accompanied by knowledge sharing efforts) from one or more countries in any of the five disciplines referred to above may be necessary. A redesigned core network of monitoring stations and sampling locations that better reflects the operational effects of current and future hydropower operations and irrigation abstractions across the whole of the Lower Mekong Basin would help inform priority use.

This approach is consistent with the Regional Road Map for Decentralisation, which identified potential 'top-up' financing for some activities from regional funding even for activities subject to a high degree of decentralisation.

Overall Recommendations

Recommendation D.1: *For decentralised monitoring activities that do not have existing handover arrangements in place, develop agreements with Member Country contributions of around 25% in 2020, 50% in 2025 and 100% in 2030 to align more closely with the transition to self-financing.*

Recommendation D.2: *Establish a Joint Decentralisation Support Facility potentially as a sub-account of the Basket Fund to fund capacity building, knowledge sharing, and maintenance support where it is more efficient to do so at a regional level and to ensure ongoing availability of critical data for regional needs.*

Recommendation D.3: *Prepare and implement capacity-building plans for each decentralised monitoring activity, supported by regional funds through the Facility proposed in Recommendation D.2 and with maximum use of country-to-country learning and knowledge sharing. This would include identification of opportunities for knowledge sharing and capacity building support from Thailand and Viet Nam to Cambodia and Lao PDR.*

Recommendation D.4: *Distinguish between critical monitoring activities and those that are less than critical and for the latter group, either suspend or substantially scale-back operations to enable resources to be directed to higher priority needs. The MTR considers the critical activities are: (i) hydro-meteorological monitoring; (ii) discharge measurement and sediment monitoring; (iii) water quality monitoring; (iv) fisheries monitoring; and (v) regular provision of socio-economic data.*

Recommendation D.5: *Building on the work of this MTR, the MRCS and MCs undertake an audit of all existing monitoring stations and sampling locations in the basin for three key environmental disciplines (hydro-meteorology, sediment, water quality) and of existing socio-economic datasets and identify opportunities for synergies, re-alignment, enhancement and removal of redundancies to enable a more cost effective overall monitoring effort. A cost-benefit analysis would then be conducted by the end of 2019 on options for a re-designed core network in order to meet future regional needs, having regard to current and future mainstream and tributary dam operations and other development activities with potential transboundary impacts. Require hydropower developers as part of Concession Agreements to share data for any stations they own that are part of this network.*

Recommendation D.6: *The MRCS prioritise the upgrade of the MRC-IS over the next two years by establishing and resourcing a task-force of MRC staff and external IT support, and overseen by a senior executive project committee within MRCS, to ensure the MRC-IS upgrade is completed and all historical data is uploaded and accessible to stakeholders by the end of 2019.*

Specific Actions for each Activity

Monitoring near real-time hydro-meteorological parameters (HYCOS stations)
• Discuss options with AFD to keep the planned expansion of the HYCOS network on hold until problems with maintaining the existing network are resolved and the optimal network design to meet future challenges is agreed. One exception to this may be a new station at Xieng Kok, which is an obvious need. • Undertake an audit of the entire existing and planned country and regional networks to identify station redundancy and opportunities for synergies considering existing and planned infrastructure operations. Only fund station maintenance for stations critical to that future design. • Undertake a comprehensive cost-benefit analysis comparing continued operation of the HYCOS network against an expanded manual reporting network (more stations and twice daily reporting) considering the data needs from each station in terms of parameters and frequency and in consideration of national telecommunications coverage. • Accelerate implementation of the Joint Environmental Monitoring program to support agreed protocols and data sharing arrangements between developers, local, regional and national authorities and the MRCS. Member Countries should impose obligations on developers to share data. • Identify opportunities for the harmonisation of station equipment, operations and data management at a national level; at least for stations funded and managed by national line agencies. • Establish an ftp server at DMH in Lao PDR (and any other country where it is lacking) to enable direct data transmission from stations to national line agencies. • Identify and address barriers to applying a single budget process for funding the operation and maintenance of all national hydro-meteorological stations (including those providing regional data). • Implement a joint funding arrangement through Member Country contributions to the MRC budget to ensure continued delivery of critical monitoring parameters essential for CRBMF delivery. Such a funding arrangement should support the decentralisation process by only being used where absolutely necessary for continued operation, and in association with capacity building and knowledge sharing activities to help with the transition. • Prepare and implement a plan for regular knowledge sharing and capacity building activities between and within countries, especially for operators with responsibility for station maintenance; and ensure its delivery through joint regional funding.

Manual monitoring of rainfall and water levels (other hydro-met stations)
• Agree a performance benchmark for the timeliness and quality of data provision and put in place a targeted plan for national level support to countries to meet that standard. There may be a case for different benchmarks for different categories of stations to be gradually improved over time. • Support plans might include options for raising awareness of the importance of the data with local observers, providing more instruction on the procedures for SMS reporting, and helping ensure pre-paid sim cards have sufficient credit. Performance-based payments could be trialled in some locations. • Support the building and maintaining of relationships between flood centre staff and line agencies in Member Countries through regional knowledge sharing activities, where feasible; and examine the potential for knowledge exchange between Cambodia and Lao PDR on ways to improve performance. • Undertake an audit of the entire existing and planned country and regional networks to identify station redundancy and opportunities for synergies considering existing and planned infrastructure operations.

Identify new local, national or regional stations that have been installed since 2015 and any stations that are inoperable. For those not working or considered redundant either fix or remove them from the network. The MRCS should maintain a database of all hydro-met stations within the LMB and have agreements with MCs for them to update the database at regular intervals.

- RFMMC should prepare an analysis of the additional accuracy that could be achieved in both flood and drought forecasting by expanding the number of stations included within the MRC reporting network. This would serve as a basis for countries to consider providing additional data, especially for rainfall data both inside and outside the LMB and could include an investigation of the feasibility for twice-a-day reporting, particularly at stations that already collect data at 12-hourly intervals.
- Agree regular transmission arrangements between the MRCS and Member Countries for historical data necessary to keep the MRC DSF up-to-date (where such data is not otherwise regularly provided as part of this activity). For example, every two years in conjunction with the publication by some Member Countries of their hydrological yearbooks.
- Combine this activity (manual monitoring of rainfall and water levels) with the monitoring of hydro-meteorological parameters (HYCOS) to improve integrated assessment and better overall use of hydro-meteorological data and assign responsibility to a single unit within MRCS.
- Identify options to harmonise rain gauges between national stations and regional stations where there are differences (e.g. in Viet Nam).
- Review Member Country soil type data and provide updated products to RFMMC to improve accuracy of flash flood guidance.

Discharge measurement and sediment monitoring

- The MRCS should immediately renegotiate a new MoU with Lao PDR and make the necessary funds available to enable discharge measurement and sediment monitoring between Thailand and Lao PDR to proceed. The delivery of this activity is a separate issue to the funding of maintenance costs for HYCOS stations and conflating the two does not take into consideration the high value of sediment data at a regional level.
- By the end of 2019, the MRCS to work with the *Expert Group on Data, Modelling and Forecasting* to agree an ongoing design for the discharge measurement and sediment monitoring activity in conjunction with the Joint Environmental Monitoring initiative and drawing from previous reviews and recommendations for the DSMP.
- Following agreement to the overall design of the ongoing activity, prepare and sign handover agreements between the MRCS and each Member Country with revised financial handover schedules that have a more gradual transition occurring between now and 2030. A 25% contribution by MCs in 2020, a 50% contribution in 2025 and a 100% contribution in 2030 could be an appropriate trajectory.
- Make regional funds available to support critical data collection, maintenance and capacity building needs and including to purchase new equipment for distribution to MCs in advance of the handover. Such a funding arrangement should support the decentralisation process by only being used where absolutely necessary for continued operation, and in association with capacity building and knowledge sharing activities to help with the transition.
- Develop updated rating curves for mainstream and key tributary stations that are not affected by tidal influence.

Routine water quality monitoring

- Improve the MRC Information System as a matter of urgency and as soon as possible upload all existing water quality data, making it available for visualisation and download. This should include not only the indices agreed under the Procedures for Water Quality, but the data for each of the individual monitoring parameters.
- Evaluate the benefits and risks of undertaking Proficiency Testing of laboratories at a lower frequency than every year. Once every two years may be sufficient although this frequency should be informed by a risk-based approach considering performance to-date and otherwise compliance with international standards.
- Continue to fund Proficiency Testing at a regional level using basket funds with a single contractor to test laboratories in each Member Country. A single procurement arrangement is likely to be more efficient than four separate processes.
- Undertake a review of water quality sampling locations in conjunction with locations for ecological health monitoring and hydrological monitoring and consider opportunities to better align.
- Following the design of the emergency response activity, evaluate the need for additional monitoring parameters and more regular data transmission to enable rapid identification of water quality issues in response to pollution events.

Ecological health monitoring

- Improve the MRC Information System as a matter of urgency and as soon as possible upload all existing ecological health data, making it available for visualisation and download. This should include not only the indices agreed in the technical guidelines/handbook, but also the data for each of the individual monitoring parameters for each biological marker and sampling site.
- Undertake a review of ecological health sampling locations in conjunction with locations for water quality monitoring and hydrological monitoring and consider opportunities to better align. If opportunities cannot be identified, re-consider the necessity of this activity over the long-term as the value in this kind of data is substantially enhanced by examining how it relates to changes in flow regime and water quality.
- Either develop an integrated assessment methodology to examine the relationships between bio-indicators and changes in flow and water quality or consider suspending this activity indefinitely.

Fisheries monitoring

- Improve the MRC Information System as a matter of urgency and as soon as possible upload all existing fisheries data, making it available for visualisation and download.
- Prepare a detailed implementation costing for the revised Fish Abundance and Diversity Monitoring, share with the Member Countries and implement the revised methodology as soon as possible.
- Prepare Handover Documents based on the revised FADM methodology and agree with each Member Country a longer financial transition period up to 2030. A 25% contribution by MCs in 2020, a 50% contribution in 2025 and a 100% contribution in 2030 could be an appropriate trajectory.
- Ensure adequate training and knowledge sharing between countries for all personnel involved in FADM.
- Align databases at national and regional level to facilitate the transmission and quality control of data.
- Prepare a regional fisheries monitoring report that covers all fisheries monitoring activities, not only

FADM. There needs to be greater transparency in the data analysis and presentation.

- Explore opportunities for alternative monitoring of migratory fish at Khone Falls as part of the Joint Environmental Monitoring initiative.

Field data collection for SIMVA

- The number of indicators used in SIMVA surveys needs to be reduced. Following the current benchmark survey, the indicators and questions should be prioritised to enable cost effective implementation over the long-term. The sampling effort for each country should reflect population density in each of the SIMVA zones.
- If not involved in the survey implementation, National Statistics Offices would ideally have a role in quality assurance and control as Thailand intends to do; and in the establishment of LMB socio-economic databases at the national level that are fully integrated with national systems.
- Integrate data from the SIMVA survey into the broader socio-economic database. As long as SIMVA continues, it will provide some of the richest insights into water dependency of basin communities, notwithstanding its geographical scope limitations.
- Although SIMVA is unique in its focus on water-dependency of livelihoods, once arrangements are in place for the provision of basin-wide socio-economic data in accordance with the MRC Indicator Framework and the data availability at a sub-basin scale for each indicator is known, the need for SIMVA monitoring should be re-evaluated based on a consideration of the costs and benefits of the data collection. Basin-wide socio-economic data will not be a complete substitute for the richness of SIMVA data. However, if the availability of data at a sub-basin scale can be improved it may be sufficient for basin planning and impact assessment purposes. At the very least, the MRCS and MCs may wish to re-consider the need for thematic studies and just concentrate on a full survey every five years to provide data from which trends in conditions can be established.

Ad-hoc provision of socio-economic data for basin planning

- Finalise the MRC Indicator Framework as soon as possible and put in place arrangements to collate, process and transmit the necessary data in support of basin planning.
- Agree handover arrangements for collating and transmitting existing datasets relevant to the MRC-IF.
- The regional socio-economic database needs to be redesigned to enable seamless integration of national and regional databases. Upgraded infrastructure with improved search, display and download functions is an essential part of this.
- In future, the ability to undertake integrated data analysis between, for example, flood extent and severity and household economic losses would be valuable. These kinds of issues need to be considered in database design and the upgrade of the MRC Information Systems.
- Change the title of this activity to “Regular provision of socio-economic data for basin planning”.

Preparation and coordination of NIPs for basin planning

- Review lessons learned from implementing the current NIPs and how they have influenced planning and investment decisions within each country and contributed to the objectives of the Basin Development Strategy. Revise the approach and guidelines for NIP preparation and proposed content accordingly.

- Implement a rolling preparation and implementation process for NIPs such that they are reviewed and updated every year to accommodate new joint and regional initiatives.
- Change the description of this activity to recognise that it involves coordination in the implementation phase as well in the preparation phase of the NIP (e.g. Coordination of the preparation and ongoing implementation of NIPs for basin planning).
- Include measures to enhance technical capacity for implementation in addition to the necessary financial resources and prepare a funding mobilisation strategy to accompany each NIP.
- Prepare handover documents that include the role of the NMCs and all relevant line agencies in preparation and implementation of the NIPs and which are signed by all parties.

1.0 Introduction to decentralisation and approach to this review

1. The decentralisation of Core River Basin Management Functions of the Mekong River Commission (MRC) is a central part of the riparianisation of the organisation. In 2010, the Hua Hin Declaration by the Heads of Government of the four MRC Member Countries called on the MRC Secretariat to explore decentralisation modalities in order to transform the MRC into a leaner organisation that can be fully financed by its Member Countries by 2030.

2. The Road Map for reform was outlined in 2014 at both a regional and national level and identified a staged approach to decentralisation both in terms of the sequencing of activities and the transition period for different countries. Activities were classified according to those to remain centralised and those to be decentralised to varying degrees, with implementation proposed to occur in batches. This phased approach is still in place although on an activity-by-activity basis according to an agreed financial transition schedule, rather than in batches or groups of activities considered to be at a similar degree of readiness. The handover period for monitoring activities commenced in 2012 and extends until 2028, with most activities due for complete financial handover by 2021.

3. While initially 26 activities were identified for decentralisation, over time this has been narrowed down to nine (Table 1). The 2014 periodic review of the CRBMF activities for decentralisation found that some activities were already implemented at a national level with no need for decentralisation, and that some should remain centralised. In addition, some activities are still under development and while they may be decentralised in future, their implementation will require further consideration once the approach is finalised and agreed (e.g. monitoring and managing wetland health).

4. The decentralised activities, which are mostly part of Core River Basin Management Function 1 (*data acquisition, exchange and monitoring*), are a critical foundation to the other Core River Basin Management Functions (CRBMFs). Without the basic data and information provided by these activities it is difficult to see how the MRC can credibly deliver on the other CRBMFs. The importance of this data and information to the MRC's work and the organisation's standing as a regional knowledge broker and platform for water diplomacy cannot be overstated. Time and again, through the consultations done for this review, participants identified the MRC's knowledge base and unique record of historical data as one of its most valuable assets.

Table 1: Core River Basin Management Function activities agreed for decentralisation

List of decentralised CRBMF activities	
1.	Monitoring near real-time hydro-meteorological parameters (HYCOS stations)
2.	Manual monitoring rainfall and water levels (other hydro-met stations)
3.	Discharge measurement and sediment monitoring
4.	Routine water quality monitoring
5.	Ecological health monitoring
6.	Fisheries monitoring
7.	Field data collection for Social Impact and Vulnerability Assessment (SIMVA)
8.	Ad-hoc provision of socio economic data for basin planning
9.	Preparation and Coordination of National Indicative Plans (NIPs) for basin planning

5. As outlined in the 2014 Road Map, the decentralisation of CRBMFs is intended to achieve:

- *Strengthened Member Country ownership and Member Country led implementation of the Core River Basin Management Functions*
- *A financially self-sustained MRC focused on delivery of its core functions under an agreed institutional framework*
- *A streamlined and smaller MRC Secretariat that is pro-active to regional needs and emerging issues*
- *Increased efficiency and effectiveness of LMB transboundary planning and management*
- *Balanced and well-coordinated operations at regional and national levels*

6. The changes to the initial plan of the 2014 Road Map for decentralisation and the narrowing down to nine activities indicates there was already a high degree of decentralised implementation within the operations of the MRC and so the efficiency gains from decentralisation may not be as great as initially expected. For most activities the on-ground implementation was generally already conducted by Member Countries involving technical experts in line agencies; the difference being these activities were funded through the MRC budget (with both Member Country and Development Partner funds), rather than directly through national line agencies.

7. It is important therefore to appreciate that in referring to decentralisation, we are for the most part referring to the way in which the activities are funded. The decentralised modality hands responsibility for funding the activities to the national level, to be achieved either through national budget processes or if necessary through arrangements between Member Countries and third parties such as Development Partners. Funding the activities in this way could be expected to: achieve greater country ownership and control with national line agencies having a greater stake in their success; provide opportunities for more efficient implementation by integrating more fully with national activities; and free-up the use of the MRC Basket Fund for more ad-hoc and value-added activities addressing emerging regional needs and priorities that cannot otherwise be done at the national level.

8. In accordance with the reform agenda and the objective for self-financing, decentralisation is occurring at a time of increasing budgetary contributions by Member Countries to the MRC. Member Country contributions are currently 23 per cent of the total MRC budget and forecast to reach 38 per cent in 2020. This is in addition to the budget demands now coming to bear on line agencies to fully fund the implementation of decentralised activities (Table 2).

9. Various reviews, monitoring and reporting on decentralisation have been carried out as planned (indeed more frequently). Monitoring progress is being integrated into the Monitoring and Evaluation system for National Implementation Plans. The last extensive review of the CRBMF activities for decentralisation was undertaken by the MRCS in 2017[2] with an internal follow-up assessment in January 2018. Reports on progress and a summary of the issues that were identified through those exercises were made to the Joint Committee (JC) in 2017 and 2018. Specific recommendations were made to the JC on regional funding support for activities where problems were emerging but which were considered too important from a regional perspective to fail: *hydro-meteorological monitoring* and *discharge measurement and sediment monitoring*. No decisions have yet been taken on alternative funding arrangements for these or any other decentralised activities.

[2] Note that the 2017 Review only provided MRCS perspectives on progress with decentralization. This MTR has considered both MRCS and Member Country input.

Table 2: Estimated annual costs (USD) for Member Countries to implement decentralised monitoring activities[3] not including regional costs for MRCS coordination, support and activity improvement

	Cambodia	Lao PDR	Thailand	Viet Nam
Near real-time hydro-meteorological parameters (HYCOS)	$37,500 (O&M)	$40,000 (O&M)	$27,500 (O&M)	$37,500 (O&M)
Monitoring rainfall and water levels (other Hydro-met stations)	$217,333 (2014 RRM)	$72,000 (2014 RRM)	$8,667 (2014 RRM)	$100,000 (2014 RRM)
Discharge measurement and sediment monitoring	$59,243 (2018 MoU)	$61,180 (2018 MoU)	$35,000 (2018 MoU)	$25,813 (2018 MoU)
Water quality monitoring	$50,342 (2015 MoU)	$64,915 (2014 MoU)	$8,667 (2014 RRM)	$60,147 (2015 MoU)
Socio-economic data provision	-	-	-	-
Ecosystem health monitoring	$49,264 (2015 MoU)	$41,912 (2015 MoU)	$35,215 (2015 MoU)	$33,300 (2015 MoU)
Fisheries monitoring	Dai - $23,900 (MoU) LDM - $20,844 (MoU) ADM - $29,138 (MoU)	LT - $12,741 (MoU) ADM - $47,322 (MoU)	ADM - $35,817 (MoU)	LDM - $22,957 (MoU) ADM - $27,125 (MoU)
SIMVA	$63,171 (2014 MoU)	$74,788 (2014 MoU)	$63,666 (2014 MoU)	$69,897 (2014 MoU)
Total:	**$550,735**	**$414,858**	**$214,532**	**$376,739**

10. This review is part of the Mid-Term Review of the Strategic Plan. It assesses the implementation and status of decentralisation of the nine CRBMF activities listed in Table 1; identifies the implementation challenges arising from decentralisation, how these issues have been addressed to-date, and what options could be further considered by the MRCS and MCs to ensure these activities continue to meet national and regional needs into the future.

11. The assessment is based on an analysis of MRC documents, such as handover agreements for decentralised activities where available, decentralisation plans, internal review papers, relevant guidelines, reports produced by these activities, and on interviews and meetings conducted with the responsible staff at the MRCS and with Member Countries. MC staff consulted included officials of National Mekong Committee Secretariats and relevant line agencies. A full list of agencies consulted is at Attachment A. The performance indicators applied in this review to the financial and technical handover from MRCS to MCs are the same as applied during the internal 2017 review (Table 3).

Table 3: Performance indicators applied to financial and technical handover of CRBMF activities to MCs

Financial handover to MCs	
ON TRACK	• MCs can meet agreed financial handover schedule with their own financial resources
FOLLOW-UP NEEDED	• Financial handover schedule agreed, but MCs need to secure additional funding
MAJOR MEASURES NEEDED	• MCs cannot yet allocate national budget according to the financial handover schedule
Technical handover to MCs	
ON TRACK	• Technical handover being prepared according to the defined schedule • Handover nearly complete or complete, with no need for additional technical support
FOLLOW-UP NEEDED	• Handover nearly complete or complete, but there are some remaining technical issues to be solved
MAJOR MEASURES NEEDED	• Handover nearly complete or complete, but there are major issues affecting the sustainability of the activity

[3] O&M = MRCS estimated operation and maintenance costs per station ($2,500 per year); RRM = Regional Road Map budget estimates (One-third of estimated three year cost as reported in Regional Roadmap for 2013-2015); MoU = Memorandums of Understanding between MRCS and MCs. All cost estimates, but especially those from the RRM, should be treated with caution as they may not reflect up-to-date values and have not been subject to independent scrutiny.

2.0 Implementation Modalities

12. For this MRC Strategic Plan period 2016-2020, CRBMF activities due for decentralisation have been integrated into the National Indicative Plans (NIPs) prepared by each country. The NIPs are the country's plan for contributing to the objectives and strategic priorities of the Basin Development Strategy. They identify joint and national projects relevant to implementing the Basin Development Strategy as well as the planned approach, scope of work and requirements for undertaking the decentralised activities. In addition, Cambodia and Lao PDR have both prepared Project Information Notes (PINs) for each of the decentralised monitoring activities, describing the work that needs to be done, the key performance objectives and indicators and the resources required to ensure successful support to basin-wide monitoring. It was envisaged these PINs would provide a basis for proposals for financial support to Development Partners in cases where funding gaps exist.

13. The national implementation of decentralised activities is coordinated at a regional level through the implementation of the Strategic Plan. The Strategic Plan 2016-2020 does not identify any specific output related to coordination, nor for transition or ongoing support to the decentralisation process. Instead, this is considered part of the implementation of ongoing monitoring arrangements under CRBMF 1 (*Data Acquisition, Exchange and Monitoring*) and in particular under Output 6.1 (*Monitoring and Forecasting Systems for MRC Procedures and Indicator Framework developed and maintained*) where one of the indicators of success is *Decentralisation of monitoring is implemented according to the Road Map*.

14. Under the Regional Road Map the MRCS has a role in coordinating and reporting for each activity as well as undertaking analytical work and commissioning of specific studies where necessary. In particular, this involves providing technical oversight, facilitating communication between all parties, receiving data from national agencies and managing in a central database, analysis and reporting of data from a regional perspective, and coordinating and providing material support to activity implementation to ensure continued data collection. The specific nature of the role was intended to be dependent on the degree of decentralisation with some activities being decentralised to a higher degree than others. The Road Map also identifies ways in which the MRCS can support capacity building in Member Countries including through:

- identification of competencies required;
- identification of expertise and training opportunities to support capacity building;
- strategic secondments and other alternative capacity development approaches;
- evaluation of training outcomes; and
- working with Member Countries to build and maintain a training register.

15. Accessing and building national level expertise and implementation capacity in national line agencies is considered in the Road Map to be one of the key requirements for undertaking the joint and shared roles to implement decentralisation.

16. To formalise the decentralisation between the MRCS and Member Countries, Handover Agreements (with detailed Terms of Reference)[4] are signed between the parties for each activity.

[4] While this is the standard approach, in some cases the Member Country has simply issued a letter acknowledging the handover of responsibility for a particular activity.

These agreements outline the roles and responsibilities of the Member Countries in taking on responsibility for the decentralised activities and include where relevant the financial transition schedule. They are a basis for Member Countries to prepare budget proposals to Government or to bilateral development partners to cover the country's share of the activity funding.

17. Where a transition schedule exists, requiring transfer of funds from the MRCS to the Member Country for some or all of the costs of the activity in a particular year, a Memorandum of Understanding (MoU) or Work Agreement with attached Terms of Reference is used to agree the quantum of funds to be provided and the purpose for which those funds will be used in accordance with the MRC's Annual Work Plan. Following the complete financial handover, these MoUs are no longer necessary.

18. At a national level the relevant line agency with responsibility for implementing each activity must prepare a budget for submission to its Ministry of Finance and/or Ministry of Investment and Planning and if this is agreed it is then it is submitted to Government (Cabinet and then Parliament) for approval. If approved by Government, the funding is notionally available for the activity, but disbursement of funds can sometimes be delayed due to lack of availability of funds and competing priorities. To be implemented effectively, there needs to be at least one year lead time for the budget to be prepared and approved, noting that countries have different fiscal years with Thailand's for instance running from 1 October to 30 September.

19. The ministry and line agency responsible for undertaking the activity and therefore preparing the budget submission varies for different activities. In some cases the National Mekong Committee Secretariat is itself responsible for undertaking the activity and may sub-contract the work to relevant technical agencies, universities or institutes. In other cases it will be the line agency within the same ministry as the NMCS (e.g. the Ministry of Natural Resources and Environment) and in others it will be a different ministry altogether (e.g. Ministry of Agriculture and Rural Development). The specific organisational arrangements vary by country and by activity. Arrangements for technical implementation including data collection, management and transmission also vary by activity and are described in the relevant sections below.

20. As noted above, the reporting on the implementation of decentralised activities is part of the Monitoring and Evaluation system for the NIPs. This system requires the filling of NIP reporting forms every six months (previously quarterly) to measure progress on the defined indicators for the decentralised activities. These NIP reporting forms should be submitted to the NMCS, but were not available to the MTR at the time of writing as the system is still being set-up.

21. The development and implementation of the NIP M&E system is led by the OCEO and Planning Division within MRCS. For decentralisation, the M&E and reporting covers the decentralisation process and the implementation of decentralised activities, as well as post-handover implementation and compliance to regional standards and protocols. Reporting on decentralisation progress is a standing item in the agenda of the regular MRC JC and Council meetings.

22. As part of the broader reform of the MRC and the move towards a leaner and more efficient organisation, four Expert Groups have been established to facilitate work between regional and national levels. These groups are *technical platforms, where experts from the river basin*

organisation and line/implementing agencies of the MCs regularly meet to jointly develop routine or emergent work related to transboundary water management, and to coordinate the implementation of activities in the different countries. The group with oversight of river monitoring activities is the *Expert Group on Data, Modelling and Forecasting*. One of its functions is to provide *guidance for the ongoing decentralisation of data acquisition and reporting*[5]. This group also undertakes work in relation to many of the MRC products and services that rely on the data provided by the decentralised monitoring activities. This Expert Group will be an important avenue for Member Countries to take-on a greater technical leadership role for individual monitoring activities.

[5] MRC (2017) Draft Terms of Reference for the *Expert Group on Data, Modelling and Forecasting*.

3.0 Implementation Status

3.1 Overall progress

23. The process of decentralisation, referring to the handover of the financial and technical responsibilities for river monitoring related activities from the MRCS to the Member Countries, has made some good progress but also faced a number of delays and obstacles. Progress is evident in the clear and unambiguous acceptance of responsibility for monitoring activities by Member Countries as documented in signed handover agreements, and in the ongoing data collection, transmission and reporting activities. However, some critical issues are emerging which if not addressed will jeopardise the ongoing availability of critical data underpinning the MRC's CRBMFs.

24. Delays in the roll-out of decentralisation indicate the timing of the initial plan was too ambitious, neither reflecting sufficiently the different capacities of country systems, nor accounting for the major restructuring upheaval and related lack of continuity of staff. The delays have principally resulted from Member Countries having insufficient budgets in place to fund monitoring activities due to the delayed preparation and signing of Handover Agreements and otherwise competing national funding priorities. Inadequate coordination and leadership at MRCS for some activities has also been a factor, requiring the financial transition schedule to be pushed back.

25. Handover Agreements have been delayed for several reasons including further work required on regional methodological issues (e.g. for Fisheries Abundance and Diversity Monitoring), insufficient technical expertise at the MRCS due to staff movements, and a need for enhanced coordination due to joint sampling involving more than one country (e.g. discharge measurement and sediment monitoring). These delays have necessitated a relatively flexible approach to the implementation of decentralisation to meet the emerging needs and challenges. This flexibility is illustrated in the adjustment of timeframes for several activities, re-defining and splitting some activities, and agreeing changes to the financial handover schedules.

26. Table 4 illustrates the current planned financial transition for each of the decentralised activities. As at the end of 2018, three activities had been completely handed over across all four Member Countries[6]. However, the performance of data collection and transmission to the MRC for these activities has declined, mostly due to lack of resources for operation and maintenance of HYCOS stations (*near real-time hydro-meteorological monitoring*), but also due to a lack of handover agreements specifying what is required by who and by when (*socio-economic data provision*). For example, the number of automatic hydrological (HYCOS) stations not working increased sharply from 2015 to 2017 because station maintenance was insufficient; a situation exacerbated by factors beyond the control of relevant agencies – i.e. changes in national telecommunications networks.

27. There are also ongoing operational challenges including delays in reporting rainfall and water levels from manual stations (albeit mostly within one country), and equipment and systems issues related to updates, licencing, software compatibility, unreliable internet connections etc. These are not necessarily problems caused by the financial or technical handover but with insufficient resources they become more apparent.

[6] The three activities completely handed over to Member Countries as of December 2018 were: (i) near real-time monitoring of hydro-meteorological parameters (HYCOS stations); (ii) manual monitoring of rainfall and water levels (other hydro-met stations); and (iii) ad-hoc provision of socio-economic data for basin planning.

Table 4: Planned financial handover schedule (Member Country contributions) to decentralised activities from 2016-2022, as at December 2018[7]

Activity	2016	2017	2018	2019	2020	2021	2022
Monitoring hydro-meteorological parameters (HYCOS stations)	*100% handover in 2012 for Thailand and Viet Nam; and 2015 for Cambodia and Lao PDR*		MRC budget (AFD funds) used to fix stations				
Monitoring near real-time rainfall and water levels (other hydro-met stations)	C – X%[8] L – X% T – 100% V – 100%	C – 100% L – 100% T – 100% V – 100%					
Discharge measurement and sediment monitoring		C – 0% L – 0% T – 0% V – 0%	C – 25% L – 25% T – 25% V – 25% MRC budget covering 100%	C – 50% L – 50% T – 50% V – 50%	C – 75% L – 75% T – 75% V – 75%	C – 100% L – 100% T – 100% V – 100%	
Routine water quality monitoring	C – 75% L – 75% T – 100% V – 100%	C – 75% L – 80% T – 100% V – 100%	C – 75% L – 83% T – 100% V – 100%	C – 100% L – 87% T – 100% V – 100%	C – 100% L – 100% T – 100% V – 100%		
Ecological health monitoring		C – 0% L – 0% T – 0% V – 0%		C – 50% L – 50% T – 50% V – 50%		C – 75% L – 75% T – 75% V – 75%	*100% handover for all MCs in 2023*
Fisheries monitoring			C – 0% L – 0% T – 0% V – 0%	C – 40% L – 40% T – 40% V – 40%	C – 60% L – 60% T – 60% V – 60%	C – 100% L – 100% T – 100% V – 100%	
Field data collection for SIMVA			C – 0% L – 0% T – 0% V – 0%		C – 25% L – 25% T – 25% V – 25%		*100% handover for all MCs in 2028*
Ad-hoc provision of socio-economic data for basin planning	*100% notional handover to all MCs in the previous SP period*		MRC budget used to fund national consultants for SOB				
Preparation and coordination of NIPs for basin planning	C – 0% L – 0% T – 0% V – 0%				C – 50% L – 50% T – 50% V – 50%		*100% handover for all MCs in 2025*

Dec 2018

Legend:

0% planned contribution from all MCs	Varying planned contributions from MCs	100% planned contribution from all MCs	Planned MC contribution was not met

[7] Note that these plans have not been achieved for some activities and will need to be renegotiated (e.g. for Discharge measurement and sediment monitoring)

[8] The 2016 budget contributions by Cambodia and Lao PDR for manual rainfall and water level monitoring are unknown. MRCS provided a small amount of funds for consumables such as SIM cards

28. The emerging difficulties with the decentralisation process are best highlighted with the following examples with further examination of the causes of these issues in the activity assessments below:

i) Despite the monitoring of near-real time monitoring parameters (HYCOS stations) having been completely handed over since 2012 in Thailand and Viet Nam, and since 2015 in Cambodia and Lao PDR, an MRC recovery mission was required to fix up to 45 stations between March and May 2018. This was funded through the MRC budget by the French Development Agency (AFD).

ii) Despite the ad-hoc provision of socio-economic data having been notionally handed over to all countries during the previous Strategic Plan period, the MRC was required to contract consultants in 2018 to collect data for the 2018 SOBR.

iii) The planned financial hand-over of discharge measurement and sediment monitoring with Member Countries contributing 25 per cent of the costs in 2018 did not occur. As subsequently agreed with Member Countries, the MRC budget is funding the total amount. This will also be the case in 2019.

iv) Cambodia has indicated to the MRCS it will not have sufficient funding for ecological health monitoring and fisheries monitoring in 2019.

These examples illustrate that although officially the handover of some activities has occurred, they still rely to some degree or other on the MRC budget and technical support of the MRCS.

29. One activity which is largely proceeding as planned is the routine water quality monitoring. To-date the collection and provision of data from the Member Countries to the MRCS has generally been on-time and of an acceptable standard. All countries are contributing either all or some of the cost. 2019 will nevertheless be a critical test, as Cambodia seeks to increase its contribution to 100% of the activity costs (up from 75%) and Lao PDR to 87% (up from 83%). This is the next activity due for complete financial decentralisation, with that objective planned to be reached in 2020, within the life of the current Strategic Plan.

30. 2019 is an important year in the decentralisation process overall. It will be the first year that Member Countries are required to finance part of both fisheries monitoring (40%) and ecological health monitoring activities (50%) in addition to the operation and maintenance of hydro-meteorological stations and the costs for water quality monitoring (Table 4). It is likely that the financing objective for fisheries monitoring will not be met due to delays in agreeing changes to the Fish Abundance and Diversity Monitoring methodology (originally scheduled for 2017, but only agreed for testing in early 2019) and uncertainties over the cost impacts of these changes.

31. Countries providing 50% of the costs of the ecological health monitoring activity next year will be a considerable challenge given this is not an activity that countries otherwise do and is unlikely to be a high priority when national budgets are determined. Although countries have said they appreciate the ecological health monitoring methodology and would like to roll it out more broadly within the country, the cost is prohibitive given its relative national priority. Notwithstanding the Handover Agreements signed, there is no indication at present that all MCs have sufficient budget to cover 50% of the costs of this activity next year.

32. Overall, this review finds that the process of decentralisation is ***not on-track*** and at ***risk of failure.*** If the emerging problems are not immediately addressed they have the potential to undermine the benefits of decentralisation and the delivery of all the CRBMFs. Alternative funding arrangements and a longer transition time for some activities may be necessary, along with a sustained focus on capacity building and transition support.

3.2 Summary of performance for each activity

33. The implementation performance of decentralisation varies across each of the nine activities. The issues and challenges each activity faces are generally different. Overall this review considers five of nine activities are on-track with the financial handover (Table 5). However, these are mostly activities which are still being primarily funded through the MRC budget. Two activities require major measures to resolve (*Monitoring near real-time hydro-meteorological parameters* and *Discharge measurement and sediment monitoring*), while in the latter part of 2018 two activities previously considered on track from a technical standpoint are now considered to require follow-up action. These two activities are *Fisheries Monitoring* and *Ad-hoc provision of socio-economic data*.

34. The MTR considers that in 2019-2020 a further three activities (*ecological health monitoring, fisheries monitoring, and SIMVA*) will require major measures to resolve unless a change to the decentralisation approach is implemented.

35. For fisheries monitoring, the delays in finalising the revised methodology for Fisheries Abundance and Diversity Monitoring and associated handover agreements mean that country contributions to the costs of this activity in 2019 will not be met. National budget submissions need to have been made much earlier. For the provision of socio-economic data there is still no agreement on what is required to be delivered by Member Countries and therefore no agreement on the costs. In 2018, the MRC funded consultants to collect relevant data for the preparation of the State of the Basin report rather than receiving the information directly from Member Countries.

36. On the technical handover, four activities require follow-up, with two (*Discharge measurement and sediment monitoring* and *Ad-hoc provision of socio-economic data for basin planning*) requiring substantial further work to resolve basic technical issues including the monitoring parameters to be collected, the frequency of collection, and the equipment and protocols to be followed.

37. The dramatic decline in HYCOS station performance between 2015 and 2017 was partially addressed by an MRC recovery mission to fix the non-performing stations in May 2018. This was funded using AFD contributions to MRC as part of the second phase of the Mekong HYCOS project, but there are still issues with the performance of the network, which in general is substantially lower than the manual stations. The primary cause of the performance issues has been a lack of station maintenance. However, Member Countries also report some issues being due to poor internet connection to the server at the MRCS preventing the receipt of data (before time-outs) and changes to national telecommunications networks beyond Member Countries' control. Some relate to malfunctioning parts that need replacing at the station. The need to fund this maintenance with Development Partner support through the MRC budget is a clear warning sign that decentralisation is not proceeding as planned. All countries had previously flagged they had insufficient budget for the replacement of spare parts.

38. Manual monitoring of rainfall and water levels has been fully decentralised and is generally occurring as planned. There are nevertheless some outstanding issues in relation to missing data and late reporting of data to the MRC in support of flood forecasting, and indeed a similar performance dip between 2015 and 2017 as with the HYCOS stations, albeit less substantial. This is a critical activity for regional flood forecasting (more so than the automatic HYCOS stations) and so any dip in performance should be of concern. The MRC Regional Flood Centre has identified a need to not only ensure maintenance of this network and improvements in the accuracy and delivery of on-time data but to enhance the collection of data with additional locations including rainfall stations outside the LMB which would help improve flash flood guidance in upper catchment areas.

Table 5: Summary of financial and technical handover performance of each decentralized activity as rated by MRCS in November 2017[9] and by the MTR team in December 2018 and projected to 2019 and 2020

November 2017	December 2018	Projection 2019-20	Documents	Handover End	Remarks
Monitoring near real-time hydro-meteorological parameters (HYCOS stations)					
Financial handover Technical handover			✓ 2012	T/V 2012 C/L 2014	Stations fixed with AFD funds
Monitoring rainfall and water levels (other Hydro-met stations)					
Financial handover Technical handover			✓V/T 2016 ✓C/L 2017	V/T 2016 C/L 2017	Mainly Lao PDR tributaries have difficulties
Discharge measurement and sediment monitoring					
Financial handover Technical handover			✗	2021	2018 Delays between T/L
Routine water quality monitoring					
Financial handover Technical handover			✓V/T 2015 ✓C/L 2017	V/T 2015 C 2019 L 2020	Proficiency Testing funded through MRCS
Ecological health monitoring					
Financial handover Technical handover			✓2017	2021	MCs may lack 2019 budget
Fisheries monitoring					
Financial handover Technical handover			✓2017 (part) ✗ (FADM)	2020	FADM method changes agreed
Field data collection for SIMVA					
Financial handover Technical handover			✗	2028	Design issues to resolve
Ad-hoc provision of socio economic data for basin planning					
Financial handover Technical handover			✗	2015	Formalisation pending
Preparation and Coordination of National Indicative Plans for basin planning					
Financial handover Technical handover			✗	2025	Formalisation pending

39. For the ad-hoc provision of socio-economic data, although this is notionally decentralised, there is no clarity on what this activity actually requires of all the parties (no Handover Agreements have been signed with any country) and as the preparation of the 2018 State of the Basin report

[9] An updated rating for each activity was also provided by MRCS to the JC in August 2018. It noted that for the HYCOS stations the financial handover rating was red and the technical handover rating was yellow.

demonstrates the lack of clarity is having an impact on the MRC's capacity to deliver outputs. The limited socio-economic data available was largely not fit-for-purpose and information from international organisations had to be used instead. The Council Study relied to a large extent on socio-economic data from the 2015 SIMVA survey, which may be appropriate when considering potential impacts of development along the mainstream corridor but is inappropriate for assessing the status and trends in socio-economic conditions for the whole of the basin.

40. The planned financial transition of discharge measurement and sediment monitoring also had MCs financing 25% of the costs in 2018, rising to 50% in 2019 (Table 4). This is not happening in the current year (the MRC budget is being used to pay all costs) and is unlikely to occur in 2019 as Handover Agreements have not been signed and therefore national budgets are unlikely to be available. Further delays in the financial transition of this activity will need to be agreed with Member Countries. Given the importance of changes in sediment regimes due to basin development it is commendable that this activity has been re-instated in 2018, but the delay in providing funds to Lao PDR for monitoring this year and the lack of agreement among all countries on a way forward is of serious concern.

41. Table 6 provides a snapshot of implementation between 2016-2018 across each activity as it relates to handover documents, transitional agreements and financial arrangements, the collection, management and transmission of data and reports. It identifies the category of issues each activity is facing.

42. Handover agreements for all countries are currently behind schedule for *Discharge measurement and Sediment monitoring, fisheries monitoring and the ad-hoc provision of socio-economic data*. For fisheries monitoring, agreements are in place with Cambodia and Viet Nam for fish larvae drift and juvenile monitoring and with Cambodia for the stationary Dai monitoring. There is a MoU with Lao PDR for Lee Trap monitoring for 2018-19 but an understanding this activity will not continue beyond this year due to legal prohibitions on use of the gear. No agreements have been signed with any country for Fish Abundance and Diversity Monitoring due to earlier delays in agreeing the revised method.

43. There are no handover agreements for the ad-hoc provision of socio-economic data for basin planning. Thailand acknowledged the handover of this activity in 2015, but as already noted there is no detail in what this actually entails. No signed agreements have been sighted by the MTR on the handover to Cambodia and Thailand of manual rainfall and water levels monitoring activity.

44. MoUs and ToRs are only required when there is a transfer of funds from the MRCS to the Member Country for activities that are not yet completely decentralised. In all cases these appear to be in place for 2018-19 when they need to be.

45. Financial schedules for transitional arrangements have been agreed for all activities although for discharge measurement and sediment monitoring, SIMVA, socio-economic data provision, fisheries and the preparation and coordination of NIPs these are yet to be formalised in handover agreements. Where funds are required to be transferred from the MRCS to Member Countries to undertake activities this has occurred as planned, other than to Lao PDR for discharge measurement and sediment monitoring. The review team understands the MRCS had been withholding the transfer of these funds to Lao PDR *in lieu* of the costs incurred by the MRCS to fix the HYCOS stations in May 2018. This hold-up in funding, in addition to security concerns expressed by Thailand around

the Thai sampling team accessing the riverbank on the Lao side without the necessary permits from Lao PDR authorities, means that joint discharge measurement and sediment monitoring in the mainstream between Thailand and Lao PDR for 2018 has not yet commenced.

46. For activities where national budgets needed to have been made available in 2018 to fund activities, this is only known to have occurred for water quality monitoring. Budgets for hydro-meteorological monitoring do not appear to have been sufficient for operations and maintenance of stations and the review team has doubts there has been any increase in budgets by Member Countries to cover these activities. Although this has not yet been confirmed by Member Countries it is likely the cost of these activities has needed to be absorbed within existing operations. Indeed, all countries have said they have insufficient budgets for replacing spare parts (read: maintenance); a large part of the reason for the decline in performance of these networks, exacerbated by some factors beyond the control of relevant national agencies, as noted earlier.

47. The transmission of data from Member Countries to the MRCS, whether under a handover agreement or MoU, has faced some difficulties. The completeness of the near real-time hydro-meteorological monitoring data has been poor across all countries in 2016 and 2017 and particularly so from stations in Lao PDR and Thailand. Conversely, the timeliness and completeness of data transmission under the manual rainfall and water level monitoring has been good across all countries, albeit with Lao PDR having consistently lower performance than the others.

48. The data that is transmitted to the MRCS is generally stored on internal hard-drives within the different divisions of the MRCS responsible for each activity, other than for the hydro-meteorological data which is transmitted to the central database. This hydro-meteorological data is the only data available for visualisation and download as of December 2018 although requests to access the data must be made either by email or online to the MRCS Information System and Database Specialist. There is also a socio-economic database but this has not been updated since 2015, is extraordinarily slow and cumbersome to navigate and has limited functionality.

49. The reporting arrangements for MRC work generally involve each country producing a national report based on the monitoring and analysis of data within their part of the Basin and the MRCS producing a regional report which provides the overarching basin results and analysis. Where reports have been required by Member Countries these have been provided for water quality monitoring and ecological health monitoring and are in progress for fisheries monitoring, the benchmark SIMVA survey and for discharge measurement and sediment monitoring in Cambodia and Viet Nam. Lao PDR and Thailand will not be able to prepare a report for discharge measurement and sediment monitoring until data collection and analysis can proceed. National reports are not required for hydro-meteorological monitoring parameters, socio-economic data provision or the preparation and coordination of NIPs.

50. With the data that has been provided MRCS has been able to produce regional reports and deliver regional products and services on hydro-meteorological parameters (daily, seasonal and annual flood bulletins, forecasts and reports); and water quality (regional reports available for 2015 and 2016); but is still finalising the ecological health monitoring regional report for 2015. Due to gaps in monitoring for sediment and fisheries since 2015, no regional reports have been produced on those activities in this Strategic Plan period. In relation to socio-economic data provision, the SOB for 2018 is close to being finalised.

Table 6: Summary of the implementation status of decentralised activities between 2016 and 2018

Decentralised Activity	Handover agreement in place				MoU in place for 2018/19 (if required)				Financial schedule formally agreed				All funds transferred from MRCS in accordance with financial schedule				National budget allocated according to agreed responsibilities in 2018				Data collected between 2016 and 2018 according to protocols				Quality control procedures in place				Data transmitted to MRCS				Data included within MRCS-IS and available for visualisation or download				National reports provided to MRCS in accordance with MoU				Agreed activity financial contribution of MC (in 2018 %)				Regional analysis and report produced	Identified Issues									
	C	L	T	V	C	L	T	V	C	L	T	V	C	L	T	V	C	L	T	V	C	L	T	V	C	L	T	V	C	L	T	V	C	L	T	V	C	L	T	V	C	L	T	V	MRCS	*HR technical capacity*	*O & M of stations/sampling*	*Timeliness of data provision*	*Quality of data provided*	*National systems integration*	*National data storage*	*Regional data storage*	*National budget priorities*	*Methodology concerns*	*Other…*
Monitoring near real-time hydro-meteorological parameters (HYCOS)																									?	?	?	?													100	100	100	100		☒	☒		☒	☒	☒	☒	☒			
Manual monitoring of rainfall and water levels (other hydro-met)																	?	?	?	?					?	?	?	?													100	100	100	100		☒		☒	☒	☒	☒	☒			
Discharge measurement and sediment monitoring															?																										0	0	0	0		☒	☒				☒	☒	☒	☒	
Routine water quality monitoring																																									75	83	100	100		☒					☒	☒			
Ad-hoc provision of socio-economic data for basin planning																																									100	100	100	100				☒	☒			☒		☒	
Ecosystem health monitoring																																									0	0	0	0		☒			☒		☒	☒			
Fisheries monitoring																																									0	0	0	0								☒		☒	
Field data collection for SIMVA																																									0	0	0	0							☒	☒		☒	
Preparation and coordination of NIPs for basin planning																																									0	0	0	0								☒			

Legend:

Met	Partially met	Not Met	Not applicable

4.0 Success Factors

51. For activities where decentralisation is proceeding relatively well (manual monitoring of rainfall and water levels, and water quality monitoring), the following factors have generally played a part:

- *Consistent and well understood technical methodologies agreed in advance and already practiced in national monitoring systems*

  The methodologies and protocols for water quality monitoring have been developed over more than 20 years and are practiced extensively by countries for both regional and national needs. This provides a solid human and laboratory capability base from which to build. Manual rainfall and water level monitoring is practiced at hundreds of stations at national, provincial and local levels throughout each country.

  In the case of discharge measurement and sediment monitoring, countries generally only monitor Total Suspended Solids for national needs and continue to have questions about the need for other sediment monitoring parameters (e.g. bed load and Suspended Sediment Concentration) and whether the equipment is appropriate. The handover of fisheries monitoring has been delayed due to the need to revise the Fisheries Abundance and Diversity Monitoring methodology. Socio-economic data provision is not functioning well because there is no agreement on the indicators to be used and the specific data to be transmitted.

- *Monitoring that does not involve highly trained operators and expensive capital equipment, spare parts and consumables*

  The monitoring of rainfall and water levels provides substantially more accurate and reliable data than the near real-time hydro-meteorological (HYCOS) network. The low tech nature of the manual monitoring activity, with minimal ongoing costs beyond the person reading the gauge (e.g. telecommunication charges for sending data by SMS or email; vehicle access and fuel) and simple procedures, is likely to be an important reason. Indeed, this manual hydro-meteorological dataset is arguably the most valuable the MRC holds.

  The HYCOS network on the other hand involves high costs with more highly trained operators, with relatively expensive equipment and spare parts. While countries do have other automatic hydro-meteorological stations within their territory these do not always use the same equipment and procedures. Discharge measurement and sediment monitoring requires expensive equipment with highly trained operators, often working in difficult conditions.

- *Handover agreements documenting requirements and standards agreed well in advance of the first year that country contributions are due*

  Having handover agreements in place prior to the transition of activities is important because these provide Member Countries a basis for making budget submissions to Government with an understanding of expected costs over multiple years. The financial handover of fisheries monitoring has been delayed as there are no handover agreements in place for Fish Abundance and Diversity monitoring. For socio-economic data provision there has also been no

formalisation of the protocols and procedures for data transmission and management. No handover agreements exist for discharge measurement and sediment monitoring. These activities have nevertheless generally been able to continue with the agreement between parties of MoUs with detailed Terms of Reference for the use of regional funds provided through the MRCS.

Although arrangements for near real-time hydro-meteorological monitoring have been in place for some time and with ample lead time for countries, the high cost of operations and maintenance has over-ridden this factor in this case.

5.0 Summary of issues and challenges

52. While progress has been achieved in decentralising the CRBMFs, a number of issues are emerging and need to be addressed if the outcomes expected from decentralisation are to be achieved. The following are issues which have been identified with the implementation to varying degrees across all of the decentralised monitoring activities. However, only the first three are considered issues directly related to the decentralisation process. The others would be issues regardless of whether the activity was centralised or decentralised.

(i) Competing national budget priorities

Member Countries have recognised the value the MRC provides through their commitment to complete riparian financing of the organisation by 2030 and have made good progress in increasing their contributions to the MRC budget in-line with that commitment. This progress stands in contrast to the evident difficulty countries face in obtaining funding support on an activity-by-activity basis through national agency budgets, and the risks this now poses to the continued delivery of MRC monitoring activities.

Funding directly through line agencies introduces risks but can also help to crystallise the value that national governments place on the work. Risks include competing national priorities for funding and the need for greater coordination effort to ensure funds available for regional activities across multiple ministries continue to go toward the highest regional priorities. There is always a risk that different line agencies will be more successful than others at achieving budget support but this will not necessarily be for the activities with the highest regional need. The coordination role of the NMC throughout the budget process is critical in this regard.

Of course the value national governments place on regional activities can be limited by a lack of awareness of these activities, particularly within line agencies and at ministerial level, and especially if products and services are not quite fit-for-purpose or aligned with national needs and if there has traditionally been a separation of management of activities delivered for regional needs and those delivered for national needs.

Difficulties in achieving budget support on an activity-by-activity basis relate to:

(a) the lack of direct use of the data that is collected, which is only a component of the overall regional dataset, and when often there are no existing mechanisms or processes to incorporate and apply the data at a national level

(b) alternative data sources within the country, for example hydro-meteorological stations managed by various agencies, often within close proximity to stations providing data to the MRCS

(c) the additional administrative steps necessary to include additional budget lines and seek budget support for activities that have not traditionally been funded

(d) national line agencies having a difficult case to make for additional budget for monitoring when finance ministries point to the national funds already committed to the MRC central budget

National contributions for some activities are funded through budgets obtained by NMCSs who then contract a national technical agency and some are funded through budgets obtained directly by a relevant line agency. Either way, there will always be competing national priorities for scarce funds. The Project Information Notes (PINs) which identify specific projects important to achieving the National Indicative Plans (NIPs) include decentralised activities and identify funding short-falls. It is not clear to what extent these have been used to approach Development Partners for funding support. In any case, funding in this way would presumably be a temporary measure to ease the transition to country funding arrangements.

(ii) Only indirect use of most monitoring data

In interviews and consultations conducted for this review, all Member Countries re-iterated the value they place in the data provided by and for the MRC products that use this data. This was particularly the case for the flood forecasts and the water-level information provided on the MRCS website. For example, several Viet Nam agencies reported monitoring of water levels on the MRC website multiple times during the day during the flood season.

Responses to the MRC's survey on flood forecast services were far more positive than negative although for all of the products identified, the number of respondents with a neutral view was similar or greater than those who had a positive view. This could be due to lack of awareness of the services, the respondents not being a user of the service or otherwise mixed views about the value the service provides. Importantly, the survey included only a very small number of Member Country government respondents who are key constituents in relation to support for decentralised activities within countries.

The MTR only identified two instances where data from MRC monitoring activities is used directly by the countries. This was for manual hydro-meteorological data (including for flood forecasting), and water quality data. In these cases the data is generally transmitted to national databases used to inform an understanding of conditions in the basin. For other activities, the use of MRC data does not appear to be direct. Although there have been some notable exceptions reported, such as Viet Nam's Delta Study and Cambodia's Sambor study, the data is mostly used by the MRCS to undertake studies, assessments and planning exercises and it is these value-added products that are then referred to by Member Countries. In part, this is also because the small component of the data that comes from any one country has limited value in and of itself. It is the regional dataset and its uses for regional purposes where the most value is obtained but often this regional dataset is not very accessible. It is highly likely that this indirect

pathway in the accessibility and use of MRC data makes it more difficult for Member Countries to obtain budgets for monitoring on an activity-by-activity basis.

It is also the case that in many instances there are no mechanisms to make use of the data that is collected. For example, ecological health monitoring is not otherwise undertaken in countries and so there are no established planning or assessment processes for considering that kind of data. For fisheries monitoring, some activities produce data that is used to inform local and regional authorities of the status of the resource (e.g. Dai fisheries in Cambodia), but the MTR did not receive evidence that other data has been incorporated into national planning and decision-making processes.

The lack of direct use of monitoring data in the countries makes it challenging to identify opportunities to ensure the activities are identified as a higher priority in national budget decisions. The Decentralisation Roadmap identified the importance of building understanding at a national level of the role and benefits of the MRC to support the decentralisation process, and there is clearly more work to do in this regard.

(iii) Alternative data sources within a country

To support budget proposals, the draw on the budget for monitoring activities needs to be as efficient as possible and this is where integration of national and regional monitoring becomes important. A view often expressed in consultations with stakeholders is that there is an 'MRC network' separate to the 'national network' when it comes to monitoring. MRCS and Member Countries frequently refer to the 'MRC stations' or the 'regional or mainstream' monitoring network as opposed to the 'national network' and so forth. The more that the stations where data is used for regional purposes is seen as separate to the rest of the national monitoring network, the greater the challenge in ensuring continued national funding. These stations will generally have lower priority to others where the perceived national need and use comes first.

It is also possible, indeed likely, that there is substantial redundancy in the current network with duplicate stations measuring the same parameters only a short distance away (See Figure 2 in section 8.1). This review has collated the information it could on the network of hydrological stations across the whole of the basin, but a more thorough review is necessary. The information is in different formats with inconsistent identifiers on stations and lack of clarity on exactly how many stations there are, where they are located, what is measured, how each is operated and managed, and by whom.

The MRCS is already undertaking a major exercise to align the information it has as part of the data migration to the new MRC-IS. However, there are a large number of new stations being established or upgraded across the LMB, especially in Cambodia and Lao PDR, with development partner support. For example, in recent years Cambodia has installed 33 hydro-meteorological stations on tributaries of the Tonle Sap with the support of Japanese International Cooperation Agency (JICA) and 24 automatic stations with the support of the Asian Development Bank (ADB). The ADB is has also funded the installation of at least 19 new automatic stations in Lao PDR. Hydropower developers are also installing new stations to help inform operations of new dam projects, as illustrated below, including within feet of the existing mainstream HYCOS network.

(iv) Member country human and technical capabilities

Member countries have regularly commented on human capacity needs across a range of activities. These capacity issues are likely to exist regardless of the way in which activities are funded (through MRCS or directly through national budgets) and perhaps have more to do with the overall level of resourcing and the relative priority of regional activities when compared to other needs. Nevertheless, the issue of capacity is important in determining the level of readiness of countries to take on decentralised activities and the review team finds there has been a lack of focus on this issue through the transition process.

Member Countries reported that the number of training and regional knowledge sharing workshops conducted across all activities declined sharply from 2015. Where activities have been undertaken they appear to be generally of a more technical nature focused on data analysis and management rather than on the basics of station operational procedures and maintenance. Both are important, but to-date have been clearly insufficient given the scale of the transition and the differing capacity levels across Member Countries. In consultation for this review Member Countries raised issues with high staff turnover, changes in departmental responsibilities and the need for regular refresher training in station operation and maintenance in order to maintain standards over time. A lack of manuals and procedures in local languages also does not help.

As identified in some of the national roadmaps for decentralisation, human capacity needs include building the skills of existing staff at national and provincial level but also ensuring sufficiently qualified university graduates in future in areas such as water chemistry and hydrology. Both short-term and longer-term plans are needed. The following categories of human capability need have been identified:

- Equipment procurement, set-up, handling, maintenance and repair
- Field sampling and laboratory testing, analysis and interpretation
- Data handling and management including QA/QC
- Scientific report writing and communication skills including to local communities
- Management, coordination and oversight of monitoring activities

Capacity issues are exacerbated by (i) re-assignment of activities to national agencies that had not previously had responsibility (e.g. in Thailand EHM has been transferred to the Pollution Control Department which had no previous experience with the methodology); (ii) turnover of staff at the national level; and (iii) a shortage of qualified technical staff.

A lack of capacity at MRCS has also been a significant issue for some activities. For example, delays in decentralisation of discharge and sediment monitored have been in part due to a lack of qualified staff providing regional coordination and leadership. While this has now been addressed, decentralisation of the activity is behind schedule. The review team has heard that for much of 2018 due to the departure of experienced staff there has not been a primary specialist responsible for discharge measurement and sediment monitoring.

(v) Reaching agreement on monitoring design and resolving technical issues

One of the main reasons for delay in preparing and signing handover agreements, which then causes delays in Member Countries submitting national budget proposals and integrating activities into national work plans, has been a delay in reaching agreement on methodological issues. Two activities have been most affected by this: the fisheries monitoring activity and the SIMVA survey.

In the case of fisheries, there was a need to ensure consistency in approaches to Fish Abundance and Diversity Monitoring across Member Countries (in relation to gear type) so that the results will be comparable and can support regional studies and evaluation, and also some uncertainty about whether Lee trap monitoring could continue in Lao PDR due to a recent national prohibition on the deployment of the gear. The delay in preparing and agreeing changes to the FADM has delayed the financial decentralisation of the fisheries monitoring activity. MCs were not able to seek budget support in 2018 and indeed may also have been delayed for 2019 when they are expected to cover 50 per cent of the total fisheries monitoring costs. It is important this issue is resolved in the first quarter of 2019 if countries are to have enough time to seek budgets for 2020.

In the case of SIMVA, Member Countries raised concerns about sample sizes and the selection of indicators. These methodological issues have been addressed for the purposes of the 2018-19 benchmark survey and have not unduly affected the decentralisation of SIMVA to-date given the longer transition period planned for this activity. However, this is an issue to watch due to potential modifications to the design including further prioritisation of indicators between the benchmark survey conducted in 2018-19, any thematic studies in 2020, and the roll-out of the full survey in 2023 when Member Countries will be expected to cover 50 per cent of the costs. Member Countries have raised concerns about the number of indicators, the cost of undertaking this activity and the difficulty integrating this survey into their broader socio-economic work programme.

(vi) Reliability and capacity of systems and equipment

There are significant problems with data storage and management at a regional level and with the integration of national and regional data and systems. To illustrate, the data from a number of monitoring activities at present simply exist on an internal hard drive without any systematised and central storage, retrieval and publication arrangements. Some historical data apparently exists only on an individual laptop or external drive.

The Operational Review has commented on additional problems with access to data at a divisional level whereby a specialist needing technical documents/reports held by a Division other than his/her own, requires a request to the Director of the Division which holds the information. As the Operational Review notes "*it is clearly evident that these methods of data sharing have exceeded their usefulness, and that wholesale re-imagining of how knowledge is stored, shared, disseminated and secured is considerably overdue*". Potential loss of data (indeed some EHM data has been lost[10]), difficulty in public access, and additional effort

[10] 2011 Ecological Health Monitoring data for Cambodia is no longer available at MRCS or in the relevant line agency

required to make data available (even internally) for analysis, presents a very high risk to the credibility of the MRC as a regional knowledge hub.

The MRC has embarked on a commendable improvement plan to fix some of these issues and some good work has been done to-date. This is largely on-track in terms of the Strategic Plan work programme but it needs to be accelerated and substantially enhanced. The high-level political commitment from Member Countries and Development Partners provided in a joint statement in August 2018 needs to be acted on.

Improving the information and data management systems should be one of the highest priorities in the proposed consolidation of MRC work over the remainder of the Strategic Plan period. Not only is it central to the capacity for MRC to deliver on other priorities, but inadequate systems undermine support within Member Countries for the decentralisation effort. If countries do not see where the data is going and how it is being used and shared, there is less motivation to continue to invest time and resources in its collection.

The efforts to improve integration between MRCS and Member Country held data appear to be largely focused on alignment between MRCS and NMCS data and information systems. If Member Country data held and managed within line agencies is not tightly integrated into the NMCS architecture it will be a lost opportunity to achieve efficiencies and ensure greater ownership by line agencies of the monitoring effort.

The systems and infrastructure to support data management is one thing but there is also concern staff do not necessarily understand their responsibilities as data custodians. The MTR heard concerns expressed about the way this has slipped for some activities since prior to 2015 when there were dedicated staff to follow-up and manage the quality assurance and uploading of data to the system. Further effort is required, not just on improved software and hardware, but in ensuring staff are supported in using data management systems appropriately. With the upgrading of systems, protocols and training for MRCS staff will also need to be updated. New protocols on sharing of data and technical information both within the MRCS and externally will be required. The MRCS and MCs could benefit from further consideration of Government and development partner focus around the world towards more open data systems which increase transparency and public access of public resources.

Data collection and analysis as it pertains to the decentralised activities is also problematic in some cases. For instance, some stakeholders identified the overall poor performance of the HYCOS network, with gaps in the data and unreliable readings, making use of the data for any modelling or planning work next to impossible. Instead, modelling work relies largely on the manual water level data network. Until this year, HYCOS station performance was never higher than 77% (below the 80 percent WMO benchmark[11]) and the data generally only used by MRC as a cross-check and to fill in gaps in the manual data for flood forecasting purposes. Given the cost invested in the network to-date and the ongoing maintenance issues with stations, it is alarming so little use is being made of the data. Unsurprisingly, one component of the second

[11] According to the review report of the first phase of the Mekong HYCOS project. The MTR team were not able to verify this benchmark figure and the basis for it.

phase of the Mekong HYCOS project is concerned with improving hydro-meteorological data usage through increasing capacity in data analysis.

Member Countries reported old and outdated equipment as hampering data collection and analysis efforts for activities including fisheries monitoring, discharge measurement and sediment monitoring and water quality monitoring. The need to upgrade equipment will put further pressure on line agency budgets as decentralisation continues.

(vii) Alignment and integration of monitoring stations and between activities

The development of MRC monitoring activities under the old programme structure of the MRC means that the choice of station or sampling location often appears to have been undertaken without apparent regard to opportunities for synergy and integration. It is unclear for instance why any sediment monitoring samples would be collected in places where are there are not existing hydrological monitoring stations (there appear to be three such examples in Cambodia). Similarly, with the importance of links between hydrology and all other aspects of riverine health, sampling locations for water quality and ecological health and to the extent possible, fisheries, should be selected with regard to a corresponding hydrological station which is also providing data to the MRCS as part of a regional database. The 2018 Joint Environmental Monitoring report makes further comment on this issue.

In addition, collecting Ecological Health Monitoring samples at water quality sampling locations at the same time, could provide an opportunity to reduce the amount of water quality testing required (EHM also requires some water quality parameters to be measured) and also to enable analysis of overall riverine health considering both biological and physicochemical indicators. The review team heard of difficulty in some instances finding natural riverbanks on which to take EHM samples, which may be an issue at some WQM sampling locations, but this is unlikely to be prohibitive.

As noted above, part of the challenge is that the number of monitoring stations continues to grow. It is unclear what opportunity this additional investment might provide for a more cost effective system as a whole. Of course, changing or removing any stations from the regional network should not be undertaken lightly. A continuous historical data record is important for modelling and planning purposes. Nevertheless, as the Joint Environmental Monitoring report notes, there are ways this can be addressed through the use of models, periods of parallel operation and remote sensing data.

The overall monitoring network is quite different now to what it was when the stations were initially selected and opportunities to rationalise in the context of diminishing resources should be considered. It is beyond the scope of this review to recommend changes to any particular stations other than to point out that the whole LMB station network should be considered in terms of current and planned development projects, potential impacts of climate change, and the importance of changes in the tributaries to impacts on the mainstream and across national borders. The review team does not have confidence the current network design is optimal.

To consider this issue properly requires detailed examination of the full LMB network. As a result of staff turnover and changes at the MRCS as well as bilateral programmes and projects

such as the JICA and ADB ones referred to above, the full extent of the current and planned network is not currently documented. Doing this should be the first step in considering opportunities for improved integration between national and regional monitoring to enhance whole-of-basin planning, operational coordination and reporting.

It is worth noting that this applies equally to socio-economic data as it does to environmental data. An understanding of the landscape of socio-economic data achieved through various national studies and surveys and the nature of the data at a sub-basin level (e.g. province or district) is currently lacking and hampering efforts to move forward on the decentralisation of the ad-hoc provision of socio-economic data.

53. Table 7 provides a summary of the key issues for each monitoring activity as recorded by MRCS in January 2018 and as assessed by the review team in November 2018. Each of these individual issues is examined more fully in the activity-by-activity section below (section 5.0).

54. The issues summarised above and presented in table 7 can all be addressed with sufficient commitment and cooperation between Member Countries and the MRCS. It is in all parties' interest to ensure a sensible and measured decentralisation that does not jeopardise the core functions of the MRC and the basis for effective water diplomacy in the process. One of the challenges, however, is that the ambition for the MRC's work programme has not reduced in line with the reduction in resources and this applies to the SP more broadly as it does to the monitoring activities themselves. The Operational Review identified a clear mismatch in this regard.

55. The MTR did not hear anyone suggesting some monitoring activities may need to be curtailed to better align with available resources, even though some countries are clearly struggling with the responsibility. Indeed, the only messages heard were of plans for expansion and enlargement including as part of the Joint Environmental Monitoring activity. While no doubt there is considerable room to improve and build greater understanding of the state of the basin from further monitoring activities, additional monitoring effort seems to be at odds with the reality of the budget situation facing the Member Countries and the MRCS. With limited and declining resources, choices need to be made. Priorities need to be identified – if everything is a priority, nothing is a priority.

Table 7: Summary of the key issues for each decentralised activity

Decentralised Activity	Key Issues Jan 2018 or earlier (from MRCS reports)	Resolved or outstanding	Additional issues/remarks as at Nov 2018
Monitoring near real-time hydro-meteorological parameters (HYCOS stations)	- Financial sustainability of monitoring stations (esp. Lao PDR) - High number of stations not working (equipment/network issues) - Lack of use being made of data - Problems with data transmission incl. telecommunications network coverage, old servers and software not up-to-date - National and regional systems not well integrated	☒ ☑ ☒ ☒ ☒	- Stations partially fixed, but performance issues remain (82% of stations functional in December 2018) - Lack of regular and timely maintenance due to insufficient budget is the main issue - Servers not so much the issue; rather reports of poor internet connections and changes in national telecommunication networks requiring upgraded modems
Manual monitoring of rainfall and water levels (other hydro-met stations)	- Timely and accurate data collection (technology & human issues) - Problems with server and software - Integration of data transfer, storage and management	☒ ☒ ☒	- Additional rainfall stations required to improve flood forecasting accuracy
Discharge measurement and sediment monitoring	- Financial capacity (no monitoring since 2016) - No agreement on monitoring arrangements, especially for joint stations - Thailand/Lao - Human capacity at MRCS – lack of strong leadership/coordination - Scope and methodologies yet to be agreed - Data storage and management at regional level	☒ ☑ ☑ ☒ ☒	- Financial capacity (monitoring resumed in 2018) - Agreement on arrangements for joint stations - Thailand/Lao, but delays on transfer of funds from MRCS - Human capacity at MRCS addressed with new staff - No handover agreements (2018 scope & methods agreed) - MC concerns about state and choice of equipment, selection of monitoring parameters
Routine water quality monitoring	- Data quality assurance and laboratory proficiency - Data storage and management at regional level - Ongoing capacity building - Links with EHM and with future emergency response activities (timeliness of data provision and parameters monitored)	☒ ☒ ☒ ☒	- Consideration being given to less frequent proficiency testing - Data storage and management at regional level - Training workshop planned for Feb 2019
Ecosystem health monitoring	- Data storage and management at regional level - Need stronger links with water quality monitoring	☒ ☒	- Handover schedule will not be met by some countries - Limited use being made of data
Fisheries monitoring	- Delay in handover documents; Delay in financial handover - Methodological differences (FADM – different gear; Lee traps prohibited in Lao PDR) - Need updated monitoring guides (Cambodia & Lao PDR requests) - Human capacity issues (ongoing)	☒ ☒ ☒ ☒	- Handover schedule will not be met by some countries - Lee traps in Lao PDR allowed for 2018 but now discontinued
Field data collection for SIMVA	- Lack of integration with broader socio-economic data collection and management - Lack of agreement over methodological issues incl. survey design	☒ ☒	- Design issues resolved for the 2018-19 survey
Ad-hoc provision of socio-economic data for basin planning	- No formal handover documents; lack of clarity on data requirements and inconsistencies between countries; no systematisation of processes - No financial capacity for additional data collection beyond what is already collected - Storage and management of data (outdated database)	☒ ☒ ☒	- 2018 SOBR relied on national consultants to collect data
Preparation and coordination of NIPs for basin planning	- Significant coordination task; ongoing improvement needed in quality of plans	☒	- Timeliness of preparation of NIPs given country budget timelines

6.0 Overall recommendations to address the issues

56. The decentralised monitoring activities underpin the delivery of all the Core River Basin Management Functions of the MRC. They are essential to the MRC's role as a regional knowledge hub and a platform for water diplomacy. The basis for MRC monitoring systems to be effective in delivering the CRBMFs is largely in place. A substantial effort over many years has led to the design and establishment of high quality river monitoring activities covering environmental disciplines of relevance to the 1995 Mekong Agreement (hydro-meteorology, sediment, water quality, aquatic ecology and fish), as well as a uniquely targeted survey examining the wellbeing and livelihoods of water-dependent communities along the mainstream (i.e. SIMVA).

57. Maintaining these activities requires ongoing investment in basic data collection, analysis and reporting, support systems, and in ongoing capacity building and refinements to methodologies to ensure they continue to meet evolving basin needs and priorities. As resources decline, choices will need to be made about what to continue, what to cease and what to scale-back to a more sustainable form. The decentralisation process itself is intended to help crystallise this choice by encouraging Member Countries to consider carefully what is absolutely critical to support regional needs and what is a relative luxury in a more resource constrained world.

58. Member Countries have recognised the value the MRC provides through their commitment to complete riparian financing of the organisation by 2030 and have made good progress in increasing their contributions to the MRC budget in-line with that commitment. This progress stands in contrast to the evident difficulty countries face in obtaining funding support on an activity-by-activity basis through national agency budgets, and the risks this now poses to the continued delivery of MRC monitoring activities. National line agencies have a difficult case to make when finance ministries point to the national funds already committed to the MRC central budget.

59. It is apparent to the MTR that the implementation of monitoring activities for regional needs will require joint efforts to resolve, recognising the differing capacities between countries and the degree of readiness to take on complete responsibility for financing. The nature of these integrated monitoring activities is that if one country fails to secure sufficient budgetary resources it has the potential to undermine the whole regional effort – the value is in the whole, not the constituent parts. Recognising the substantial commitment Member Countries have made to self-financing of the MRC and that some activities are more efficiently delivered through joint arrangements, the MTR recommends:

- a more gradual transition process for decentralisation between now and 2030;
- greater emphasis on transitional support through a dedicated joint funding facility;
- a systematic and focused capacity building effort in support of decentralisation;
- hard choices are made about monitoring activities that could cease, be scaled-back or re-designed as informed by a comprehensive audit of monitoring activity across the LMB.

i. A more gradual transition process for decentralisation between now and 2030

60. The decentralisation of CRBMFs is happening at an extraordinary pace, given the level of readiness within Member Countries and their differing capacities and needs. The MTR is not convinced such a pace is necessary, and indeed is putting the continued availability of critical data at risk.

61. A more gradual transition process could mean the handover of financial responsibility to Member Countries would more closely follow the trajectory of self-finance of the MRC, from the 23 per cent it is today to the 100 per cent it is expected to be in 2030. The MTR recommends that existing handover agreements should stand but that a more gradual transition schedule could be applied to activities for which agreements have not yet been signed, in particular for fisheries abundance and diversity monitoring and discharge measurement and sediment monitoring. A handover schedule approximating 25% Member Country contributions in 2020, 50% by 2025 and 100% by 2030 might be appropriate. The SIMVA survey is already planned to have a longer transition arrangement along these lines and any additional activities identified for decentralisation should also have an appropriately long handover schedule.

Recommendation D.1: *For decentralised monitoring activities that do not have existing handover arrangements in place, develop agreements with Member Country contributions of around 25% in 2020, 50% in 2025 and 100% in 2030 to align more closely with the transition to self-financing*

ii. Greater emphasis on joint transitional support and capacity building with dedicated regional funding

62. The key challenges to effective decentralisation are sufficient budgetary resources and the technical and managerial capacity of national staff to effectively integrate regional activities into their work. Both of these issues relate to the level of support that all parties provide each other through the process, recognising their differing capabilities and level of readiness.

63. With the focus over the past two years having been on establishing handover arrangements, implementing organisational and administrative changes, and resolving methodological issues with some activities, there has been insufficient focus on national level capacity building and transitional support to the decentralisation process. This is particularly so in terms of country-to-country support but also in relation to the MRCS's coordination and technical leadership role.

(a) Regional Funding Support

64. The MTR recommends the Member Countries establish a Joint Decentralisation Support Facility using the Basket Fund and allocated under the decision-making authority of the JC to capacity building, knowledge sharing, and maintenance support where it is more efficient to do so at a regional level and to ensure ongoing availability of critical data for regional needs. This would involve setting aside an agreed quantum of funds each year as part of the annual work planning process for transition support activities and could be topped-up by Member Countries and Development Partners if desired. The implementation of this Facility by the MRCS could be through a sub-account of the Basket Fund and:

i) would be supported by clear principles and criteria to guide the JC in allocating funds and their disbursement by the MRCS in accordance with the Annual Work Plan approved by the Council. The facility should not lead to a *de-facto* re-centralisation of decentralised activities. Criteria for allocating funding could include:

   (i) the extent to which the expenditure of funds is more efficient at a regional level;

   (ii) the criticality of the data to the delivery of the CRBMFs;

   (iii) the role of knowledge sharing and capacity building associated with the use of funds;

   (iv) any supporting work required to transition from this financial arrangement over time.

   The Facility would not be used for the MRC's agreed contribution to each activity during the transition period. This would continue to be budgeted by each division, as necessary.

ii) would quarantine joint funding to a subset of critical monitoring activities. Based on the development challenges facing the LMB and the results of the Council Study in relation to potential future trade-offs, the MTR believes these critical activities are: (i) Hydro-meteorological monitoring; (ii) Discharge measurement and sediment monitoring; (iii) Water quality monitoring; (iv) Fisheries monitoring; and (v) Regular provision of socio-economic data;

iii) would effectively extend the transition period for decentralisation by allowing financial handover for these supporting functions to occur in-line with Member Country contributions to the basket fund, gradually reaching 100 per cent by 2030;

iv) should reinforce the substantial coordination role which remains at MRCS by empowering a more proactive engagement of MRCS staff with NMCSs and line agencies on implementation of decentralised activities. The MRCS would coordinate the delivery of activities through the Facility and manage contractual arrangements or MoUs with national agencies and third party suppliers.

65. The rationale for a dedicated facility, potentially as a sub-account of the Basket Fund, is to ensure transparency and accountability in the allocation of funds to support the decentralisation process. Because of the potential use of funds for cross-financing of Member Country commitments, this arrangement with the oversight of the JC will help ensure that the use of Basket Funds in support of decentralisation does not become a *de-facto* re-centralisation of activities. The use of the Basket Fund also ensures flexibility to adjust the allocation of funds from year-to-year subject to need and other priorities.

66. The MTR estimates approximately US$435,000 would be required each year from 2020 (more in years when SIMVA data collection is required) assuming human and technical capacity building costs of around 20% of total annual activity costs, spare parts for HYCOS stations of around 50% of maintenance costs, and use of funds to support equipment purchases and temporarily cross-finance part of the implementation for discharge measurement and sediment monitoring and for Proficiency Testing and some consumables for water quality labs, and that the other recommendations in this review as indicated in the table below are followed. This total amount is roughly 65% of the additional annual contributions Member Countries are expected to make

between now and 2020 and 11% of the projected total 2030 budget (assuming 5% annual inflation in monitoring costs).

Recommendation D.2: *Establish a Joint Decentralisation Support Facility for Member Countries (and Development Partners) potentially as a sub-account of the Basket Fund to fund capacity building, knowledge sharing, and maintenance support where it is more efficient to do so at a regional level and to ensure ongoing availability of critical data for regional needs.*

(b) Capacity Building Support

67. The MTR recommends MRCS, working with the *Expert Group on Data, Modelling and Forecasting*, develop and implement capacity building support plans for all decentralised activities. Plans should focus on human capacity development to address technical skills and staff turnover at a national level, and recognising differing levels of capacity between countries through substantial use of country-to-country learning and knowledge sharing. Capacity building activities could:

i. be closely tied to the use of the funds from the Joint Decentralisation Support Facility such that any use of funds in relation to the Facility would have a capacity building element associated with it. For example, any station maintenance activities would involve training of national operators and country-to-country knowledge sharing at the same time;

ii. draw on the existing expertise of national institutes, line agency experts and other regional bodies in establishing a community of practice around each monitoring activity. Online forums such as established under the HYCOS helpdesk do not work without an active and engaged community as knowledge resides with people not in online systems and databases.

Recommendation D.3: *Prepare and implement capacity-building plans for each decentralised monitoring activity, supported by regional funds through the Facility proposed in Recommendation D2 and with maximum use of country-to-country learning and knowledge sharing. This would include identification of opportunities for knowledge sharing and capacity building support from Thailand and Viet Nam to Cambodia and Lao PDR.*

iii. Prioritise monitoring activities and step-up the integration of regional and national monitoring systems

68. The MTR recommends greater delineation between monitoring activities that are absolutely critical and those that, while valuable, might more appropriately be considered 'nice-to-have'. As noted above, in the first category would be hydro-meteorological monitoring, sediment, water quality, and fisheries monitoring along with the transmission of basin-scale socio-economic data. In the second category would be the ecological health monitoring and the SIMVA survey. The overall approach for each are proposed as follows:

Monitoring activity	Priority	Rationale	Recommended approach
Hydro-meteorological (automatic & manual)	1	Hydrological data is the basis of any river system analysis and necessary for implementing the MRC procedures, flood forecasting and flood response	Combine the two hydro-met activities. Redesign the overall network for cost efficiency and with regard to current and future hydropower; and support critical station maintenance with regional funding

Discharge measurement and sediment monitoring	1	In addition to physical barriers, sediment is the most critical transboundary matter affected by mainstream development	Longer transition period with regional funding of equipment replacement, training and maintenance. Clarify indicators and monitoring parameters
Water Quality	1	Water quality is necessary for implementing MRC procedures and is critical to human and aquatic health and agricultural use	Regional funding and procurement of Proficiency Testing and some consumables for laboratories
Fisheries	1	Fisheries are the key resource trade-off associated with mainstream development and critical to food security	Longer transition period with regional funding of equipment replacement and maintenance
Socio-economic data provision	1	Provides essential information for assessing the status and trends in condition and examining trade-offs	Clarify and formalise arrangements around an agreed set of indicators and monitoring parameters for transmission to MRCS once every 5 years as linked to the SOBR
Ecological health	2	Without integrated analysis, the utility of this data is limited, especially when key matters of interest are already being monitored (i.e. WQ and fish)	Suspend activity pending a review of integrated multi-disciplinary assessment options that may enable more valuable use to be made of the data
SIMVA	2	Although the richness of SIMVA data cannot be replicated across the whole basin, its limited geographical scope limits the utility of this data; greater provision of broader scale socio-economic data at a sub-basin scale in accordance with the MRC Indicator Framework may be sufficient to inform future basin planning	Scale back to only the full survey every 5 years with a small set of core indicators (~20-25) and no thematic studies

Recommendation D.4: *Distinguish between critical monitoring activities and those that are less than critical and for the latter group, either suspend or substantially scale-back operations to enable resources to be directed to higher priority needs.*

69. One of the key barriers to effective decentralisation is the perception in some cases there are (or should be) two separate monitoring systems, one in support of national needs and the other in support of regional needs with each having their own set of monitoring stations, financial obligations, and operating arrangements. This is unlikely to lead to a cost effective, sustainable monitoring effort.

70. To ensure effective decentralisation there should be as far as possible only one monitoring network in each country for each activity. While in the short-term there may be a distinction in who is funding and managing each station, in the long-term the only distinction should be the extent to which data is transmitted to the MRCS to support sustainable basin development and multi-lateral cooperation in the LMB.

71. The Joint Environmental Monitoring (JEM) activity provides the basis for a more integrated and coordinated monitoring effort including the collection of data according to agreed protocols and methodologies and its sharing amongst a range of actors. This is an activity that was not identified when each of the individual monitoring activities was designed but may turn out to be one of the most important monitoring initiatives. The JEM has the potential to lead to a more cost-effective monitoring effort overall. It is critical, however, that this activity does not become just an argument for more monitoring. The opportunities for more effective, targeted (and some cases less) monitoring are enormous. The MTR recommends:

i) the MRCS and MCs, working through the *Expert Group on Data, Modelling and Forecasting,* (or a sub-group) undertake an audit of all existing and planned monitoring stations and sampling locations within the LMB, whether identified as supporting regional needs or not. This audit would encompass all stations and sampling undertaken by national line agencies and provincial authorities, as well as those established with bilateral development partner support or by dam developers on the mainstream and the tributaries (Attachment B to the separate Decentralisation Review Report provides a starting point to this review);

ii) based on the above audit, the MRCS undertake a consultative process with expert technical support to identify gaps (especially in relation to the location of existing and new hydropower dam and agricultural development projects), duplication and redundancy in the existing (and near future) network and develop a plan to address these issues based on the cost effectiveness of the network as a whole;

iii) commission a consultant to undertake an independent cost-benefit assessment of several network designs to support the review including consideration of the use of automatic telemetry stations versus an upgraded manual system (with more stations and twice-a-day reporting where useful) for river level, flood and drought forecasting, flash flood guidance, and operational modelling needs;

iv) as part of the above design work, investigate options to better align hydrological and sediment monitoring locations and water quality, and ecological health (if continued) monitoring locations to support integrated assessment methodologies and improved causal analysis;

v) the MRCS, working with the *Expert Group on Data, Modelling and Forecasting* and National Statistics Offices from each Member Country*,* finalise and agree in 2019 the ongoing socio-economic data requirements to evaluate the status and trends in socio-economic conditions across the basin. The MRCS could then formalise acquisition, transmission and management arrangements through handover agreements with MCs consistent with the *Procedures for Data and Information Exchange and Sharing*; and upgrade the regional socio-economic database with linkages to national systems as is being done for environmental parameters in the MRC-IS.

Recommendation D.5: *Building on the work of this MTR, the MRCS and MCs working through the Expert Group on Data, Modelling and Forecasting undertake an audit of all existing monitoring stations and sampling locations in the basin for four key environmental disciplines (hydro-meteorology, sediment, water quality) and of existing socio-economic datasets and identify opportunities for synergies, re-alignment, enhancement and removal of redundancies to enable a more cost effective overall monitoring effort. A cost-benefit analysis would then be conducted by the end of 2019 on options for a re-designed core network in order to meet future regional needs, having regard to current and future mainstream and tributary dam operations and other development activities with potential transboundary impacts. Require hydropower developers as part of Concession Agreements to share data for any stations they own that are part of this network.*

iv. Enhanced support systems for collecting, transmitting and managing data

72. The quality of the systems used to collect, transmit and manage data at both a national and regional level are essential to a sustainable monitoring network and allowing effective use of the outputs. Data and Information management systems need to be urgently modernised and systematised across all activities. The MTR recommends the MRCS and MCs prioritise the completion of the upgrade of the MRCS information and database systems over the remainder of this Strategic Plan period and ensure all historical data is uploaded and accessible to stakeholders by the end of 2019. This would include:

i) having all official and approved data available for direct download through the website rather than on request;

ii) enabling integration and cross interrogation of different datasets within the same database (e.g. sediment, hydrology and water quality);

iii) updating protocols on the management, use and sharing of specific categories of data, as necessary;

iv) ensuring linkages between national and regional databases so that a single source of truth can be established and all Member Countries are working from the same source data;

v) providing guidance for all staff with data management responsibilities on their obligations to ensure quality assured datasets are kept up-to-date and maintained within the MRC-IS.

73. In addition, the MTR recommends the *Expert Group on Data, Modelling and Forecasting*, prepare a concept note on harmonising the operation of all like-for-like monitoring stations and sampling procedures over time in relation to data transmission and management systems (software, telemetry, QA/QC processes), and O&M procurement arrangements with a measured, incremental approach to achieving higher standards and more reliable operations across the entire LMB.

Recommendation D.6: *The MRCS prioritise the upgrade of the MRC-IS over the next two years by establishing and resourcing a task-force of MRC staff and external IT support, and overseen by a senior executive project committee within MRCS, to ensure the MRC-IS upgrade is completed and all historical data is uploaded and accessible to stakeholders by the end of 2019.*

7.0 Conclusions

74. Although some good progress has been made, the decentralisation of monitoring activities is happening too quickly. This is particularly the case for Cambodia and Lao PDR, where the increased financial obligation is greatest. With the difficulties Member Countries face in accessing financial resources for these activities, the decentralisation process is at serious risk of failure. Line agencies are making budget submissions when they are required to do so, but these are often not being approved. Central agencies (finance and investment and planning) in each country are questioning why additional funds are necessary for monitoring activities when countries are already increasing their contributions to the MRC budget.

75. The planning for decentralisation foresaw the need for substantial capacity building and transitional support to Member Countries to ensure successful handover of responsibility. However, while needs were identified and plans developed there has been minimal follow through. There is a strong need for further resource allocation and sustained commitment to improving capacity in support of the decentralisation effort. Capacity needs will be ongoing for some time. Regular refresher training and knowledge sharing especially at a national level is necessary to address high staff turnover and to instil good practice.

76. The decentralisation of monitoring activities is occurring without any serious prioritisation of monitoring effort or investigation of options for more efficient delivery in the changing Lower Mekong Basin environment. This includes insufficient steps to improve integration of regional and national monitoring and to scale-back and even cease some monitoring in order to match the level of effort to the available resources. The Joint Environmental Monitoring initiative is a good step in this direction. However, this initiative needs to be infused with a perspective for more efficient whole-of-basin monitoring and rationalisation of networks where appropriate to do so.

77. Data and information management systems are poor and are not working in support of decentralisation. If Member Countries do not see where the data is going and how it is used it undermines the motivation to collect it. Regional datasets simply must be uploaded and maintained in a central database accessible to all relevant agencies in each country. While recognising the good work that has been done to date and that it is not a simple process, the slow progress in upgrading the MRC-IS needs to be addressed.

78. All parties have demonstrated good faith and a generally cooperative spirit to implement the decentralised monitoring activities to-date. When issues have presented these have mostly be addressed. However, now is the time to deal with the more fundamental problems. The implementation of monitoring activities for regional needs will require joint efforts to resolve, recognising the differing capacities between countries and the degree of readiness to take on complete responsibility for financing. This will require a longer transition period, the use of regional funds to support some activities, and a sustained focus on building human and technical capacities.

8.0 Activity-by-Activity assessment

8.1 Monitoring near real time hydro-meteorological parameters (HYCOS stations)

8.1.1 Introduction

79. *Monitoring near real time hydro-meteorological parameters (HYCOS stations)* is undertaken through automatic hydro-met stations located on the mainstream and tributaries. Along with *Manual monitoring of rainfall and water levels (other hydro-met stations)*, this activity is undertaken to provide data to support transboundary modelling and assessment of flows, floods (*Transboundary flood modelling* and *Regional flood forecasting*) and droughts (*real time drought assessment and forecasting)*. Monitoring hydro-meteorological parameters is also important for all other environmental monitoring activities because of the links between changes in flow and other environmental conditions including sediment transport, fisheries, ecological health and water quality.

80. The current MRC hydro-meteorological telemetry network includes 60 stations, of which 13 are new drought stations, on the Mekong mainstream and major tributaries. There are 15 HYCOS stations in Cambodia, 17 in Lao PDR, 11 in Thailand, and 15 in Viet Nam, each scheduled to transmit data every 15 minutes. Two stations are located in China although these no longer use HYCOS equipment and submit one hour interval measurements once a day from 1 June to 31 October.

81. Some documents identify 62 stations in the MRC regional network, but two (Cua Tieu and Dinh An stations) have been withdrawn from the Delta in Viet Nam due to their inappropriate locations where they were affected by siltation, wave action, and sea water corrosion.

82. As part of the second phase of the Mekong-HYCOS project, in 2017 the MCs agreed to construct one new station at Xieng Kok, the most upstream site in the LMB in Lao PDR, and to upgrade eight existing stations from manual to automatic operation: three stations in Cambodia (Preah Romkel, Koh Khel and Neak Luong), three stations in Lao PDR (Thakhek, Paksane and Savannakhet), and two stations in Viet Nam (Tra Vinh and Dai Ngai). The planned expansion was put on hold in order to address problems with performance of the current network and is currently being revised. It is anticipated the expansion will be implemented in 2019.

83. The HYCOS stations automatically collect and transmit water level and (in most cases) rainfall data to MRC servers and to national line agencies in some countries. With the upgrade of the MRC-IS the MRC has over recent months been updating water levels on its information portal every 15 minutes and makes it available for viewing in 24 hour, 1 week and 2 week periods. Rating curves, which are updated from time-to-time at some stations in conjunction with the discharge measurement and sediment monitoring activity, can be used to convert water levels to flow or discharge, necessary for calculating sediment load and for other analytical purposes.

84. The two parameters collected at HYCOS stations, water level and rainfall, are measured automatically with sensors and stored on a data logger. The data logger must be emptied periodically so that it can continue to record new data. Except in Lao PDR, each station has dual parallel FTP[12] addresses for the transmission of the data to the FTP servers of both the National Hydrological Service (line agency) and the MRCS. The transmission via national telecommunications networks

[12] FTP stands for File Transfer Protocol and is a standard network protocol used for the transfer of computer files from a server to a client using the Client-server model on a computer network.

(GPRS or 3G) requires a functioning modem with up-to-date software and drivers. Transmission is subject to having adequate signal coverage; a challenge in some areas.

85. Various hydrological software packages are used for the management and quality control of data. HYDMET (a commercial software), is used for screening data from the MRCS FTP-server and MRCS has in the past paid the license for the four MCs. HYDRAS3, a free software, is used to fill data gaps, field downloading of data and data screening. HYMOS was introduced by MRCS many years ago in the MCs and only Cambodia and Lao PDR are still using it for data storing (input and extract).

86. Three additional software packages (*Trigger* for transmission of data, *Online QA* for quality assurance, and *HYCOSconverter* for data formatting) were produced and previously used by the MRC for hydro-met data management at the regional level but these are now being replaced. The upgrading of the MRC-IS has introduced *Aquarius*, a data management software to support online data integration and quality assurance, synchronisation of databases, and the manipulation, visualisation and export of time-series data. It is now being used for the automatic hydro-met data and is planned to be rolled out to other MRC time series data in 2019. This software, in association with other upgrades, will help streamline the process of data conversion and integration with the master database.

8.1.2 Network Handover

87. The handover of responsibility for the initial 47 LMB HYCOS stations took place in 2012 with handover ceremonies taking place in each country. Thailand and Viet Nam took responsibility for 100 per cent of the activity costs at that time but the MRC continued financial support to Cambodia and Lao PDR until the end of 2014. Both Thailand and Viet Nam issued certificates of acknowledgement for the handover. Cambodia and Lao PDR entered into handover agreements with the MRCS identifying what their responsibilities were and recognising that the MRCS would continue to hold spare parts in a central storeroom to be made available according to procedures agreed by all parties and with the donor, the French Development Agency (AFD).

88. From 2015 all countries have had full ownership including financial responsibility for operating and maintaining the stations within their territory. There are however, ongoing discussions on how the MCs can guarantee the sustainability of the network given high costs of maintenance. Cambodia and Lao PDR have both indicated they have insufficient funds available for operating and maintaining the stations and all countries have stated they do not have funds for the supply and installation of spare parts. Recognising the capacity challenges involved in the handover, Phase II of the Mekong HYCOS project funded by AFD has involved establishing a helpdesk function to support network sustainability.

8.1.3 Network Performance

89. The first phase of the Mekong HYCOS project ran from 2008 to 2012. The final evaluation report for the project identified station performance in 2012 at 86 per cent, with 42 of 49 stations functioning well. MRC records, however, identify only 30 stations being fully operational in 2012 and 32 stations in 2013, with 16 and 9 stations partly operational in those years respectively (Table 8). It may be the HYCOS project evaluation team counted some partly operational stations as performing well enough. In any case, there have always been HYCOS stations that have not worked, for a range of reasons as discussed below.

Table 8: Number of operational HYCOS stations in each country and the whole network from 2012 to 2018

No. of Operational Stations														
Years	Cambodia		Lao PDR		Thailand			Vietnam			Mekong River Commission			Total
	Full Operation	Partly Operation	Full Operation	Partly Operation	Full Operation	Partly Operation	No operation	Full Operation	Partly Operation	No operation	Operational	Partly Operation	No operation	
2012	9	3	9	3	8	2	1	4	8		30	16	1	47
2013	12	0	8	4	7	1	3	5	4	1	32	9	4	45
2014	11	1	5	7	8	3		9	1		33	12		45
2015	10	2	3	9	9	2		10	0		32	13		45
2016	10	2	0	12	3	8		9	1		22	23		45
2017	5	7	0	12	1	10		6	4		12	33		45
2018	9	3	10	2	10	1		9	1		38	7		45
Note: for 2012 and 2013, if the number of operation day is less than 200 that means partlt operation														

90. In 2014 and 2015 overall performance of the network was relatively stable, at 73 and 71 per cent of stations fully operational at the end of each year respectively (Figure 1). In 2016 performance declined to 49 per cent and then fell again to 26 per cent in 2017. In 2016 and 2017 not a single station was working in Lao PDR. Station performance only recovered in 2018 following a dedicated recovery mission from March to May 2018 instigated by the MRCS and costing USD 118,835 to fix stations in every country. Throughout this period it is worth noting that Member Countries continued to report manual observations from the HYCOS stations, under the *manual monitoring of rainfall and water levels activity* and so information on mainstream water levels was still available.

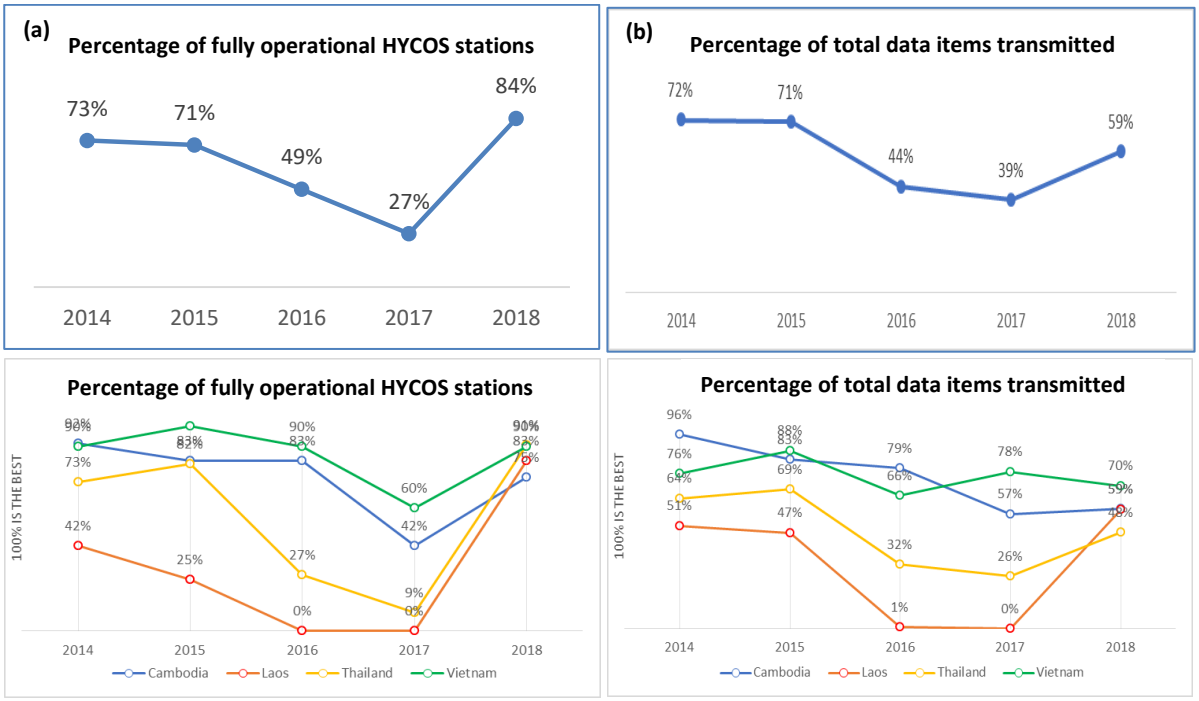

Figure 1: (a) Station and (b) data transmission performance of HYCOS stations overall and for each Member Country from 2014 to 2018 as indicated by the percentage of stations fully operational, and the percentage of total data items successfully transmitted

91. Based on MRC records and due primarily to this recovery mission, 2018 is the first year the network has met the World Meteorological Organisation (WMO) minimum performance target of 80 per cent of stations operational[13]. In June 2018, shortly after the recovery mission, it was reported that 91 per cent of stations were operating[14]. This had reduced to 87 per cent by July[15], then 84 per

[13] This is the benchmark according to the 2012 Mekong HYCOS Phase I Project Evaluation Report
[14] MRC Report for Joint Environmental Monitoring of mainstream hydropower (draft June 2018)

cent by August (Figure 1) and as of November stood at 82 per cent with ten of 58 LMB stations not operational according to the MRC website[16].

92. In terms of data provision, performance of the HYCOS stations in August 2018 was only 59 per cent (i.e. 41% of data items were missing), higher than the 39 per cent recorded in 2017 but not altogether encouraging. Slightly more than half the data due to be collected, transmitted and stored from these stations is actually making it into the MRC regional database.

93. The Mekong HYCOS helpdesk has a feature, recently established, to notify Member Countries every morning by email the status of the HYCOS stations. For a few months now Member Countries have also been able to check the stations on the monitoring portal of the MRC website.

8.1.4 Value and use of the data

94. In the consultations undertaken for this review all Member Countries said they highly value the river water level information provided by the MRC on its website. This was particularly the case for Cambodia and Viet Nam where the impact of mainstream flows on flooding is more pronounced. Officials from Viet Nam pointed out they regularly monitor the MRC website for information on river levels throughout the flood season and believe that near real time information is critical in being able to prepare and respond quickly to emergency situations. In Viet Nam automatic telemetry stations are set to transmit data every 10 minutes rather than every 15 as in the regional network[17]. Lao PDR reported using the data for national flood forecasting services.

95. The poor performance of the network, however, with gaps in the data record and many stations either not operational or only sending partial data, means that the database is only used as a back-up system for flood forecasting by the MRC River Flood Management and Mitigation Centre (RFMMC). The MRC's flood forecasts rely on the manual water level and rainfall data sent by the Member Countries once a day and only use the automatic HYCOS data when there are gaps or to cross-check the reliability of the manual data. The review team also heard from people who have undertaken a considerable amount of modelling and scenario impact assessment work for MRC in the past and who reported the dataset from automatic stations is not reliable enough to be used for this purpose. The lack of an integrated dataset including automatic and manual data also does not help in this regard as the historical HYCOS data, when it exists, only extends back to 2010. This is after the baseline period agreed for MRC modelling exercises as part of the DSF (currently 1985-2008; Output 6.3 of the MRC SP seeks to agree an updated baseline to 2017).

96. Hydro-meteorological data is a critical foundation for any river basin management work. It is central to understanding and attributing change in almost all other environmental parameters whether due to natural variability, development activities or indeed climate change. The HYCOS data appears to be an important resource for people that have a need to understand what current river levels are and how they compare to defined alarm and flood stage levels over short observation intervals including for emergency respons. Short observation intervals for hydrological events can be useful in understanding the nature of flooding events. For example, MRCS reports the characteristics of a rising flood can show significant changes due to human activity which may only be detected if data in short intervals are available.

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[15] Report to the JC on implementation status of decentralised activities
[16] Website review (http://monitoring.mrcmekong.org/) for this report
[17] Note that it is important to have sufficient time between transmissions to allow data from the previous transmission to clear, otherwise one backs up on the other.

97. Short observation intervals may also be important during extreme events. However, the fact the HYCOS data is not used for river flood forecasting by the MRC suggest that daily water levels in the Mekong are generally sufficient. In the near future short observation interval data may become more important in coordinating the control of dam operations and to ensure operations comply with agreed rules. Nevertheless, it is important not to overstate the value of automatic telemetry data relative to manual readings, particularly as manual readings are also scalable. If necessary, more than one manual reading could be taken and reported in a day. Some manual stations already record water levels at 12 hour intervals.

98. The MRC regional network of automatic telemetry stations is only part of a broader network of stations within Member Countries, both automatic and manual. That network continues to grow as both Member Countries and dam developers establish new stations to meet national and project needs. Therefore any consideration of the value of MRC regional data and the cost effectiveness of its production needs to understand the alternative network designs and technologies that might be available to meet both current and future needs.

8.1.5 Issues and causes

99. This review has identified three main issues with the monitoring of near real time hydro-meteorological parameters, all of which are interrelated. These issues are: (i) the poor performance of the network; (ii) the limited use made of the data in MRC products and services; and (iii) the potential inefficiency of the network given the changing circumstances of the Basin.

100. All Member Countries have expressed a commitment to maintaining the network, recognising the importance of hydro-meteorological data to deliver the CRBMFs. However, national budgets for these stations are very limited and taken together with the other hydro-meteorological stations across the basin, the MRC stations are likely to be less relevant to national needs and therefore lower priority in budget decisions. National agencies have access to other sources of hydro-meteorological data and this is growing.

(i) Poor performance of the network

101. The poor performance of the HYCOS network is illustrated in section 8.1.3. Even following a dedicated MRC recovery mission in 2018, the transmission of data is on average only 59 per cent of total data items that should have been delivered. Station performance has slipped again from 91 per cent to 82 per cent of stations fully operational in only five months. It would appear likely that station performance will again slip below the WMO benchmark of 80 per cent in the near future.

102. Through examination of previous reviews and consultation with MRCS staff and Member Countries the main reason for the poor performance of the network is insufficient maintenance. The MRC recovery mission in 2018 found that station performance was higher when equipment and civil works had been well maintained through regular checks by operators who carefully follow operational procedures. Much of this routine maintenance is technologically relatively simple. For instance, emptying the data logger memory so that new data can be recorded, replacing or recharging batteries, ensuring sufficient credit on pre-paid sim cards, re-setting the modem, and downloading the latest versions of software. However, an apparent high turnover of staff with responsibility for operations and staff not necessarily following procedures closely including due to unfamiliarity with equipment and out of habit or convenience means that difficulties present even with relatively simple tasks.

103. Training and capacity building was a key part of Phase I of the Mekong HYCOS project. More than 15 training sessions were held between 2008 and 2012. However, it is unclear how much operator training has occurred since then to cater both for new staff and to refresh knowledge and help instil some discipline in operator practice for existing staff. Member Countries reported that training and capacity support for decentralised activities declined markedly from 2015.

104. Human capacity issues are exacerbated when multiple systems are operating within a country as operators with experience at one type of station may not have knowledge and skills in how to operate and maintain another. All countries have automatic telemetry stations within their country that are not part of the HYCOS network. Greater alignment and harmonisation of systems could provide economies of scale in training for operators across the whole of the country network.

105. Insufficient maintenance is also caused by a lack of funding for the acquisition and installation of replacement parts. All countries have previously identified they lack budget for spare parts (especially new modems, which were necessary following changes in national telecommunication networks) so it is perhaps not surprising that one of the main activities in the recovery mission was the purchasing and installation of replacement parts. The MRCS entered into a supply contract agreement with OTT Hydromet Company, the original supplier of MRC hydromet equipment, in December 2017 both to immediately replace parts not working and to reserve a supply of parts for the next two years. While the lack of funding is the main issue in relation to spare parts, Member Countries also expressed confusion about warranty arrangements for existing equipment installed under previous MRC contractual arrangements with OTT and procurement procedures as they relate to acquisition of parts from international suppliers.

106. For a maintenance regime to be effective, the people responsible need to know when problems have occurred. Although FTP servers were supposed to have been installed in each country to allow the transmission of data both to MRC and to the national agency, for Lao PDR this did not occur and so data is only being transmitted to the MRCS. Before the improvements to the MRCS website and the availability of the near real-time data in the last few months, national staff report they had no way of knowing there was a problem.

107. There are also several technological problems that are causing issues with network performance including slow internet connections to servers at both national agencies and the MRCS which may be leading to time-outs before the full data package is received. The use of the telecommunication network for the transmission of data from station to server means that the strength of network coverage is an important factor in successful transmission. Some stations are reported to be in areas with poor network coverage and frequent changes of telemetry systems by telecommunication companies also causes regular interruption of data transmission, and requires a regular update of equipment and associated spare parts.

(ii) Limited usability of near real-time data

108. One of the biggest concerns with this activity is the apparent limited use of the automatic data provided from HYCOS stations. The use of the data is closely related to issues with station performance, and it appears that the data is too unreliable to be used for any analytical (e.g. forecasting, planning or impact assessment) purpose. The current use (only recently enabled) appears limited to visualisation of current and recent water levels and rainfall on the MRC website. This use is not without value. As noted earlier, there are many stakeholders that find it useful to understand flow levels upstream and therefore likely changes in conditions downstream, particularly in Cambodia

and Viet Nam during the flood season. However, more reliable rainfall and water level observations are available on the MRC website for 22 mainstream stations as part of the MRC's flood forecasting service, albeit updated daily during the flood season (and weekly during the dry season) rather than every 15 minutes. These forecasts draw on a network of 125 manual observation stations across the LMB and are presented as two days of observed water levels and seven days of forecast water levels (3 days for Thai stations in the flood season). The forecast water levels are made using rainfall-runoff regression and hydrodynamic models maintained and run by the RFMMC.

109. The HYCOS network has been established with substantial cost since 2008 (€4,500,000 from AFD + Australian contribution to AHNIP + MC in-kind) and expansion of the network to fill perceived gaps is planned. The MRCS has indicated that up to USD 120,000 per year would be necessary to maintain the network of all existing stations. In an operating environment where support to coordinating dam operations becomes more relevant to the MRC the higher frequency transmission of data from automatic stations may become more important. Nevertheless, the cost-benefit proposition of maintaining the system as a whole needs greater scrutiny.

(iii) Suboptimal network design to meet future challenges

110. As described in the Mid-Term Review report, the basin is rapidly becoming more regulated and there is increasing need for MRC to focus on coordination of operational aspects related to potential transboundary impacts, supplementing the strategy and planning role that has been prominent to-date. While hydro-meteorological data will always be critical it is not immediately obvious the current automatic network is well designed to meet the challenges of these changing circumstances. The increasing regulation and operation of dams means that shorter frequency transmission could become increasingly valuable with information needed on rapid rises and falls in water levels. However, this will only apply if the stations are appropriately located with regard to current and future infrastructure and its effects.

111. Questions are being asked about whether the current make-up of the network is optimal in providing the hydro-meteorological data necessary to support the MRC mandate into the future. The MRC Joint Environmental Monitoring team identified a number of instances of redundancy in the network and when examining the location of new planned reservoirs on the mainstream postulated that several stations will soon lose their functionality due to their close location to planned dams. For instance, the Luang Prabang station in Lao PDR will soon be influenced by the backwater of Xayaburi and so is likely to be forced out of service. Maintaining the operation of these stations may not be the best use of resources, other than to calibrate the historical record with any new stations established nearby.

112. Another example identified by the JEM team in a site visit and meeting with the Xayaburi developers is the building of a new station with telemetric monitoring system and automatic gauges less than one metre away from the existing MRC monitoring station (Figure 2). This kind of redundancy is not efficient. Of course arrangements for the sharing of data would need to be made and agreed by relevant parties, but there would appear to be substantial opportunity for cost reductions by sharing the operation and maintenance burden in cases like this.

Figure 2: Xayaburi monitoring stations (example): left and middle picture shows new Xayaburi station directly next to existing MRC station, right picture shows radar level sensor on road bridge upstream of Xayaburi dam (Source: MRC, 2018)

113. The number of hydro-meteorological stations across the Basin is growing. Cambodia has recently installed 33 hydro-meteorological stations on tributaries of the Tonle Sap with the support of the Japan International Cooperation Agency (JICA) and 24 automatic telemetry stations with the support of the Asian Development Bank (Figure 3). These stations use different systems to the MRC HYCOS stations and are not part of the regional network. Viet Nam too has additional automatic telemetry stations not part of the regional network, as these operate on a 10 minute transmission frequency rather than 15; a relatively minor technical issue to resolve.

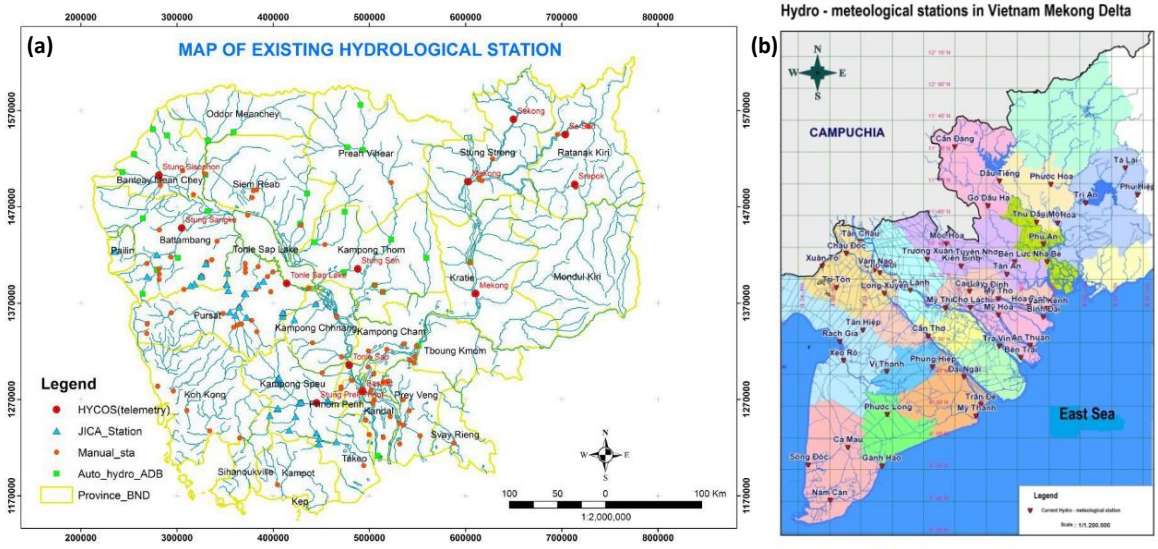


Figure 3: Locations of existing hydrological stations in (a) Cambodia including Mekong HYCOS, JICA stations and ADB automatic telemetry stations; and (b) the Mekong Delta in Viet Nam including manual and Mekong-HYCOS stations (Source: via CNMC and VNMC)

114. Having regional HYCOS stations not considered part of the national hydrological network requires them having a separate budget line and administrative arrangements at a national level. This opens up possibilities that stations outside the national network will be a lesser priority in national budget submissions.

8.1.6 Potential solutions

115. The issues identified above are not new and have been largely documented in previous decentralisation reviews. In addition to expanding the Mekong hydro-meteorological monitoring network, Phase II of the Mekong HYCOS project (2016-2021) focuses explicitly on:

- Establishment of a Mekong-HYCOS helpdesk to increase network sustainability[18]; and
- Improvement of hydro-meteorological data usage based on statistical and other analyses

116. Although the helpdesk may be a useful initiative and could help build capacity over time it does not address the fundamental sustainability issue, which is funding for operation and maintenance of the existing network. Indeed the first objective of the project, to expand the network with an additional nine automatic stations (eight of which will be upgraded manual stations), is likely to exacerbate the current problems. More stations require more trained operators, more maintenance and more spare parts. AFD agreed to put the expansion on hold while the HYCOS stations were fixed in 2018, but the implementation of the new stations is planned to occur in 2019. As the issues of financial sustainability remain, the MRCS and MCs should discuss with AFD options for keeping the expansion on hold until the ongoing maintenance issues are resolved.

117. Improving hydro-meteorological data usage is a worthy objective given the current limited use of the Mekong HYCOS data. Greater use of the data would provide greater impetus to fund station operation and maintenance. If the MRC and MCs are to operate an automatic telemetry network for hydro-meteorological data it is imperative it is adequately maintained.

118. All the current issues with network performance can be addressed with the provision of adequate financial resources for maintenance and ongoing capacity building activities for national operators. Member Countries are evidently having difficulty achieving this through national budgets. All have requested funds from Government but these have not been forthcoming.

119. The MCs do not appear to be having so much difficulty increasing their national contributions to the MRC budget in-line with stated Heads of Government commitments towards self-financing. As proposed by MRC to the JC, it may therefore be appropriate to consider setting aside some of these increased MC contributions to the MRC to ensure the necessary data is available at a regional level to support delivery of the CRBMFs. Both Cambodia and Lao PDR have expressed a view that this activity is one which requires joint efforts and regional funding.

120. Providing regional funds to decentralised activities that have already been fully handed over to MCs has the potential to undermine the decentralisation process. The benefits from having direct financial responsibility, including a sharper focus on priorities and greater impetus to explore cost effectiveness through harmonisation with national networks, may be lost. That said, as implementation remains the responsibility of line agencies there may be ways to mitigate this risk.

121. The MRCS and MCs could consider some safeguards on the use of regional funds to support monitoring activities to ensure the benefits of decentralisation can still be achieved. These benefits include greater ownership by Member Countries and a more efficient overall network achieved through greater integration of national and regional systems. Safeguards could include a decision framework for approving the use of funds that takes into account (a) the extent to which the activity can be done more efficiently at a regional level; (b) the criticality of the data to the delivery of CRBMFs; (c) the role of knowledge sharing and capacity building associated with the use of any funds; and (d) any supporting work required to transition from this financial arrangement over time.

[18] Note that the helpdesk has subsequently been considered not useful by Member Countries and alternative mechanisms are being put in place. For instance, a daily email alert on the operational status of all stations is being sent to relevant line agencies, enabling identification of issues for resolution.

122. A transition to full funding by line agencies is still desirable; the more that Member Country contributions to the MRC are used for basic activities that could be done by the Member Countries themselves, the less value-added work that can be done by the MRC in supporting water diplomacy and the sustainable development of the Basin. Of course, without the data, the capacity for MRC value-added work is at any rate diminished. A balance must be struck.

123. To support the implementation of such an arrangement the MRC and MCs would benefit from giving further consideration to what an optimal future hydro-meteorological network looks like both in scope and design with regard to current and future hydropower and other development projects and including in relation to:

(i) Number and location of stations
(ii) Automatic or manual operation
(iii) HYCOS or alternative systems
(iv) Data integration, management and dissemination

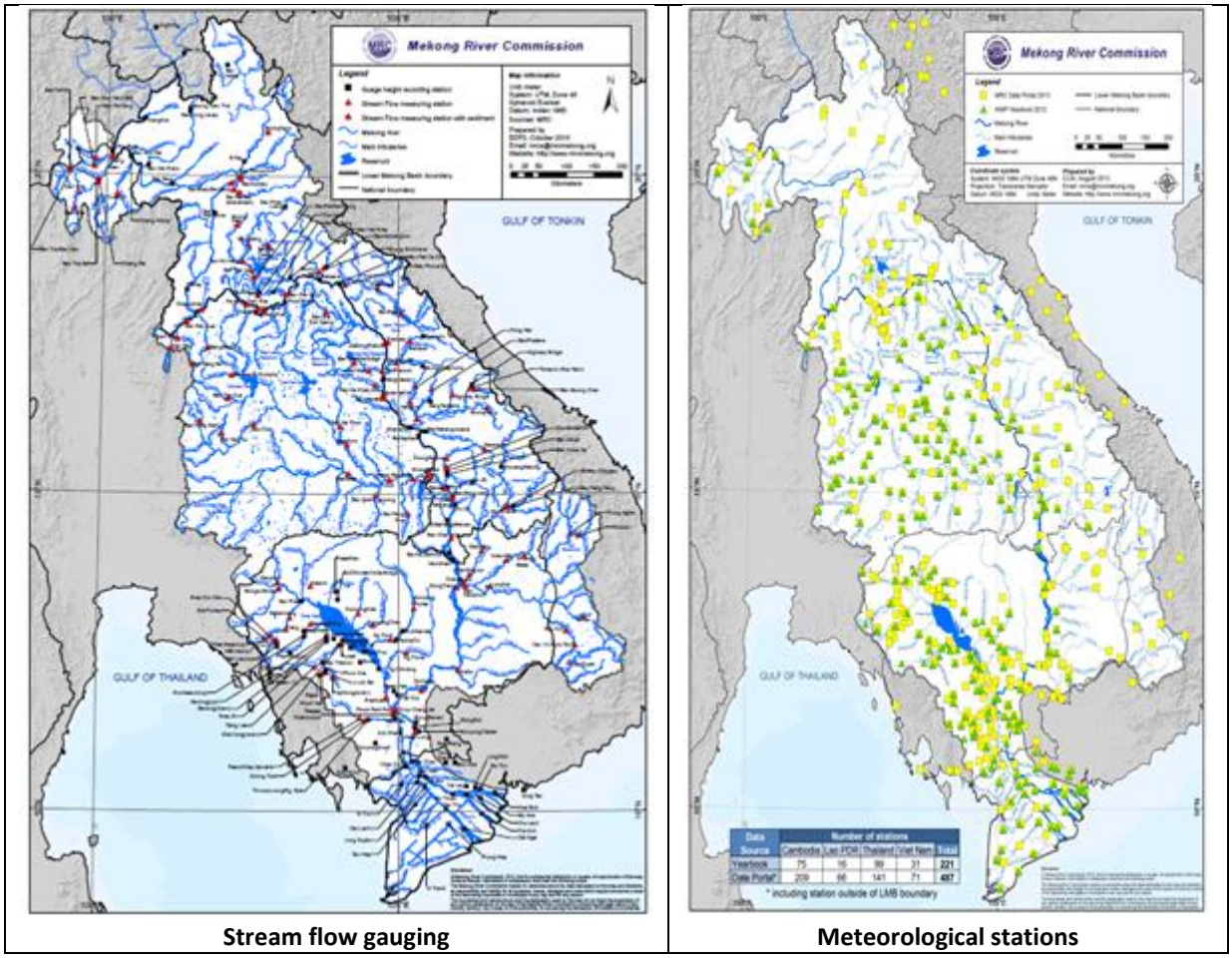
124. These considerations should be driven by an examination of benefits from the various known uses of the data and the costs of upfront investment and ongoing operations and maintenance. At present, the system appears to offer limited benefits and high costs.

125. It is well known there are many other hydro-meteorological stations operating throughout the LMB (Figure 4) and as illustrated above the number is growing. The Joint Environmental Monitoring team identified the following numbers of stations collecting hydro-meteorological data in total and in each Member Country:

- Hydrological data
  - Parameters: water level
  - Stations: 142 (Thailand: 39, Lao PDR: 37, Cambodia: 35, Viet Nam: 31)
- Meteorological data (including rainfall data and other parameters)
  - Parameters: Rainfall, Air Temperature, Relative Humidity, Wind Speed, Wind Direction, Evaporation, Sunshine Hour, Solar Radiation, Air Pressure
  - Stations: 114 (Thailand: 44, Lao PDR: 7, Cambodia: 28, Viet Nam: 35)
- Rainfall data
  - Stations: 478 (Thailand: 141, Lao PDR: 63, Cambodia: 204, Viet Nam: 70)

126. Some of these stations are more permanent than others, being operated by agencies at national, provincial or local levels, while others will be occasional or project-based stations serving a particular time-limited objective. Data from 125 of these stations is used by the MRC for river flood forecasting and flash flood guidance, but much of the monitoring effort is not accessible or documented. The data that is available can be found in public documents such as in National Hydrological Yearbooks but this is historical data often at least two years old by the time it is published.

127. These stations and future needs for flood forecasting are discussed further under the section on the *manual rainfall and water level* monitoring activity, but the numbers are highlighted here to illustrate that the Mekong HYCOS stations are not a separate entity but part of a broader network. Considering the optimal design for the future under the constraint of available resources, the full network role and performance needs to be taken into account.



Stream flow gauging | **Meteorological stations**

Figure 4: Full hydro-meteorological network in the Lower Mekong Basin (*Source: MRC, 2018. Draft Joint Environmental Monitoring Concept Paper*)

128. While Cambodia and Viet Nam supplied maps of existing hydro-meteorological stations within their territory, and Lao PDR provided lists of some of the additional stations being established with Chinese and development partner support, the data available for this review was sparse. It is recommended that the MRCS work with the *Expert Group on Data, Modelling and Forecasting* to undertake a complete audit of all existing and planned hydro-meteorological stations in the basin. At a minimum the audit should investigate and document for every hydro-meteorological station in the Basin:

(i) Station name and number identifier
(ii) Station location coordinates
(iii) Monitoring parameters collected
(iv) Frequency of data collection
(v) Technology used in data collection, transmission, QA/QC and management
(vi) Station owner and source of funds
(vii) Annual operating and maintenance costs for personnel, equipment repair and replacement, consumables (e.g. transport; telecommunications charges) at each station
(viii) Who has access to the data and the purpose to which it is used

129. This audit would serve as a basis for considering the optimal future design of the network in order to minimise costs while maximising utility for regional and national needs. Redundant stations could be retired, stations soon to be out of service due to reservoir construction could be moved,

stations operating at a national level or by developers but not providing data to the MRC could be integrated into the network, and any further gaps identified. Any network alteration would need to consider how to maintain historical datasets although this is not of much concern with the HYCOS data as it only extends back to 2010 and in any case has substantial gaps.

130. The information provided by this audit could serve a useful basis for a cost-benefit analysis of several network design options with different mixes of automatic and manual stations in different locations. For the HYCOS component specifically, the MRC may need to choose between one of two paths forward:

a) Accept that HYCOS is inherently unreliable and continue to use it only as a back-up to the manual network potentially with reduced capacity

   On this path, available funding would be targeted towards a minimal maintenance budget at only a small number of stations in key locations where short-term water fluctuations are critical (e.g. immediately downstream of dams, at the confluence of important tributaries and where large flood impacts can occur). The greater amount of resources would be put towards expanding and maintaining performance of the manual network to improve river and flash flood forecasting and guidance; or

b) Decide that although the HYCOS network has limited usability today, future operations in a highly regulated basin will mean its high frequency of data transmission is likely to become substantially more useful.

   On this path, effort would be put to maintaining as much of the network as resources will allow and indeed expanding it where necessary, turning some existing manual stations to automatic as planned under Phase II of the Mekong HYCOS project and seeking to incorporate other automatic national stations established under other national programmes and by developers.

131. The future role of the HYCOS network depends heavily on the future role of the MRC. In a future where the organisation continues to focus on strategy development, planning and scenario impact assessment the utility of the HYCOS network is not immediately obvious. Where MRC plays more of a coordinating role in relation to operations, the value of the HYCOS network is enhanced.

132. The Joint Environmental Monitoring activity in relation to mainstream hydropower projects provides an important opportunity to establish the framework for a more efficient network in future, not only for the hydro-meteorological data but for all regional monitoring activities.

133. A summary of the status of the handover of this activity, the issues that require resolution and the options to resolve them are described in Table 9.

Table 9: Summary of the status of monitoring near real-time hydro-meteorological parameters, key issues and potential solutions

Monitoring near real-time hydro-meteorological parameters (HYCOS stations)	
Handover documents were signed in 2012 with financial handover complete for Thailand and Viet Nam in 2012 and Cambodia and Lao PDR in 2014. There is continuing support from Phase II of the Mekong-HYCOS Project with funding for an expansion in the number of stations, establishing the HYCOS Helpdesk[19] and improving data usage based on statistical and other analyses.	
Overall Performance	
Financial handover	
	Key issues to be resolved • The funding gap for the operation and maintenance of stations (Cambodia and Lao PDR) and the purchase of spare parts (all countries) • Planned expansion of the network creating additional operational and maintenance costs
Technical handover	
	Key issues to be resolved • Operator capacity at a national level including due to high staff turnover, reports of staff possibly not strictly following procedures, and lack of manuals in local languages • Data transmission and receiving problems associated with national telecommunications networks, software not updated, and poor internet connections to servers • The overall design of the network within the context of other national stations across the LMB including new stations in Cambodia and Lao PDR and future dam operations
Summary of key issues and causes	
1. Poor network performance The HYCOS network is inherently unreliable. Station performance was relatively stable for a few of years between 2012 and 2015, albeit below the WMO benchmark, and has since declined markedly. Even after recent fixes, approximately one in four stations is still not collecting and transmitting data with only around 59 per cent of data being successfully received. The causes appear to be mainly due to lack of maintenance and poor operator performance with several technical issues including incompatible software versions, outdated modems, poor internet connections, telecommunication system upgrades and outages; and high turnover of staff with some operators not strictly following procedures. 2. Limited use of near real-time data The data from the HYCOS network has limited use other than visualisation of recent flows. This is useful for stakeholders monitoring river levels and seeking to understand the potential implications for water levels downstream. However, its unreliability and gaps in the record mean its use for any analytical purpose is constrained. The high frequency of data transmission will likely become more useful in a more heavily regulated operating environment in future. However, the benefits at present do not appear to be justifying the high upfront investment and ongoing costs. Greater cost-benefit scrutiny is warranted. 3. Potential inefficient network design	

[19] Note that the helpdesk has subsequently been considered not useful by Member Countries and alternative mechanisms are being put in place. For instance, a daily email alert on the operational status of all stations is being sent to relevant line agencies, enabling identification of issues for resolution.

There is clear redundancy and overlap in the current LMB hydro-meteorological network and a lack of integration between regional and national networks is leading to inefficient operations undermining the potential promised by decentralisation. In an environment where coordination of operations becomes increasingly important, consideration needs to be given as to what an optimal hydro-meteorological network design looks like. As all stations come with an ongoing cost, more is not necessarily better and improved integration needs to be achieved with existing and new national systems.

Actions to support implementation of the overall recommendations

- Discuss options with AFD to keep the planned expansion of the HYCOS network on hold until problems with maintaining the existing network are resolved and the optimal network design to meet future challenges is agreed. One exception to this may be a new station at Xieng Kok, which is an obvious need.
- Undertake an audit of the entire existing and planned country and regional networks to identify station redundancy and opportunities for synergies considering existing and planned infrastructure operations. Only fund station maintenance for stations critical to that future design.
- Undertake a comprehensive cost-benefit analysis comparing continued operation of the HYCOS network against an expanded manual reporting network (more stations and twice daily reporting) considering the data needs from each station in terms of parameters and frequency and in consideration of national telecommunications coverage.
- Accelerate implementation of the Joint Environmental Monitoring program to support agreed protocols and data sharing arrangements between developers, local, regional and national authorities and the MRCS. Member Countries should impose obligations on developers to share data.
- Identify opportunities for the harmonisation of station equipment, operations and data management at a national level; at least for stations funded and managed by national line agencies.
- Establish an ftp server at DMH in Lao PDR (and any other country where it is lacking) to enable direct data transmission from stations to national line agencies.
- Identify and address barriers to applying a single budget process for funding the operation and maintenance of all national hydro-meteorological stations (including those providing regional data).
- Implement a joint funding arrangement through Member Country contributions to the MRC budget to ensure continued delivery of critical monitoring parameters essential for CRBMF delivery. Such a funding arrangement should support the decentralisation process by only being used where absolutely necessary for continued operation, and in association with capacity building and knowledge sharing activities to help with the transition.
- Prepare and implement a plan for regular knowledge sharing and capacity building activities between and within countries, especially for operators with responsibility for station maintenance; and ensure its delivery through joint regional funding.

8.2 Manual monitoring of rainfall and water levels (other hydro-met stations)

8.2.1 Introduction

134. *Manual monitoring of rainfall and water levels (other hydro-met stations)* is undertaken through manual readings at hydro-met stations located on the mainstream and tributaries. This activity is undertaken to provide data to support transboundary modelling and assessment of flows, floods (*Transboundary flood modelling* and *Regional flood forecasting*) and droughts (*real time drought assessment and forecasting)* as well as implementation of the *Procedures for Monitoring Flow on the Mainstream (PMFM)*. Monitoring hydro-meteorological parameters is also important for all other environmental monitoring activities because of the links between changes in flow and other environmental conditions including sediment transport, fisheries, ecological health and water quality. Although telemetry data from HYCOS stations is also provided to the RFMMC, the manual monitoring of rainfall and water levels is the primary source of data for regional flood forecasts during the flood season and so timely collection and transmission to the MRC is essential.

135. In total, there are 125 stations[20] on the Mekong mainstream, Bassac, Mekong tributaries, Tonle Sap, and Tonle Sap tributaries providing data to the MRCS. Of these 125 stations, 42 stations are located in Cambodia, 28 in Lao PDR, 13 in Thailand, and 42 in Viet Nam. In Cambodia, the stations are managed by two entities: 8 stations by the Department of Hydrology and River Works (DHRW) and 34 by the Department of Meteorology (DOM). In Viet Nam, the stations are also managed by two entities: 6 stations under the Southern Region Hydro-Meteorological Centre (SRHMC) and 39 stations under the Hydro-Meteorological Service (HMS), both of which sit under the Ministry of Water Resources and Environment (MONRE). In Lao PDR (Department of Meteorology and Hydrology) and Thailand (Department of Water Resources) all the stations are under one Department.

136. The majority of the stations that provide rainfall and/or water level data for MRC under this activity are traditional hydro-met stations; some are automatic stations or former automatic stations (including HYCOS stations) read manually. The 125 stations provide rainfall data on a daily basis during the flood season (June-October) and once a week during the dry season (November-May). 63 of the 125 stations provide water level data only. 45 of the 125 stations are HYCOS stations read manually, which provides a useful check of accuracy with the telemetry readings, and the remainder are manual stations providing both water level and rainfall data.

137. The data are collected by operators at the observation stations, sent to the national terminal of the line agency and then transferred to the RFMMC data terminal through e-mail and/or the HYDMET data base software. The HYDMET software was installed in each country although in some cases only one agency has a licence to use it (e.g. in Viet Nam).

138. Data should arrive before 8.30 am for the RFMMC to compile and analyse the data for river flood forecasting/river monitoring activities and for the timely dissemination of the flood forecasting/river monitoring bulletins between 10 am and 10.30 am to the MCs and other interested organisations.

139. The stations that provide data to the MRCS are only a fraction of the total number of hydro-met stations within the Lower Mekong Basin. Based on a review undertaken by the RFMMC in 2018

[20] Handover agreements with Member Countries require reporting from 135 stations, but only 125 stations are currently operational

using 2015 data, there are 449 stations in total, of which 153 are in Cambodia, 109 in Lao PDR, 110 in Thailand and 73 are in Viet Nam. Only 413 of these stations were operational at the time of that review. In addition, new stations continue to be added. For example, in Cambodia 33 stations have recently been installed with the support of the Japan International Cooperation Agency (JICA); and 24 automatic stations have been installed with the support of the Asian Development Bank (ADB). ADB has also supported the construction of 19 new automatic stations in the Sebangfai and Sebanghiang river basins of Lao PDR and other stations are understood to have been established with the support of the World Bank, ADB and China (Attachment B).

8.2.2 Network handover

140. The handover of financial responsibility for the collection and transmission of manual rainfall and water level data occurred in 2016 in Thailand and Viet Nam and in 2017 in Cambodia and Lao PDR. Handover agreements or MoUs with each country include detailed Terms of Reference which document the data that needs to be collected, the lists of stations from which to collect it and reporting requirements and transmission arrangements for each agency involved.

8.2.3 Network performance

141. Staff at the MRCS and consultants report that the manual data submitted by Member Countries is consistently more accurate than the near real-time telemetry data provided through the HYCOS network. This is the case across all countries as the system for monitoring rainfall and water levels is well established and of high priority to each Member Country. The reporting to MRCS is generally only from part of a broader national hydro-met network.

142. As noted above, the timeliness of data provision is crucial in relation to the distribution of the daily flood forecast bulletin during the flood season. The timeliness and completeness of data is tracked for each station and reported by RFMMC in the weekly flood situation report. Average times for data delivery and the number of missing data items are reported for the past week and the past month. The RFMMC also prepares an annual report on the performance of data collection and transfer for each flood season.

143. Overall performance from the manual monitoring network is good, although is better at the HYCOS stations where both manual and automatic readings are taken. In 2018, the proportion of manual data arriving on time from the HYCOS stations across all countries was an average of 97 per cent and the proportion of total data provided was 96 per cent (Figure 5). The lowest readings were from Lao PDR but in 2018, 90 per cent of manual data from Lao PDR HYCOS stations was still being provided on-time. Overall there was a dip in performance in 2016 and 2017 and subsequent improvement in 2018 following the MRC recovery mission to fix issues with the stations.

144. For manual stations that are not part of the HYCOS network, the performance is lower but overall is still very good. In Cambodia in 2017, the timeliness of delivery from all stations operated by DHWR was greater than 98 per cent with missing data less than 10 per cent for all stations except one. For stations operated by DOM more than 80 per cent of data was provided on-time and less than 2 per cent of data was missing at any station. In Lao PDR, delivery of data in 2017 for the six mainstream stations (covered in the HYCOS figures above) was generally good, but very poor for stations on the tributaries where on-time data delivery ranged from zero to 40 per cent and often with more than 60 per cent of data items missing.

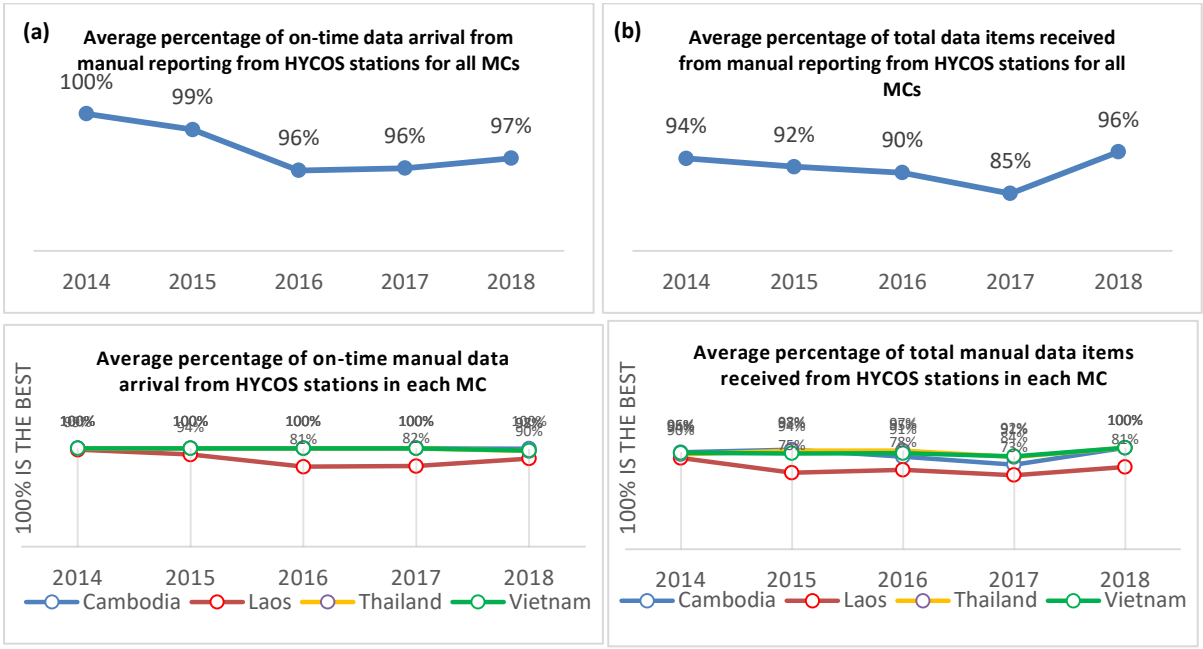


Figure 5: Performance of manual reporting from HYCOS stations in terms of (a) the proportion of on-time data arrival; and (b) the proportion of total data arriving

145. In Thailand, performance was very good, with more than 90 per cent of data from all stations arriving on-time and close to zero per cent missing except for Ban Mai Bua Daeng station where more than 50 per cent of data was missing in 2017. In Viet Nam, around 90 per cent of data arrived on-time from SRHMC and around 80 per cent from HMC, except for three stations where on-time delivery dropped to about 70 per cent.

8.2.4 Value and use of the data

146. The data provided by the manual rainfall and water level network is perhaps the most valuable that the MRC holds. It is the basis for regional flood forecasting and water level monitoring and provides the historical datasets essential for modelling activities in support of planning and impact assessment work at both national and regional levels.

147. It is more reliable and has fewer gaps than the near real-time data from the HYCOS stations. Part of the reason this activity is generally very successful is due to the monitoring being completely integrated into national networks. Its low tech nature makes it relatively easy to implement with minimal training and less potential for computer glitches. It has lower dependencies on other systems (e.g. telecommunications networks) and lower maintenance costs.

8.2.5 Issues and causes

148. This review has identified three main issues with the monitoring of rainfall and water levels (other hydro-met stations). These issues are: (i) Late or missing data from the Lao PDR tributaries; (ii) the need for additional data to improve flood forecasts; and (iii) the provision of historical data to allow updates to the MRC Decision Support Framework (DSF).

(i) Late or missing data from Lao PDR tributaries

149. The proportion of data arriving late or not at all is much higher in the Lao PDR tributaries than elsewhere. This is problematic given the importance of these tributaries to river levels in the mainstream during the flood season. This monitoring relies on local villagers and farmers to make

observations and to send the data by SMS to the Lao Department of Meteorology and Hydrology. The stations are often in difficult-to-access locations, especially during the flood season, with poor telecommunications coverage. On any given day, local people may not have the resources (e.g. petrol) or may otherwise be engaged in their livelihood activities to be able to travel to a station and record the data. These are not generally issues for the mainstream stations and the difference in performance is clear. The observers at the mainstream stations are reported to be mostly active or retired government officials with ready access to the stations and with relatively good mobile phone coverage.

150. Although not a significant issue, the performance of data transmission from other countries could be enhanced by upgrading data management systems and servers in both Member Countries and the MRCS. Connectivity issues can cause time-outs and data transmission being interrupted. When this occurs, operators will often need to transmit data by email, phone call or SMS rather than through the HYDMET system.

151. Because of these transmission issues, relationships between RFMMC staff and national line agencies are important. When data does not arrive, good communication between parties that are known to each other can quickly resolve the issues. MRCS staff report that their human networks based on previous working positions have been important in this regard and is one of the reasons that although performance is low in Lao PDR, it did improve considerably between 2015 and 2017.

(ii) Requirements for additional data from Member Countries

152. The accuracy of the flood forecasting services that rely on the rainfall and water level data could be enhanced by reporting data to the MRCS from additional stations in each country's national network. The RFMMC has identified an additional 204 stations (across all countries) that would be useful in improving river flood forecasting and flash flood guidance and a further 36 stations for river flood forecasting only (all in Lao PDR and Thailand) (Table 10). Additional rainfall data is considered by the RFMMC to be the most important as this lessens the reliance on satellite data which has higher uncertainty. To enable Member Countries to better consider requests from the RFMMC for additional data there would be value in the RFMMC clearly documenting how much improvement to flood forecasting could be achieved with this additional data. It is important that all parties are aware of the costs and benefits that collecting and transmitting additional data would entail.

Table 10: Additional rainfall and water level stations to improve accuracy of river flood forecasting and flash flood guidance (Source: RFMMC 2018 review of data availability for forecasting)

Country	Number of additional stations needed for Flash Flood Guidance and River Flood Forecasting (model accuracy)	Number of additional rainfall stations needed as Daily Operational Data for River Flood Forecasting
Lao PDR	10	21
Thailand	121	13
Cambodia	37	0
Viet Nam	36	0
Total	**204**	**36**

(iii) Provision of historical data to enable updates to the MRC DSF

153. The MRC Decision Support Framework also relies on data provided from this activity. However, MRCS has advised that some of the parameters needed for the DSF are not provided

through daily reporting. This means the MRCS and the MCs need to periodically agree separate arrangements for the collection and transmission of this historical data. At present the historical data in the DSF only goes up to 2008, more than ten years out-of-date. Given the change occurring in the basin with new hydropower and other developments, this outdated dataset will only increase inaccuracies over time in any modelling activity undertaken in support of basin planning or scenario impact assessments.

8.2.5 Potential solutions

154. Addressing the performance issues in the Lao PDR tributaries is the most pressing need under this activity. However, this is not a simple task. To start with there may be value in agreeing a performance benchmark for on-time delivery of data and preparing an improvement plan involving regional capacity building for each station or group of stations where this benchmark is consistently not met. While this could be a benchmark of 100 per cent, it may be better to identify a level more feasible than this, taking into consideration the particular difficulties in some locations, and one which enables a prioritisation of support to the country and stations in most need.

155. Raising awareness of the importance of the data with local observers, providing more instruction on the procedures for SMS reporting, and helping ensure pre-paid sim cards have sufficient credit may all be beneficial steps to take. If not already done, ensuring sim cards for the most reliable telecommunications network in each local area would be worthwhile, noting that this can change from time to time. Additional compensation for observers that need to travel to a further location to get a better signal for transmission could be considered.

156. The MTR team understands that in Lao PDR station observers receive a small monthly stipend to compensate them for the time and costs involved in making observations and reporting the data. Rather than a regular payment, it would be worth considering a performance-based fee which is subject to the on-time delivery of data. A trial of this approach in a particular area could help identify if this will make a difference to the transmission rate and would be worth rolling out more widely.

157. Additional regional support to member countries could also involve capacity building activities that enhance relationships between RFMMC staff and national agencies including to account for staff turnover, increase awareness of the value and use of the data, and to continue to build a culture of high standards in following agreed procedures and protocols. Given the high performance level in Cambodia, opportunities for knowledge sharing between Cambodia and Lao PDR may be significant.

158. An audit of all existing and planned hydro-met stations considering existing and planned infrastructure within the LMB would be as beneficial for this activity as it would for the near real-time monitoring activity. Indeed, it is essential that this is done together as a single activity as greater integration of automatic and manual monitoring will be important if the benefits from the considerable sunk investment in the automatic network are ever to be realised. This audit would establish the baseline for a database of all operational stations within the LMB including those providing data to MRC and those that are not. The database could be updated as agreed in amended handover agreements to incorporate new stations as they are established or to remove stations that are decommissioned or otherwise no longer working. All parties having an awareness of how the LMB hydro-meteorological network is changing over time will be important for identifying efficiencies and opportunities for improvements.

159. The hydro-meteorological data used in the MRC-DSF needs to be updated. Given the current pace of change, ten years is far too long a gap in the historical record. It is recommended that an approach is agreed between MCs and the MRCS for the regular provision of historical data used in the MRC-DSF at a defined interval, perhaps every two years and done to align with data preparation for national hydrological yearbooks for those countries that prepare them. The MRCS should maintain a database of all hydro-met stations within the LMB and have agreements with MCs for them to update the database at regular intervals.

160. The proposed cost-benefit analysis referred to under the near real-time monitoring of hydro-meteorological parameters would ideally consider the feasibility of an enhanced manual network as an alternative to an expanded automatic network. Such a network might include more frequent manual reporting, particularly where readings are already taken at 12 hour intervals, and the establishment of additional stations. Regardless, it is essential that a common understanding is reached between the MRCS and the Member Countries on the need to provide data from additional stations to improve the accuracy of river flood forecasting and flash flood guidance. In addition to rainfall and water level data, updated soil maps would also help improve flash flood guidance.

161. At present, MRCS staff with responsibility for this activity are not the same as those that have responsibility for the near real-time hydro-meteorological (HYCOS) network. It is recommended that the two activities are combined and that responsibility is clearly assigned to a single unit, preferably the RFMMC. Doing so would support improved integration of the networks and help identify and implement opportunities for greater data usage at a regional level. It would support the RFMMC in any future operational coordination role, and could help improve river flood forecasts with greater use of the near real-time data.

162. A summary of the status of the handover of this activity, the issues that require resolution and the proposed options to resolve them are described in Table 11.

Table 11: Summary of the status of manual monitoring of rainfall and water levels, key issues and potential solutions

Manual monitoring of rainfall and water levels (other hydro-met stations)	
Handover documents were signed in 2016 for Thailand and Viet Nam and in 2017 for Cambodia and Lao PDR with financial handover completed for each country in those same years.	
Overall Performance	
Financial handover	
	Key issues to be resolved • Nil, other than the extent to which additional financial resources may be required for the provision of data from additional stations
Technical handover	
	Key issues to be resolved • Timeliness of data provision and missing data, especially in Lao PDR tributaries • The justification for and provision of data from additional stations especially in Lao PDR and Thailand in order to improve accuracy of flood forecasts • Provision of historical data to allow updates to the MRC DSF
Summary of key issues and causes	
1. Late or missing data from Lao PDR tributaries There is a substantial amount of data being provided too late or not at all from the tributaries in Lao PDR. This is negatively affecting the daily updates to the river flood forecast during the flood season. In Lao PDR, despite improvements since 2015, only the six stations on the Mekong mainstream have what could be considered an acceptable level of performance. The remaining 26 stations on the tributaries either do not work or the data is being provided too late (after 8.30 am). The primary causes of this are stations in locations that are difficult to access and with poor telecommunications coverage, by local people who have limited resources and other livelihood priorities. 2. Requirement for additional data from Member Countries The MRC regional flood forecasts are highly dependent on the manual rainfall and water level data provided by Member Countries under this activity. All countries have identified a desire for increased accuracy in flood forecasts. However, this requires additional data, especially from the upper and middle reaches of the LMB in Lao PDR and Thailand. Rainfall data is particularly important for calibrating the satellite data used in the MRC's flash flood guidance and for improved accuracy in rainfall-runoff models for river flood forecasting. 3. Provision of historical data to enable updates to the MRC DSF The MRC DSF currently has hydrological data agreed for use up to 2008. This is more than ten years out-of-date and given the changes to the basin in that time will be having an impact on model accuracy and therefore the benefits of any scenario impact assessment and basin development work.	
Actions to support implementation of the overall recommendations	
• Agree a performance benchmark for the timeliness and quality of data provision and put in place a targeted plan for national level support to countries to meet that standard. There may be a case for different benchmarks for different categories of stations to be gradually improved over time. • Support plans might include options for raising awareness of the importance of the data with local observers, providing more instruction on the procedures for SMS reporting, and helping ensure pre-paid	

sim cards have sufficient credit. Performance-based payments could be trialled in some locations.

- Support the building and maintaining of relationships between flood centre staff and line agencies in Member Countries through regional knowledge sharing activities, where feasible; and examine the potential for knowledge exchange between Cambodia and Lao PDR on ways to improve performance.
- Undertake an audit of the entire existing and planned country and regional networks to identify station redundancy and opportunities for synergies considering existing and planned infrastructure operations. Identify new local, national or regional stations that have been installed since 2015 and any stations that are inoperable. For those not working or considered redundant either fix or remove them from the network. The MRCS should maintain a database of all hydro-met stations within the LMB and have agreements with MCs for them to update the database at regular intervals.
- RFMMC should prepare an analysis of the additional accuracy that could be achieved in both flood and drought forecasting by expanding the number of stations included within the MRC reporting network. This would serve as a basis for countries to consider providing additional data, especially for rainfall data both inside and outside the LMB and could include an investigation of the feasibility for twice-a-day reporting, particularly at stations that already collect data at 12-hourly intervals.
- Agree regular transmission arrangements between the MRCS and Member Countries for historical data necessary to keep the MRC DSF up-to-date (where such data is not otherwise regularly provided as part of this activity). For example, every two years in conjunction with the publication by some Member Countries of their hydrological yearbooks.
- Combine this activity (manual monitoring of rainfall and water levels) with the monitoring of hydro-meteorological parameters (HYCOS) to improve integrated assessment and better overall use of hydro-meteorological data and assign responsibility to a single unit within MRCS.
- Identify options to harmonise rain gauges between national stations and regional stations where there are differences (e.g. in Viet Nam).
- Review and update Member Country soil type data and provide updated products to RFMMC to improve accuracy of flash flood guidance.

8.3 Discharge measurement and sediment monitoring

8.3.1 Introduction

163. Sediment monitoring is important for assessing impacts from natural and human-induced changes across the whole catchment – including dams, river regulation and improvement works, sand and gravel extraction, land use change, and climate change. Sediment transport controls the river channel and floodplain characteristics and the distribution of ecological habitats. It is a critical discipline for sustainable and integrated water resources management as river morphology has extensive implications for human uses and natural environments.

164. The MRC's Discharge and Sediment Monitoring Programme (DSMP) has been in place since 2009. There are 17 sampling sites in the Lower Mekong Basin: 13 on the Mekong mainstream, two on the Bassac, one site on the Tonle Sap, and one on the lower 3S River. The four main parameters determined are: Discharge, Suspended Solid Concentration (SSC), Suspended Grain size Analysis (SGSA) and Bedload. Other parameters related to these include cross-section, water level and flow velocity. Different equipment is used at different locations (Table 12) and not all parameters are measured at every site. For example, bed load is only collected at three sites (Chiang Saen, Nong Khai and Kratie) and SGSA is determined at only eight of the 17 locations.

Table 12: Instrumentation used at each of the DSMP sites (Source: MRC, 2018)

Site	Country	Discharge	Sediment Sampling
Chiang Sean	Thailand	CM	D-96
Luang Prabang	Lao PDR	CM	D-96
Chiang Khan	Thailand	CM	D-96
Nong Khai	Thailand	CM/ADCP	D-96
Nakhon Phanom	Thailand	CM	D-96
Mukdahan	Thailand	CM	D-49
Khong Chiam	Thailand	CM	D-49
Pakse	Lao PDR	CM	D-96*
Stung Treng	Cambodia	ADCP	D-96
Kratie	Cambodia	ADCP	D-96
Chrouy Changvar	Cambodia	ADCP	D-96
Prek Kdam	Cambodia	ADCP	D-96
Koh Norea	Cambodia	ADCP	D-96
OSP MRC	Cambodia	ADCP	D-96
Tan Chau	Viet Nam	CM/ADCP	VN-5 (SRHMC)
Chau Doc	Viet Nam	CM/ADCP	VN-5 (SRHMC)
Sekong Bridge	Cambodia	ADCP	D-96

* MRC (2018) report sediment sampling equipment at Pakse as D-49/Uppsala. DMH clarified they use the D-96 at each site.
CM: Current Meter; ADCP: Acoustic Doppler Current Profiler.

8.3.2 Activity handover

165. Handover agreements have not been signed with any country for this activity. The planned financial transition schedule had Member Countries contributing 25 per cent of the costs in 2018, 50 per cent in 2019, 75 per cent in 2020 and 100 per cent in 2021. However, the objectives for 2018 have not been met and will not be met in 2019 either. In 2018, all countries agreed MoU's with the MRCS which provided for the MRC budget to fund the full costs of implementation.

8.3.3 Activity performance

166. Monitoring of discharge and sediment occurred each year between 2009 and 2015 but was interrupted through the transition period at the MRCS, only resuming again in 2018. It is likely that this year data collection will be incomplete as the MRCS has been withholding funding to Lao PDR *in lieu* of the costs incurred by MRCS to fix the HYCOS stations in Lao PDR during May 2018. In response, the MTR team understands Lao PDR has terminated the MoU with MRCS. This disruption is also having an impact on the capacity for Thailand to undertake sampling for joint stations on the border between Lao PDR and Thailand.

8.3.4 Value and use of the data

167. Sediment transport data is typically used in impact and scenario analysis work, understanding the status and trends in environmental conditions and to inform basin development planning. It was a key input to the Council Study and to Viet Nam's Delta study. The time series data is itself useful in understanding the impact of hydropower construction and other development projects on sediment loads downstream. For instance, the major reason for a reduction in sediment loads to the Lower Mekong Basin over the last 10 years is attributed to the construction of the Lancang hydropower cascade in China. Sediment transport data is also critical to understanding issues associated with subsidence in the Delta, and the productivity of agriculture in floodplain areas and of both freshwater and marine fisheries.

8.3.5 Issues and causes

168. This review has identified three main issues with the decentralisation of discharge measurement and sediment monitoring activity. These issues are: (i) Uncertainty about future funding arrangements; (ii) Lack of agreed methodology and technical design with related human capacity constraints; and (iii) Difficulties in coordinating implementation between Lao PDR and Thailand. There is substantial uncertainty about the future implementation of discharge measurement and sediment monitoring at the MRC. Given the documented changes in sediment transport already occurring and the potential future impacts from basin development and climate change as outlined in the Council Study, this uncertainty needs to be resolved as soon as possible. Discharge measurement and sediment monitoring is a critical activity for supporting Member Countries on decisions related to future investments and potential trade-offs.

1. Uncertainty about future funding arrangements

169. The principle issue to resolve is how this activity will be funded over the longer term. All Member Countries have stated they believe this activity to be one which requires joint efforts and regional funding. The main reasons for this are the high costs of implementing the activity and the need for coordinated cross-border field work between Lao PDR and Thailand.

170. The high costs result due to the need to acquire and maintain expensive equipment including boats, winches, samplers, current meters and so forth. The equipment is deployed in sometimes harsh environmental conditions with fast moving water in deep locations which can increase maintenance and fuel costs. Cross-border coordination is essential for sampling the channel between Lao PDR and Thailand. Cross-sectional measurements must be taken from one riverbank to the other in order to calculate rating curves and ensure accurate flow and sediment measurements.

All personnel involved must have approvals from relevant authorities on both sides of the river and ideally be accompanied by a government official from the other side to ensure no misunderstandings with border guards.

2. Lack of agreed methodology and technical design with related human capacity constraints

171. The cost of the activity is related to its design in terms of the number of sites, the intensity of sampling, and the different parameters that should be collected as well as the type of equipment that is used. In consultations for this review, each Member Country raised methodological concerns including in relation to the heavy equipment and safety issues around its use in fast flowing, deep water with a lot of other river traffic, especially in the Delta region. Questions were also raised about the need to monitoring particular parameters such as bed load. Previous reviews of the DSMP have identified a number of opportunities for improvement in the design and implementation of this activity (e.g. see Box 1).

Box 1. Recommendations from a review of the DSMP (Koehnken, 2015)

Field equipment and monitoring regime

- The monitoring programme should be maintained and gaps in monitoring due to funding and contractual issues should be eliminated by obtaining funding and negotiating contracts well in advance, preferably through the establishment of multi-year agreements;
- Monitoring equipment should be upgraded at sites where the river conditions are outside of the design parameters of the monitoring (e.g. river too deep and fast flowing to be accurately monitored with available equipment);
- Equipment should be maintained or upgraded to provide accurate and comparable results;
- Field QA/QC exercises should be implemented between the different monitoring teams to ensure consistency;
- Bedload transport should be monitored at all sites where an ADCP is used to measure discharge by completion of the 'loop-test'
- An additional monitoring site should be established between Nong Khai and Nakhon Phanom to monitor better the large sediment influx that occurs within this region;
- Water transparency using a secchi disc or transparency tube should be completed during the DSMP field monitoring so the results can be cross-references with aquatic ecology monitoring.

Laboratory

- QA/QC exercises should be conducted between the various laboratories to ensure consistency of results;
- Automated grain-size analysis equipment (laser or X-ray) should be acquired to eliminate the need to collect and filter large volumes of water, improve the accuracy of results, and allow grain-size determination at a larger number of monitoring sites;

Data management

- The forms used to report the discharge measurement and sediment monitoring results should be reviewed and simplified where possible, or the older forms should be used for reporting results;
- A database of the discharge measurement and sediment monitoring results should be developed that also includes continuous flow results and the WQMN results such that these data sets can be integrated and

172. Agreeing the ongoing design of this monitoring activity will be important for decentralisation to proceed effectively. As long as there is uncertainty about the approach and less than full commitment to the methodology from Member Countries, decentralised operations will be challenging to say the least. A requirement for strong coordination will be an ever present feature.

173. The use of different teams in different countries using different types of equipment raises questions about the accuracy and comparability of results. Ongoing capacity building with regular QA/QC activities will be important, and there would be value examining opportunities for new cost effective equipment as has been documented by the Joint Environmental Monitoring initiative.

3. Coordinated implementation between Lao PDR and Thailand

174. As noted above, discharge measurement and sediment monitoring on the border between Lao PDR and Thailand requires a joint cooperative effort. This is because sampling teams require access to both side of the river. Officials from Thailand raised safety concerns about access to the Lao PDR riverbank due to lack of clearances or permits available to relevant personnel and concern about being confronted by border guards. Lao PDR noted the administrative process can be long and cumbersome and requires close joint planning. For instance the names, photos and details of all personnel involved need to be known and provided well in advance so that appropriate documentation can be processed. The permits that are necessary require payment of a fee, so this also needs to be budgeted. Also important is joint access to equipment given different capacities between countries.

175. The problems implementing discharge measurement and sediment monitoring between Lao PDR and Thailand have also been hampered by a lack of leadership on this activity at MRCS. Uncertainty about the assignment of responsibility associated with the departure of experienced staff meant the facilitative role the MRCS should be playing for all decentralised monitoring activities did not occur well enough to resolve the issues.

8.3.6 Potential solutions

176. The MRC has proposed the JC consider joint funding of critical monitoring activities, including discharge measurement and sediment monitoring, through the Basket Fund. As is the case for monitoring near real-time hydro-meteorological parameters, providing regional funds to decentralised activities has the potential to undermine the decentralisation process. The benefits that come from having direct financial responsibility, including a sharper focus on priorities and greater impetus to explore cost effectiveness through harmonisation with national networks, may be lost. That said, in the case of discharge measurement and sediment monitoring there is no national network and the critical nature of the data at a regional level is surely without question.

177. The high equipment and maintenance costs and the speed of the decentralisation process is leaving some Member Countries inadequately prepared to take-on this activity. The lack of agreement on the ongoing monitoring design means that the capacity for more cost effective implementation at a national level is limited, and indeed is a risk to future data quality and integrity. If each country chooses to go its own way with sampling procedures and type of equipment, the value of this regional activity will be diminished.

178. Regional funding support through the transition period is an option worth considering. As with funding support to the HYCOS station maintenance, the MRCS and MCs could consider some safeguards on the use of regional funds for supporting monitoring activities to ensure the benefits of decentralisation can still be achieved. Safeguards could include clear principles and criteria for approving the use of funds that takes into account (a) the extent to which the activity can be done more efficiently at a regional level; (b) the criticality of the data to the delivery of CRBMFs; (c) the

role of knowledge sharing and capacity building associated with the use of any funds; and (d) any supporting work required to transition from this financial arrangement over time.

179. In addition, a longer, more gradual transition period for discharge measurement and sediment monitoring is advisable. Contributions from Member Countries which more closely align with the trajectory of self-financing would be appropriate.

180. The MTR is of the view that there is no reasonable basis to continue to withhold funds from Lao PDR for discharge measurement and sediment monitoring in 2018-19. Conflating the issue with the repair of the HYCOS stations is not productive, particularly given the high value of the sediment data for regional needs.

181. The ongoing methodology for discharge measurement and sediment monitoring needs to be agreed. There have been at least two reviews of the DSMP and a number of recommendations on how to proceed. This information has been collated by the Joint Environmental Monitoring Initiative. The MRCS needs to work closely with the *Expert Group on Data, Modelling and Forecasting* to finalise and agree a methodology that can be used going forward and which is a basis for agreeing handover arrangements with Member Countries. Clear assignment of responsibility at MRCS to coordinate this work is essential.

182. A summary of the status of the handover of this activity, the issues that require resolution and the proposed options to resolve them are described in Table 13.

Table 13: Summary of the status of discharge measurement and sediment monitoring and the key issues and potential solutions

Discharge measurement and sediment monitoring	
No handover agreements have been prepared or signed for this activity. The planned schedule for financial handover had Member Countries contributing 25 per cent of the costs in 2018 and 50 per cent of the costs in 2019 but these objectives have not been met. In 2018 the MRC budget is being used to fund the full costs of the activity in each country.	
Overall Performance	
Financial handover	
	Key issues to be resolved • The financial handover schedules for each country need to be agreed, along with ongoing funding modalities
Technical handover	
	Key issues to be resolved • Agreement to an ongoing methodology for discharge measurement and sediment monitoring including monitoring parameters to collect, equipment to be used, and frequency and locations of data collection; as well as replacement of old and broken equipment and consideration of new technologies as documented by the Joint Environmental Monitoring initiative • Coordination of joint monitoring efforts between Thailand and Lao PDR including permissions, protocols and protections for officials from one country working on the river bank of the other
Summary of key issues and causes	

1. Uncertainty about ongoing funding arrangements

   The lack of budget at a national level for discharge measurement and sediment monitoring has all MCs calling for this activity to be re-assigned for centralised implementation. This is not an activity normally undertaken at a national level and so there are likely to be substantial challenges in achieving the necessary budget support. Although national water quality monitoring programs generally monitor Total Suspended Solids (TSS), they do not monitor the Suspended Solids Concentrations (SSC) used to calculate sediment loads under the design of the MRC's Discharge and Sediment Monitoring Project. The former approach tends to underestimate larger grain sizes which is not so much of an issue in relation to water quality assessments but is important in relation to geomorphological processes.

2. Lack of agreed methodology and technical design

   The lack of agreement to an ongoing monitoring design including methodology, and sampling and equipment issues is hampering progress on the decentralisation of this activity. While MCs have agreed to implement discharge measurement and sediment monitoring in 2018 following a two year gap, all countries have raised concerns about one aspect or other in the design. These include concerns about the type of equipment being used or the state it is in and the monitoring parameters being collected. Different equipment is being used by different countries in different locations raising questions about the comparability and accuracy of results throughout the basin. This is an activity that requires strong regional leadership. Recent staff turnover and lack of clear assignment of responsibility within the MRCS has also had a negative impact on progress.

3. Coordinated implementation between Thailand and Lao PDR

   Discharge measurement and sediment monitoring requires surveys of the cross-sectional area of the river channel in order to develop hydrological rating curves that relate water levels to flow and allow a calculation of total sediment load. This requires sampling teams to have access to both river banks. Thailand has reported that in 2018 it has not been able to undertake the necessary survey work because of lack of administrative approvals and safety guarantees from Lao PDR. Lao PDR has not been able to implement its share of the activity because the MRCS has been withholding funds due to MRCS having to use basket funds to fix HYCOS stations in Lao PDR that are Lao PDR's responsibility.

Actions to support implementation of the overall recommendations

- The MRCS should immediately renegotiate a new MoU with Lao PDR and make necessary funds available to enable discharge measurement and sediment monitoring between Thailand and Lao PDR to proceed. The delivery of this activity is a separate issue to the funding of maintenance costs for HYCOS stations and conflating the two does not take into consideration the high value of sediment data at a regional level.
- By the end of 2019, the MRCS to work with the *Expert Group on Data, Modelling and Forecasting* to agree an ongoing design for the discharge measurement and sediment monitoring activity in conjunction with the Joint Environmental Monitoring initiative and drawing from previous reviews and recommendations for the DSMP.
- Following agreement to the overall design of the ongoing activity, prepare and sign handover agreements between the MRCS and each Member Country with revised financial handover schedules that have a more gradual transition occurring between now and 2030. A 25% contribution by MCs in 2020, a 50% contribution in 2025 and a 100% contribution in 2030 could be an appropriate trajectory.
- Make regional funds available to support critical data collection, maintenance and capacity building needs and including to purchase new equipment for distribution to MCs in advance of the handover. Such a funding arrangement should support the decentralisation process by only being used where absolutely necessary for continued operation, and in association with capacity building and knowledge

sharing activities to help with the transition.

- Develop updated rating curves for mainstream and key tributary stations that are not affected by tidal influence.

8.4 Routine water quality monitoring

8.4.1 Introduction

183. Water quality monitoring has been undertaken in Lao PDR, Thailand and Viet Nam since 1985 and in Cambodia since 1993. The activity is implemented in order to give effect to the 1995 Mekong Agreement, and in particular Article 3 "*Protection of the Environment and Ecological Balance*", Article 7 "*Prevention and Cessation of Harmful Effects*" and Article 10 "*Emergency Situations*". To achieve this, the Member Countries agreed the Procedures for Water Quality (PWQ) as adopted by the MRC Council in 2011. The Procedures cover provisions on water quality management and emergency water quality situations. Accordingly, the Technical Guidelines on the Implementation of the Procedures for Water Quality (TGWQ), adopted by the JC in November 2016, consist of two Parts: Part I on routine WQM and Part II on emergency water quality responses. The implementation of Part I on routine WQM was initiated by the MRCS in 2010.

184. The number of sampling locations has varied over the years since the inception of the water quality monitoring network. At present, the routine water quality monitoring occurs at 48 locations with 17 sampling points on the Mekong mainstream, 5 on the Bassac River and 26 on Mekong tributaries. Of these, there are 19 sampling points in Cambodia, 11 in Lao PDR, eight in Thailand, and 10 in Viet Nam. Member Countries also have national water quality monitoring activities involving additional sampling locations on tributaries, although do not necessarily monitor the same parameters at the same frequency. For each sampling point in the MRC network, 12 water quality parameters are analysed on a monthly basis and six parameters are analysed between April and October (Table 14). One parameter, Biochemical Oxygen Demand, is analysed on a monthly basis at only a select number of locations.

Table 14: Monitoring parameters analysed under the routine water quality monitoring activity

Parameters analysed on a monthly basis	Parameters analysed between April and October	Parameter analysed on a monthly basis for some selected stations
Temperature	Calcium (Ca)	Biochemical Oxygen Demand
pH	Magnesium (Mg)	
Conductivity (Salinity)	Sodium (Na)	
Alkalinity/ Acidity	Potassium (K)	
Dissolved Oxygen (DO)	Sulphate (SO4)	
Total phosphorous (T-P)	Chloride (Cl)	
Total Nitrogen (T-N)		
Ammonium (NH4+-N)		
Nitrite-Nitrate (NO2-3-N)		
Fecal Coliform		
Total Suspended Solid		
Chemical Oxygen Demand (COD)		

8.4.2 Activity handover

185. Handover agreements have been signed by all Member Countries. Water quality monitoring has been completely decentralised in Thailand and Viet Nam since 2016 and is scheduled for complete decentralisation in Cambodia in 2019 and in Lao PDR in 2020. Each handover agreement includes Terms of Reference detailing which monitoring parameters are to be collected at which stations at specified intervals and the procedures that must be followed for the collection, handling and analysis of samples and data.

8.4.3 Activity performance

186. Water quality monitoring is the monitoring activity that has proceeded the most smoothly since the decentralisation process began. All countries have so far managed to continue the activity, undertaking sampling, analysing results in national laboratories, preparing national reports and transmitting the results to the MRCS.

187. Annual proficiency testing of national laboratories is being undertaken with the support of regional funds through the MRC budget. Proficiency testing provides a check on the performance of national laboratories for each monitoring parameter. It is an important step in maintaining standards and ensuring results are comparable across the region.

8.4.4 Value and use of the data

188. The routine water quality data collected through this activity is essential to the implementation of the Procedures on Water Quality (PWQ) which specify the monitoring parameters to be collected and assessed on the mainstream. The data is also used in regional studies and planning exercises, for example, for the Council Study. At a national level, the data is transmitted and held in national water quality databases and can be used for environmental health reporting and to inform water users about safe water use for domestic and agricultural purposes.

8.4.5 Issues and causes

189. The most significant issue with the water quality monitoring activity is the storage and management of the data at the regional level. The data is not stored and managed in a systematic way as part of a central database and is at high risk of being lost or compromised. This is one of the longest historical datasets in the basin, but it is not available to users of the MRC data portal in a readily accessible way. This should be urgently addressed as part of the upgrade to the MR-IS, especially given the importance of the data to the implementation of the MRC Procedures on Water Quality.

190. The implementation of this activity does not strictly follow the agreed processes in terms of the timing for data transmission. While this should be done within 10 working days of the month the data was collected in, in practice the transmission is occurring once a year along with the delivery of the annual report. This may be acceptable for routine water quality monitoring but should be re-evaluated in conjunction with the progression of any work on emergency responses to water quality issues, where timing in identification of issues becomes important.

191. No country has a national budget to cover the proficiency testing of national laboratories. That is perhaps not surprising considering the testing itself is not specifically mentioned in Handover Agreements, except for Lao PDR where it states MRCS will cover the costs up to 2020. The cost of this activity is approximately $10,000 in total across all four countries. The lack of national budgets for this important task is an indicator either that (i) even in the case of this relatively successful activity, which is entirely integrated within national systems and processes, there are difficulties obtaining even modest additional funds through national budgets on an activity-by-activity basis; or Member Countries (ii) were not sufficiently aware of the need and so have not factored it in to their budget preparations; or (iii) were operating on the undocumented assumption that proficiency testing would continue to be funded through the regional MRC budget.

192. The water quality data collected by the MRC is included in an annual regional report and used to calculate three indices of relevance to water users and the environment: (i) for the protection of human health; (ii) the protection of aquatic life; and (iii) for agricultural use. While

these are useful reporting tools in their own right, much more could be made of the regional data that is available, particularly in terms of inter-disciplinary analysis with other datasets held by the MRC: hydrology, sediment, ecological health, and fisheries. The MRC's Joint Environmental Monitoring initiative has commented on the benefits of more integrated assessment. However, the lack of alignment in sampling locations is not particularly helpful in this regard and there may be scope for efficiency improvements especially in terms of aligning with ecological health sampling points as that activity also involves some assessment of water quality parameters.

8.4.6 Potential solutions

193. As for the other data collected and held by the MRC, the improvements in the MRC Information and Data Management systems are critical. As soon as improvements have been made all existing water quality needs to be uploaded and made available for visualisation or download. Importantly, the data available would ideally include not only the calculated indices but all the raw data for each monitoring parameter at each site with reference to the standards and benchmarks identified in the Procedures for Water Quality and the related Technical Guidelines.

194. In addition to the data management issue, which is a broader problem across the MRC's activities, funding and implementation arrangements for proficiency testing of laboratories across the four countries should be clarified. The MRCS has generally undertaken the testing of laboratories every year. However, it may be possible to implement this regime on a less frequent basis, particularly where laboratories are already certified against ISO-IEC 17025-2005 as they are in Viet Nam and Lao PDR for some parameters or where they can otherwise demonstrate compliance. A risk-based approach may be warranted, whereby those laboratories with a good record of performance and otherwise compliance with international standards would be subject to a less frequent proficiency test than any laboratories with a record of poor performance. Before a decision is taken on weakening the testing regime, an examination of performance records to-date is warranted.

195. Proficiency testing of water quality laboratories is a good example of an activity where there may be efficiencies in undertaking the procurement and management at a regional level. Undertaking only one procurement process as is occurring in 2018 rather than four and with a single contractor may lead to cost savings for Member Countries overall. If joint funding is agreed by Member Countries to support decentralisation transition arrangements (Recommendation D.2), this is one of the activities that could be funded that way.

196. Although water quality data is currently being transmitted to the MRCS only once a year[21], there would be value in reconsidering this arrangement as part of work on emergency responses to pollution incidents. It will be important that any water quality incident can be immediately identified by all potentially affected parties so that appropriate decisions can be taken. As part of this work there would also be benefit in considering whether any of the additional monitoring parameters identified in the Procedures for Water Quality warrant regular monitoring as part of this activity.

197. A summary of the status of the handover of this activity, the issues that require resolution and the proposed options to resolve them are described in Table 15.

[21] MCs have agreed to share data immediately if any abnormalities are detected. For this to occur requires the MCs to be immediately testing and analysing the samples. The MTR has doubts this is occurring in all cases due to delays in accessing budgets.

Table 15: Summary of the status of routine water quality monitoring and the key issues and potential solutions

Routine water quality monitoring	
Handover agreements were signed with Cambodia, Lao PDR and Viet Nam and a letter acknowledging responsibility was received from Thailand. Water quality monitoring has been fully decentralised in Thailand and Viet Nam since 2015 and will be fully decentralised in Cambodia in 2019 and in Lao PDR in 2020.	
Overall Performance	
Financial handover	
	Key issues to be resolved • No countries have budget available for Proficiency Testing of laboratories. Some have difficulty purchasing consumables such as chemicals and glassware.
Technical handover	
	Key issues to be resolved • Inclusion of water quality monitoring data within the MRC Information System and making it available for visualisation, download and integrated analysis (e.g. with hydrology) • Agreeing a Proficiency Testing regime for national water quality laboratories • Alignment of sampling locations for water quality monitoring with other monitoring parameters, where feasible and appropriate
Summary of key issues and causes	
1. Lack of data inclusion and availability within the MRC-IS The most significant issue to address in relation to water quality monitoring is the lack of appropriate data management and access within the MRC Information System. The water quality monitoring activity has one of the longest data records in the MRC (from 1985). Yet the only information made available through the MRC data portal at present is the results of a water quality index for 2015. Under the Strategic Plan implementation the focus on upgrades to the MRC-IS is on hydro-meteorological data in the first instance and the remaining time-series data to be progressively addressed in 2019. This work needs to be accelerated with additional resourcing. The upgraded system should allow for integrated analyses to be undertaken with other monitoring parameters (e.g. hydrology). 2. Lack of national budgets for proficiency testing Proficiency testing costs approximately $10,000 in total for all countries. No Member Country has made budget available for this component of the activity and so the MRC Basket Fund was used for this purpose in 2018. Proficiency testing provides a check on the performance of national laboratories for each monitoring parameter. It is an important step in maintaining standards and ensuring results are comparable across the region. It may not be critical to undertake proficiency testing every year, particularly where laboratories are already certified against ISO-IEC 17025-2005 as they are in Viet Nam and Lao PDR for some parameters or where they can otherwise demonstrate compliance. 3. Potential for greater alignment in sampling locations with other monitoring parameters The value of water quality data would be greatly enhanced if the capacity for interdisciplinary analysis was improved. One way to support this would be to achieve greater alignment between sampling locations and timing for water quality and other monitoring parameters (e.g. for ecological health monitoring). This may also lead to some cost savings as ecological health monitoring also involves collection and testing of some water quality parameters.	
Actions to support implementation of the overall recommendations	

- Improve the MRC Information System as a matter of urgency and as soon as possible upload all existing water quality data, making it available for visualisation and download. This should include not only the indices agreed under the Procedures for Water Quality, but the data for each of the individual monitoring parameters.
- Evaluate the benefits and risks of undertaking Proficiency Testing of laboratories at a lower frequency than every year. Once every two years may be sufficient although this frequency should be informed by a risk-based approach considering performance to-date and otherwise compliance with international standards. If there is any change to the approach, update the MRC General Requirements accordingly.
- Continue to fund Proficiency Testing at a regional level using basket funds with a single contractor to test laboratories in each Member Country. A single procurement arrangement is likely to be more efficient than four separate processes.
- Undertake a review of water quality sampling locations in conjunction with locations for ecological health monitoring and hydrological monitoring and consider opportunities to better align.
- Following the design of the emergency response activity, evaluate the need for additional monitoring parameters and more regular data transmission to enable rapid identification of water quality issues in response to pollution events.

8.5 Ecological health monitoring

8.5.1 Introduction

198. Ecological health monitoring with the use of biological indicators has been conducted in the Lower Mekong Basin in various guises since the 1980s. The current programme was developed between 2002 and 2010 with the methodology published in a 2010 handbook. Since then, four rounds of sampling and analysis have been undertaken, in 2011, 2013, 2015 and 2017. The next round is due in 2019. Although in the early years of activity development sampling was undertaken every year, this was reduced to once every two years as ecological conditions in the river were not considered to be changing so rapidly within the LMB. Consideration had also been given to sampling only once every five years.[22]

199. From 2002 until 2007, the biomonitoring activity was operated by the MRC using a single team of specialists from the four member countries working with two international mentors. From 2008, the activity was transferred to the national agencies with four national teams conducting the sampling. All sampling occurs during the dry season at 41 sites across the LMB. There are 17 sampling sites in Cambodia, eight in Lao PDR, eight in Thailand and eight in Viet Nam. The biological groups collected are: zooplankton, benthic diatoms, benthic macroinvertebrates and littoral macroinvertebrates. In addition, key water quality parameters are measured: DO, pH, conductivity and water transparency. Three indices of ecological health are calculated: richness, abundance and Average Tolerance Score per Taxa (ATSPT), which is an indicator of pollution at a site.

200. Biological monitoring is used throughout the world for evaluating the ecological health of running water habitats. The biological condition of any body of water depends on the quality of the water and available habitats. The different indicator groups provide a broad spectrum of descriptors of the ecological health of the Lower Mekong Basin. In general, these organisms are very sensitive to change in their habitat, particularly in relation to water quality and hydrology, and so provide a good indication of the impacts of environmental alterations. This is particularly valuable when those other variables are not measured directly, or when they are, for undertaking causal analysis of the reasons for changes in aquatic health.

8.5.2 Activity handover

201. Handover agreements were signed with all countries in 2017. Each agreement includes Terms of Reference detailing which biota are to be collected at which sampling location at which times and the procedures that must be followed for the collection, handling and analysis of samples and data. All countries have agreed to the same financial handover schedule which requires Member Countries to cover 50 per cent of the activity costs in 2019, 75 per cent of the costs in 2021 and 100 per cent in 2023.

8.5.3 Activity performance

202. No monitoring activity has been undertaken under decentralised financial arrangements as yet. 2019 will be the first year that any country has been required to contribute some of the costs directly. This is likely to be a considerable challenge for some countries and the MTR is aware both Cambodia and Lao PDR have already flagged they will not have sufficient budget to undertake this activity in 2019.

[22] MRC (2018) Draft report on Joint Environmental Monitoring of Mekong Mainstream Hydropower Projects

8.5.4 Value and use of the data

203. The data collected under this activity is reported to the MRCS in national reports from each country. The MRCS then prepares a regional report with the results for each monitoring parameter at each site and including the three calculated indices. Changes in ecological health can be tracked over time by comparing the results from each year they are reported. The reports are provided to Member Countries and the countries have stated to the MTR team that they distribute the reports to regional and local authorities. Some countries, for example Viet Nam, expressed an interest in rolling out the methodology to other waterways within their territory but the cost of doing so is prohibitive. Several countries noted the quality of the methodology and rigour in the approach, but also identified the cost of undertaking the activity as being high.

204. Comparison of the cost of this activity with other decentralised monitoring activities is that it is not particularly high (Table 2), although it is worth bearing in mind that any assessment of value will take into consideration the benefits as well. The cost may be high given the apparent lack of substantial benefits. Other than distributing the reports, the MTR team was not made aware of any specific use of the data at a national level. The relative lack of benefit from this activity is also indicated by the fact no country otherwise does this kind of monitoring. Member Countries confirmed earlier reviews identifying there are no national methods or monitoring systems of this nature in place either in the Mekong or elsewhere.

8.5.5 Issues and causes

205. One of the key issues with this activity is the lack of technical capacity at the national level. As this is not an activity that is undertaken by national line agencies, there is limited experience in its implementation. This has been exacerbated in some cases since decentralisation where responsibility has been handed over to an agency which was not previously involved and whose primary expertise is in water quality issues (e.g. the Pollution Control Department in Thailand). Given the reform process and disruption in 2016 and the reduced overall budget, there has not been sufficient capacity building support to Member Countries in recent years. A workshop with countries on diatom sampling was organised for November 2018.

206. As with the water quality monitoring activity the storage and management of the ecological health data at the regional level is problematic. The data is not stored and managed in a systematic way as part of a central database and is at high risk of being lost or compromised. Indeed some data has already been lost with Cambodia's dataset from 2011 no longer available at either the MRCS or in the country.

207. There appears to be very little use being made of the data from this activity. This may be in part because without any national monitoring activity of this kind there are no existing mechanisms for incorporating and considering the results in national planning or project development exercises, unlike for example water quality where national level databases can be readily consulted by relevant agencies looking at risks to human and aquatic health.

208. The reporting for this activity is considerably behind schedule. At the time of this review the MTR team understood that the 2015 regional report, while close to final, had still not been published. Efforts have been made to improve the timeliness of reporting and the MRCS has stated the 2017 report is almost ready. These delays appear to have been primarily a resourcing issue at the MRCS given other priorities and partly due to the disruption of the transition period and

handover in responsibilities. Nevertheless, delays in reporting undermine support for decentralisation. If national agencies do not see how the data has been used and what the overall regional results are there is less motivation to invest time and resources in further monitoring.

8.5.6 Potential solutions

209. As for the other data collected and held by the MRC, the improvements in the MRC Information and Data Management systems are critical. As soon as improvements have been made all existing ecological health data needs to be uploaded and made available for visualisation or download. Importantly, the data available would ideally include not only the calculated indices but all the raw data for each monitoring parameter at each site with reference to the standards and benchmarks identified in regional reports.

210. The value of this activity for both regional and national purposes needs to be carefully considered. Given the challenges facing the basin at present and the declining resources the MTR does not believe this activity is as high a priority as hydrology, water quality, sediment and fisheries monitoring. Due to limited capacity for ongoing funding there would be merit in Member Countries either scaling back (for example to a five yearly sampling frequency or by reducing the number of sampling locations) or suspending this activity entirely. The main reasons for this are that this type of monitoring is most useful when:

i) there is otherwise no monitoring of the things that are actually important to people (e.g. water quality, water flow, and fish); or

ii) the data can be used in an integrated assessment approach to better understand the causes of change and therefore what can be done to address those causes.

211. Neither of these conditions is in place. In the Lower Mekong Basin water quality, hydrology and fish are already being monitored, and there is no integrated assessment approach which is hampered in any case by a lack of alignment between sampling points. The saving in costs from this activity not proceeding or occurring on a less frequent schedule could be better spent on the higher priorities of hydro-meteorological monitoring (e.g. for station maintenance), water quality monitoring (e.g. for proficiency testing), discharge measurement and sediment monitoring (e.g. for the purchase of new equipment), or fisheries monitoring (e.g. for capacity building and the purchase of new gear for the FADM activity).

212. A summary of the status of the handover of this activity, the issues that require resolution and the proposed options to resolve them are described in Table 16.

Table 16: Summary of the status of ecological health monitoring and the key issues and potential solutions

Ecological health monitoring	
The handover agreements were signed with each country in 2017 and all countries have the same financial handover schedule. This activity is planned to be fully decentralised in all countries by 2023 with MCs first contributing 50% of the costs in 2019, 75% in 2021 and then 100% in 2023.	
Overall Performance	
Financial handover	
	Key issues to be resolved • There is a high risk one or more Member Countries will not have sufficient budget to undertake this activity in 2019. This is not an activity otherwise undertaken by Member Countries and so is unlikely to be a high priority in national budgets.
Technical handover	
	Key issues to be resolved • Technical capacities of Member Countries, particularly where the responsibility has been handed over to a different national agency and there has been turnover in staff. • The lack of an integrated multi-disciplinary assessment means the full value is not being extracted from this data. The value of bio-indicators of aquatic health is substantially enhanced by examining how changes relate to other variables, particularly hydrology and water quality. • Delays in the reporting of results underscore the limited utility and priority of the activity. The regional report on 2015 monitoring has still not been published.
Summary of key issues and causes	
1. Technical capacity within Member Countries The methodology is relatively complex. In some cases, national agencies that have no history or experience in applying the methodology have been assigned responsibility (e.g. the Pollution Control Department in Thailand). In addition, the two-year sampling frequency means that maintaining knowledge of procedures and analytical approaches is more difficult than for some other activities due to staff turnover and lack of regular implementation experience. 2. Limited use being made of the data Member Countries report they disseminate the results of ecological health monitoring to provincial government agencies and others. However, it is not clear how the results have actually been used if at all. The value in this kind of data is substantially enhanced by examining relationships with other variables such as hydrology and water quality to help identify stressors and the causes of environmental degradation. However, this requires an integrated assessment to be undertaken and at present there is no agreed approach for doing this. As Member Countries do not normally undertake this kind of monitoring there are no established mechanisms at a national level for applying the results. 3. Delays in reporting of results There is a considerable time lag from the time the monitoring is undertaken to when a regional report is produced. The regional report on 2015 monitoring has still not been published. This is primarily a resourcing issue at the MRCS and partly due to the disruption of the transition period and handover in responsibilities. Nevertheless, delays in reporting undermine support for decentralisation. If national agencies do not see how the data has been used and what the overall results are there is less	

motivation to invest time and resources in further monitoring.
Actions to support implementation of the overall recommendations
• Improve the MRC Information System as a matter of urgency and as soon as possible upload all existing ecological health data, making it available for visualisation and download. This should include not only the indices agreed in the technical guidelines/handbook, but also the data for each of the individual monitoring parameters for each biological marker and sampling site. • Undertake a review of ecological health sampling locations in conjunction with locations for water quality monitoring and hydrological monitoring and consider opportunities to better align. If opportunities cannot be identified, re-consider the necessity of this activity over the long-term as the value in this kind of data is substantially enhanced by examining how it relates to changes in flow regime and water quality. • Either develop an integrated assessment methodology to examine the relationships between bio-indicators and changes in flow and water quality or consider suspending this activity indefinitely.

8.6 Fisheries monitoring

8.6.1 Introduction

213. Fisheries monitoring has been undertaken in the Lower Mekong Basin since the 1990s. The current activity involves four types of monitoring (Table 17), only one of which is conducted in all four countries – the Fish Abundance and Diversity Monitoring (FADM).

Table 17: Types of regional fisheries monitoring

No	*Type of Monitoring*	*No of Monitoring sites*	*What, when and how data sent to MCS*
1	Stationary trawl bagnet/dai fishery monitoring in the Tonle Sap River	**52**	**MC:** Cambodia **What:** Date of fishing, number of haul per day, total weight of the small species sample, total weight of small species per haul, total weight of big species per haul, total weight of all big and small species (total weight of haul), depth of the dai (m), width of the dai (m), length of the dai (m), maximum mesh size of the bagnet (mm), and minimum mesh size of the bagnet (mm), etc. **When:** 17 days per month from October to March **How:** database and report sent to MRCS through CNMCS at the end of March
2	Fish larvae drift and juvenile monitoring	**4:** 2 (Mekong and Tonle Sap) in Cambodia; 2 (Mekong and Bassac) in Viet Nam	**MCs:** Cambodia and Viet Nam **What:** date of fishing, name of species/genus/family in the sample, amount of big fish, amount of a species of subsample, estimated number of individuals in the whole sample, and their length, etc. **When:** Sampling four times a day from June to September in Cambodia and from April to September in Viet Nam **How:** database and report sent to MRCS through CNMCS and VNMC at the end of September
3	Fish abundance and diversity monitoring	**38**: 11 in Cambodia; 15 in Lao PDR; 5 in Thailand; 7 in Viet Nam	**MCs:** Cambodia, Lao PDR, Thailand, and Viet Nam **What:** Fisher ID, country name, date of fishing, time start and end, hours for fishing, habitat, species name, number of fish, weight, maximum length, gear code, size of gear, mesh size, water level **When:** Daily (all year) **How:** database and report sent to MRCS through NMCSs at the end of February
4	Lee trap fishery monitoring in Southern Lao PDR	10 (Mekong)	**MCs:** Lao PDR **What:** Fisher ID, date of fishing, habitat, species name, number of fish, weight, maximum length, gear code, width of gear, height of gear, stretched mesh size, number of unit, water level **When:** daily from 24 May until the end of September **How:** database and report sent to MRCS through LNMCSs at the end of September

8.6.2 Activity handover

214. Handover agreements are in place for the Stationary Trawl (Dai) monitoring and Fish Larvae Drift and Juvenile monitoring with Cambodia, and on the latter with Viet Nam. Agreements have not

yet been reached with any country for the Fish Abundance and Diversity Monitoring or with Lao PDR for the Lee Trap monitoring, although work agreements for these activities are in place with each country for 2018. The current planned handover schedule has Member Countries contributing 40 per cent of the total costs in 2019 and 60 per cent of the total costs in 2020, with full handover occurring in 2021.

8.6.3 Activity performance

215. Fisheries monitoring was undertaken regularly up until 2015, but a lack of resources has hampered data collection since then. Monitoring for all activities except Lee Trap fisheries was re-instated in 2017 and is continuing in 2018. Lee Trap monitoring occurred in 2018 but will no longer be possible after this year. The 2018 State of the Basin Report only had access to fisheries monitoring data up to 2013.

8.6.4 Value and use of the data

216. Information on the status and trend of fisheries, fisheries yields, sources of production, abundance and diversity is necessary for the sustainable management of fisheries within the LMB. The information also supports the MRC's basin planning and scenario impact assessment work, for example, as undertaken through the Council Study, and is increasingly important in the consideration of trade-offs associated with the development of mainstream and tributary hydropower.

217. At a national level, fisheries monitoring can help enhance sustainable management and development of fisheries for poverty alleviation. The basin wide assessments can deliver knowledge of key issues affecting fisheries in the region, and contribute to improved policies and institutions for better fisheries management and development. While all countries state that the activity is important and the data valuable, this review did not identify any direct use of the data by Member Countries.

8.6.5 Issues and causes

218. The main issue with the fisheries monitoring activity has been the delay in signing handover agreements for the Fish Abundance and Diversity Monitoring (FADM) and the discontinuation of Lee Trap monitoring. For the FADM this delay was due to a proposed change in the methodology to ensure consistency of monitoring across Member Countries and enable comparable results across the basin. The revised methodology should be more scientifically robust but could increase costs for Member Countries to implement. In the meantime, the old method continues to be used, although Member Countries have also agreed to trial the new approach at one site each.

219. For Lee Trap monitoring, this activity will not continue as use of the gear has been outlawed in Lao PDR and more than 300 traps removed. The national line agencies in Lao PDR have been reluctant to implement the monitoring while they seek to enforce compliance with the new law, although an agreement was reached to undertaken the monitoring in 2018.

220. All countries have identified technical and human capacity needs associated with implementing fisheries monitoring activities. These include support for database establishment and management, computer equipment and acquisition of fishing gear as well as human capacity needs in relation to fish sampling and identification, data collection, recording and processing as well as

data analysis and report writing. Several countries have also requested updated guides (e.g. for fish species identification) from the MRC.

221. The management of data and lack of alignment between the regional and national level is a high risk to data security and quality. Each country has generally implemented its own approach to data storage and management and so collation and storage at a regional level can be time consuming and inefficient. There are gaps in the regional data records and no data is currently available for visualisation or download on the MRC data portal.

8.6.6 Potential solutions

222. Handover documents should be prepared and agreed between all parties for the Fish Abundance and Diversity Monitoring. Given the importance of fisheries data and the costs involved in collecting, it may be necessary to consider a longer handover schedule than is currently planned, taking into consideration any additional costs that may be relevant for the new method. Some countries report that initial estimates of fisheries monitoring costs are now out-of-date and the actual cost of undertaking activities is considerably higher as prices for various inputs have gone up. A full cost estimate should be made available to all countries before handover documents are signed.

223. The Lee Trap monitoring in Lao PDR will shortly come to an end. The Joint Environmental Initiative should be the basis for considering alternative options at Don Sahong to monitoring fish migrations through this area.

224. Capacity building through training activities and updated guides need to be prepared and implemented. This is particularly the case for the new FADM methodology but based on consultations with Member Countries would also be beneficial for the other monitoring activities, particularly due to the involvement of local people. Regular refresher training is necessary to support data integrity and consistent approaches across sites and countries.

225. The MRC-IS needs to be improved as a matter of urgency and all existing fisheries data uploaded into the new system and made available for use. There are substantial gaps in the data at a regional level and greater alignment between national database systems and regional systems would be beneficial. Implementation of the revised FADM methodology should be the impetus to agree common data collection and transmission arrangements with all countries. The accessibility of regional fisheries data and information is important to ensure Member Countries can see where the data is going and how it is being used. Regional reporting should encompass all fisheries monitoring activities.

226. A summary of the status of the handover of this activity, the issues that require resolution and the proposed options to resolve them are described in Table 18.

Table 18: Summary of the status of fisheries monitoring and key issues and potential solutions

Fisheries monitoring	
Handover agreements have been signed with Cambodia and Viet Nam for Fish Larvae and Juvenile monitoring and with Cambodia for the Dai Stationary Bagnet monitoring at Tonle Sap. No agreements have been signed for the Lee Trap monitoring in Lao PDR or the Fish Abundance and Diversity Monitoring in any country. The planned handover schedule had countries contributing 60% of the costs in 2019 and 40% in 2020 before complete decentralisation in 2021.	
Overall Performance	
Financial handover	
	Key issues to be resolved • There is a high risk one or more Member Countries will not have sufficient budget to undertake this activity in 2019. Delays in agreeing the new FADM methodology means there has not been enough time for budget submissions and approvals.
Technical handover	
	Key issues to be resolved • Technical capacities of Member Countries • Implementing the revised Fish Abundance and Diversity Monitoring • Monitoring of fish migration following discontinuation of Lee Trap monitoring in Lao PDR • Database management and reporting on all fisheries monitoring activities
Summary of key issues and causes	
1. Technical capacity of Member Countries Despite fisheries monitoring having been undertaken for more than ten years, Member Countries have identified technical capacity constraints in implementing the activity. Needs include support for database establishment and management, computer equipment and acquisition of fishing gear as well as human capacity needs in relation to fish sampling and identification, data collection, recording and processing as well as data analysis and report writing. Support for the revised FADM methodology will be important to ensure consistency. 2. Implementing the revised Fish Abundance and Diversity Monitoring A review of the FADM methodology in 2017 recommended to standardise the gillnet mesh sizes to enable comparative results across the basin. This approach is scientifically more robust and critical to the fisheries monitoring effort as this is the only method that is applied across the four countries. The delay in reaching agreement has delayed the signing of handover agreements, but in the meantime the activity is continuing with the old method. The new method is being trialled at one site in each country. 3. Prohibition on the use of lee traps in Lao PDR The use of lee traps at the Khone Falls in Lao PDR is now prohibited. Lao PDR has been reluctant to employ lee traps for fisheries monitoring while at the same time seeking to enforce compliance with the new law. Although monitoring was agreed to be undertaken for 2018, an alternative arrangement will need to be considered for the longer term. 4. Database management and reporting on all fisheries monitoring activities The gaps in the historical data of the regional fisheries database and lack of alignment between regional and national fisheries databases presents a risk to data security and quality control. Each country has generally implemented its own approach which creates inefficiencies in putting together a	

regional dataset. All parties need to work together to harmonise the recording and storing of data, especially for the FADM activity.

Actions to support implementation of the overall recommendations

- Improve the MRC Information System as a matter of urgency and as soon as possible upload all existing fisheries data, making it available for visualisation and download.
- Prepare a detailed implementation costing for the revised Fish Abundance and Diversity Monitoring, share with the Member Countries and implement the revised methodology as soon as possible.
- Prepare Handover Documents based on the revised FADM methodology and agree with each Member Country a longer financial transition period up to 2030.
- Ensure adequate training and knowledge sharing between countries for all personnel involved in FADM.
- Align databases at national and regional level to facilitate the transmission and quality control of data.
- Prepare a regional fisheries monitoring report that covers all fisheries monitoring activities, not only FADM. There needs to be greater transparency in the data analysis and presentation.
- Explore opportunities for alternative monitoring of migratory fish at Khone Falls as part of the Joint Environmental Monitoring initiative.

8.7 Field data collection for SIMVA

8.7.1 Introduction

227. The Social Impact Monitoring and Vulnerability Assessment (SIMVA) is a periodic survey of communities along the mainstream corridor. There are two main elements to it: (i) the full SIMVA survey and (ii) thematic studies focused on particular issues. A full baseline survey was conducted in 2011-12 and a thematic study in 2014-15 focused on shocks and trends. A further benchmark survey is being undertaken at the time of this review and is expected to produce data and analysis in mid-2019. At the regional level, SIMVA is used for:

- MRC basin planning activities and to fill in gaps for the State of the Basin Report when basin-wide data is not available; and
- various ad-hoc studies and assessments such as the Council Study evaluating the impacts of different scenarios, plans and projects on water related livelihoods and living conditions.

228. The SIMVA survey area covers five socio-ecological zones and 13 sub-zones within 15 km of each side of the Mekong mainstream, zones around two major wetlands, the Songkhram in Thailand and the Tonle Sap in Cambodia, and the 3S river confluences in Cambodia. Full SIMVA surveys cover the whole study area (the 13 sub-zones). Thematic studies may focus on certain zones only.

229. The sample size for the household survey of the full SIMVA study is about 5,600 households in total across the four Member Countries. The sample size has been determined from the results of an analysis of a sample design of the 2011 SIMVA. The study area, sample size and indicators (70 in total) are defined in the SIMVA technical guideline.

230. The main focus of the SIMVA surveys is on providing regular information on the status and trends in social conditions of people living in the basin, linked to changes in the basin's aquatic ecosystems. This includes social vulnerability (particularly for food and livelihoods) linked to changes in water resources. It examines the dependency of people on water-related resources, their level of vulnerability to changes in those resources and the coping strategies they employ in response.

8.7.2 Activity handover

231. This activity has not yet been handed over. No handover agreements have been signed. Based on current plans, Member Countries will be expected to finance 25 per cent of this activity in 2020 when the next thematic studies are due.

8.7.3 Activity performance

232. The full SIMVA survey is supposed to be undertaken every five years. Following the benchmark survey in 2018-19 the next full survey is due to be carried out in 2023. With the pace of change in socio-economic conditions across the basin, the time between the last full survey in 2011 and the 2018-19 benchmark survey is a long-time for the data not to have been updated, notwithstanding that the thematic survey conducted in 2014-15 covered many of the same indicators. The benchmark survey being conducted in 2018-19 will help refine the indicators and methodology for the next full survey in 2023 and as a basis for any thematic studies in 2020.

8.7.4 Value and use of the data

233. The SIMVA has been useful for MRC regional planning exercises and studies including the Council Study. This is because adequate socio-economic data across the LMB has otherwise not been available. The survey provides a level of detail around water-related livelihoods and living conditions that no other national surveys provide. However, its restriction to the Mekong corridor is a limitation on its use for State of the Basin Reports and basin development planning. This review did not identify any direct use of the SIMVA data at a national level, although the data is available to national and provincial planning authorities and Member Countries have said it is important.

8.7.5 Issues and causes

234. At this stage the main issues with the SIMVA activity are mostly technical. However, these technical issues in relation to survey design and scope have cost implications that will be felt by the Member Countries in due course. It is imperative that changes to the design following the current survey are driven by consideration of ongoing costs to implement this activity. This consideration relates to the number of indicators, the sampling effort in each country and zone, the frequency of full SIMVA surveys and whether there is a strong need for thematic studies in addition to the full surveys.

235. The difficulty in resolving some of these technical issues are driven in large part by the lack of socio-economic technical expertise at the MRC, both at a regional and national level. The MRC's traditional strength is in science and engineering and this is the case both at the MRCS and at NMCSs. However, with the need to further consider trade-offs between alternative plans and projects, the importance of socio-economic expertise is only likely to increase.

236. The lack of a functioning socio-economic database to store and manage SIMVA data is highly problematic. As with the other activities, it creates a high risk of data being lost or compromised and makes any analytical work at either regional or national level more difficult.

8.7.6 Potential solutions

237. To prepare for the handover of SIMVA to Member Countries, design issues with the survey need to be addressed as soon as possible after the benchmark survey currently being conducted. To ensure the countries will be able to cover the costs in future, the focus of that re-design would ideally be on reducing the scope of the activity. The number of indicators should be reduced and sampling effort proportional to population density in each socio-ecological zone. In addition, consideration should be given as to whether the thematic studies are absolutely necessary or whether it would be more beneficial to simply implement a full survey every five years using a standard methodology that enables an assessment of trends and changes over time. Until these issues are resolved, it will be difficult to agree handover arrangements as the future cost impacts will be too uncertain.

238. In cases where they are not already, to help address gaps in technical expertise and build capacity at NMCSs, the further involvement of National Statistics Offices (NSO) in the SIMVA activity would be beneficial. This does not necessarily need to be in an implementing role as NMCSs have generally been subcontracting the data collection and analysis work to specialised research institutes who are well qualified to do it. NSO's overseeing the design and quality assurance processes may be

sufficient and would help to identify opportunities for more integrated delivery of the data collection and management in future. For instance, there may be opportunity to address some of what the SIMVA survey does through other national surveys and censuses, allowing the scope of SIMVA itself to be further reduced with associated cost savings.

239. The storage and management systems for socio-economic data at both regional and national level need to be improved. The approach to socio-economic data should follow the approach to environmental data as being addressed through the MRC-IS improvement plan. Ideally, national databases managed by NMCSs and housing both SIMVA data as well as drawing in any LMB-relevant national datasets held by other agencies, would be connected to a regional database and portal that could draw on the national data as and when required. This would help ensure a single source of truth and minimise the handling arrangements for data collation and transmission.

240. A summary of the status of the handover of this activity, the issues that require resolution and the proposed options to resolve them are described in Table 19.

Table 19: Summary of status of the SIMVA survey and the key issues and potential solutions

Field data collection for SIMVA	
Handover agreements have not yet been signed for this activity. The planned financial transition schedule involves Member Countries contributing 25% of the costs to undertake some thematic studies in 2020, 75% of the costs to undertake the next full SIMVA survey in 2023, 75% in 2025, and then full handover in 2028.	
Overall Performance	
Financial handover	
	Key issues to be resolved • Nil to-date, although the scope of future surveys will impact costs • Handover agreements need to be prepared and signed
Technical handover	
	Key issues to be resolved • Socio-economic technical expertise needs strengthening at both national and regional levels • Agreeing a cost effective survey design for the next full survey in 2023 • Data storage and management at a regional level and integration between regional and national levels.
Summary of key issues and causes	
1. Socio-economic technical capacity within MRC at both national and regional levels The traditional strength of the MRC is in science and engineering. This is the case at both national and regional levels, with NMCSs generally located under ministries of environment and natural resources. The lack of socio-economic expertise has long been a weakness in the MRC's work but needs to be resolved with increasing focus on issues involving trade-offs in investment decisions. Although considerable effort has been made to ensure continuity with previous surveys, the limited socio-economic capacity at MRC hampers the ability to agree an enduring approach to SIMVA survey design, making trends and changes over time difficult to assess. 2. Agreeing a cost effective survey design for the next full SIMVA survey in 2023 The next iteration of the SIMVA survey is being undertaken in 2018-19. This benchmark survey will be used to help refine the methodology for the next full roll-out in 2023. The selection of indicators and	

choice of questions and sampling design will have a considerable impact on costs. Notwithstanding that agreements have been reached on the design for the 2018-19 survey, Member Countries have raised concerns about the high number of indicators. The indicators need to be prioritised so that a much smaller selection focused only on the critical needs is used. Agreement on sampling design should also be re-visited so that it takes into consideration population density in different zones. There is no reasonable basis for conducting the same sampling effort in all locations.

3. Lack of integration with national socio-economic databases and between national and regional levels

   It appears this activity is largely implemented by NMCSs sub-contracting the work to national research institutes. Some NMCSs are building their own databases which will house SIMVA data and also draw on relevant national datasets relevant to the Lower Mekong Basin. While this approach appears feasible, there is a long way to go in implementation and it will be crucial to have close involvement of National Statistics Offices to ensure integration with national systems and appropriate links between national and regional databases.

Actions to support implementation of the overall recommendations

- The number of indicators used in SIMVA surveys needs to be reduced. Following the current benchmark survey, the indicators and questions should be prioritised to enable cost effective implementation over the long-term. The sampling effort for each country should reflect population density in each of the SIMVA zones.
- If not involved in the survey implementation, National Statistics Offices would ideally have a role in quality assurance and control as Thailand intends to do; and in the establishment of LMB socio-economic databases at the national level that are fully integrated with national systems.
- Integrate data from the SIMVA survey into the broader socio-economic database. As long as SIMVA continues, it will provide some of the richest insights into water dependency of basin communities, notwithstanding its geographical scope limitations.
- Although SIMVA is unique in its focus on water-dependency of livelihoods, once arrangements are in place for the provision of basin-wide socio-economic data in accordance with the MRC Indicator Framework and the data availability at a sub-basin scale for each indicator is known, the need for SIMVA monitoring should be re-evaluated based on a consideration of the costs and benefits of the data collection. Basin-wide socio-economic data will not be a complete substitute for the richness of SIMVA data. However, if the availability of data at a sub-basin scale can be improved it may be sufficient for basin planning purposes. At the very least, the MRCS and MCs may wish to re-consider the need for thematic studies and just concentrate on a full survey every five years to provide data from which trends in conditions can be established.

8.8 Ad-hoc provision of socio-economic data for basin planning

8.8.1 Introduction

241. Socio-economic data for the whole of the LMB is required for periodic assessments and strategic planning exercises, such as the State of the Basin Report (updated every five years), the Basin Development Strategy and any future Basin Development Plan. Socio-economic data is also necessary for ad-hoc assessments such as the Council Study on the impacts of development scenarios in the LMB and will be an important consideration in any further work examining trade-offs between different development and management plans and projects. In contrast to the data collected through the SIMVA survey, the socio-economic data under this activity is mainly secondary data provided by the Member Countries from national data bases. It includes national economic statistics, data from the national census and surveys on household wellbeing and living standards.

242. The implementation of this activity is intended to be guided by the MRC Indicator Framework, which is still under development. The data collected to-date is housed in a regional socio-economic database, last updated in 2015.

8.8.2 Handover arrangements

243. This activity was notionally handed over to Member Countries during the last Strategic Plan period. However, there are no handover agreements formalising the arrangements. Only Thailand acknowledged the handover and committed to implement this activity in a letter sent to the MRCS in 2015. Handover agreements were planned to be prepared in conjunction with the data collection for the SOBR in 2018, but the MTR is not aware whether this occurred.

8.8.3 Activity performance

244. This activity has not been implemented since it was decentralised. Socio-economic data required for the 2018 State of the Basin report was collected by National Consultants funded using the MRC basket fund in accordance with the MRCS annual work plan. The socio-economic data used for the Council Study was taken from the 2011 and 2014 SIMVA surveys.

8.8.4 Value and use of the data

245. Socio-economic data is critical for effective basin planning and appropriate consideration of impacts and trade-offs associated with different strategies, plans and projects. Ideally the data would be available at a sub-basin scale (i.e. province, district or commune level) as this enables vulnerable communities to be identified and analysis of the impacts of different decisions on different communities and groups of people. Many of the national datasets will, unfortunately, not be available at this scale. For the SOBR, the datasets uses were mostly at a national scale and accessed from international organisations such as the World Bank and Asian Development Bank.

246. As the data for this activity is already collected at a national level the value in national and sectoral planning decisions is clear. At a basin scale, the transition from planning and scenario testing to implementation with greater consideration of trade-offs, means that socio-economic data is more relevant than ever.

8.8.5 Issues and causes

247. The main issue with the implementation of this activity is the lack of clarity on what is required by when and by whom. The handover documents have not been developed as they are pending finalisation and agreement to the MRC Indicator Framework, which will identify which indicators and monitoring parameters are to be used for basin planning and assessing the status and trends in socio-economic conditions across the basin. The delay in both of these activities is in part due to a lack of socio-economic technical capacity within the MRC at both regional and national levels.

248. One of the challenges in implementing this activity is likely to be associated with inconsistencies in datasets from different countries and from different sectors within countries. For instance, data from different Member Countries will differ in terms of units of measurements, intervals and times of collection. Therefore, the comparison and aggregation of the data at a regional level will be challenging. Nevertheless, these are issues that can be resolved in an appropriate assessment framework which pays due regard to the provenance, assumptions and caveats that relate to each dataset. Assurance needs to be provided to the data custodians on exactly how the data will be used, managed and presented.

249. This activity also involves a considerable coordination challenge at the national level. The data custodians will be spread across a range of line agencies including those responsible for national statistics, agricultural and resource economics, and central banks etc. Clear protocols for the sharing and use of required datasets will need to be agreed with each party.

250. At the regional level, there is no agreed format for the storage and management of any socio-economic data. The socio-economic database has not been updated since 2015 and uses outdated technology with a poor user interface making it slow and difficult to use. A decision was taken in 2014 not to continue updating the database, as it was a complicated and time consuming process. Some NMCSs are looking at establishing socio-economic databases at a national level in order to integrate LMB related datasets. These would be used to store data collected from SIMVA surveys as well as drawing together data from other national systems which are relevant to the LMB. This is a substantial undertaking and will require time and resources to implement. Just as it is with environmental data, it will be important to ensure seamless integration between regional and national databases to the extent possible.

8.8.6 Potential solutions

251. The main priority in the decentralisation of this activity is to agree what it actually entails. Finalising the MRC Indicator Framework is the first step, followed by the preparation and agreement to handover documents that describe exactly which data will be provided by whom, at what frequency and in which format.

252. Addressing the fundamental problems with storage and management of socio-economic data is also a critical need. This is no less of an issue for socio-economic data as it is for environmental data. The socio-economic database should be completely redesigned to align with the Indicator Framework once approved and the underlying infrastructure updated in accordance with the MRC-IS improvement plan. Ideally the regional database would simply draw on national databases managed by NMCSs in each country and so updating would occur automatically as national databases are updated with new national data and the results from the SIMVA survey. A

capacity for integrated analysis involving socio-economic data and environmental data could be useful in future.

253. A summary of the status of the handover of this activity, the issues that require resolution and the proposed options to resolve them are described in Table 20.

Table 20: Summary of the status of the ad-hoc provision of socio-economic data and the key issues and potential solutions

Ad-hoc provision of socio-economic data for basin planning	
This activity was agreed for handover in the previous Strategic Plan period. However, there are no handover documents specifying what the activity entails and how it should be implemented	
Overall Performance	
Financial handover	
	Key issues to be resolved • Nil at this stage as there is no detail on what this activity entails and the related costs
Technical handover	
	Key issues to be resolved • Socio-economic technical expertise needs strengthening at both national and regional levels. • Clarity is required on what data is to be provided by whom, at what frequency and the mechanisms for it to be processed, managed and transmitted. • Lack of consistency between country datasets and limited data available at a sub-basin scale. • Regional database is out-of-date, cumbersome and has limited functionality.
Summary of key issues and causes	
1. Socio-economic technical capacity within MRC at both national and regional levels The traditional strength of the MRC is in science and engineering. This is the case at both national and regional levels, with NMCSs generally located under the ministry of environment and natural resources. The limited socio-economic capacity has long been a weakness in the MRC's work but needs strengthening given increasing focus on the trade-offs in investment decisions. This lack of capacity hampers the ability to agree indicators and assess data suitability for input to basin planning. 2. Lack of clarity on the socio-economic data that needs to be provided and how it should be provided With the MRC Indicator Framework still not finalised, there is no agreement amongst the countries on what data should be collated, at what frequency and the manner in which it should be processed, managed and transmitted to the MRCS. This needs to be resolved as soon as possible so that socio-economic data needed for the next basin planning cycle can be made available. Close engagement with National Statistics Office is necessary at every step as the data required will generally come either from the national census, national economic statistics, or household living standard surveys. 3. Lack of consistency between datasets in different countries and limited data availability Because this activity does not involve the collection of any additional data but seeks to make use of what is already available in countries there will always be some inconsistencies between datasets. This is not necessarily a problem, but does require an agreed approach to managing and presenting data in recognition of this. Data at a sub-basin scale is particularly important in order to be able to identify vulnerable communities and the impacts of development decisions on different groups of people.	

Unfortunately the availability of data at a sub-basin scale is very limited.

4. Data storage and management at a regional level and the links to national systems

   The regional database is out-of-date, cumbersome and has limited functionality. The database infrastructure underpinning it needs updating and refreshing in-line with other improvements to the MRC Information systems.

Actions to support implementation of the overall recommendations

- Finalise the MRC Indicator Framework as soon as possible and put in place arrangements to collate, process and transmit the necessary data in support of basin planning.
- Agree handover arrangements for collating and transmitting existing datasets relevant to the MRC-IF.
- The regional socio-economic database needs to be redesigned to enable seamless integration of national and regional databases. Upgraded infrastructure with improved search, display and download functions is an essential part of this.
- In future, the ability to undertake integrated data analysis between, for example, flood extent and severity and household economic losses would be valuable. These kinds of issues need to be considered in database design and the upgrade of the MRC Information Systems.
- Change the title of this activity to “Regular provision of socio-economic data for basin planning”.

8.9 Preparation and coordination of NIPs for basin planning

8.9.1 Introduction

254. National Indicative Plans (NIPs) are the mechanism by which the IWRM-based Basin Development Strategy and the 2014 Regional Roadmap on decentralisation are implemented at the national level in each Member Country. They are the primary channel by which basin perspectives, development opportunities, priorities and CRBMF activities are mainstreamed into national strategies, plans, policies and systems. Consequently, the NIP supplements national plans with joint projects and national projects and activities that are of basin-wide significance.

255. The projects and activities included in the NIPs are described in a cross sectoral manner and include information on investment needs and allocation of funds. The purpose of this is to provide a coordinated and prioritised portfolio of projects and activities for future investment. This investment is expected to come from multiple sources, including national budgets, loans and grants and direct funding from bilateral donors.

256. Each NIP has associated Project Information Notes (PINs) attached. These notes provide a summary of the individual projects or activities relevant to implement the NIP and for which additional resources are required. Some Member Countries have prepared PINs for some of the decentralised monitoring activities due to budget shortfalls at a national level.

257. To date, the MRCS has supported the MCs and funded the preparation of the NIPs. The budget to support the 2016-2020 process was approximately USD 400,000 for all Member Countries. The preparation of the NIPs is a substantial exercise requiring strong leadership and coordination across line agencies to enable integrated budget preparation and work planning.

8.9.2 Handover Arrangements

258. The preparation and coordination of NIPs is due to be partially handed over to Member Countries for the next planning period: 2021-2025. No handover agreements have yet been signed. It is expected Member Countries will contribute 50 per cent of the costs of this activity for the preparation of 2021-2025 plans and 100 per cent of the costs for preparation of 2026-2030 plans.

8.9.3 Activity performance

259. All countries have NIPs in place for the current Basin Development Strategy period 2016-2020 and planning will need to commence shortly for the next round. All of the NIPs include lists of projects and activities. Some of these projects are being funded by international organisations and some by governments, but many are not yet funded and this includes some of the decentralised monitoring activities.

260. Although not necessarily the case across all Member Countries, a review of each country's NIP implementation undertaken in 2017 identified a lack of ownership of NIP projects and activities in line agencies, a need for improved coordination and leadership of NIP implementation, and better promotion of projects and activities to funding bodies.

8.9.4 Value of the activity

261. The NIPs have an important role to play in the achievement of the strategic priorities of the Basin Development Strategy. It is through these plans that coordinated national action for regional

objectives occurs. However, the high number of unfunded projects and activities within the NIPs indicates that what is currently included is not necessarily closely aligned with the highest national priorities. Through the reviews of the NIPs undertaken by national consultants in 2017 it was found that some line agencies did not believe the projects and activities in the NIPs were particularly relevant to their mandate. Many of the projects and activities were not well integrated into the national budgets and work plans of relevant line agencies.

262. The value of this activity is entirely dependent on the product that is produced and this depends on the extent of involvement of all relevant parties in its development. It is apparent there is room for improvement in both of these aspects.

8.9.5 Issues and causes

263. Countries have commented on the difficulty implementing NIP activities due to delays in finalising and approving the NIPs during the previous planning round. As preparation and approval of national budgets normally takes at least two years there will necessarily be a delay in implementing activities from a NIP that has only just been approved. The timing of NIP preparation is dependent on the timing of preparation of the Basin Development Strategy, which is normally only finalised in the year before the planning period commences. While these two exercises can be conducted in parallel (and indeed are), in both cases there is a need to recognise the ongoing process of one plan rolling into the next and avoiding radical changes in approach or focus, wherever possible. Gradual improvement and strengthening is called for rather than a complete re-think.

264. Countries have also identified a lack of technical capacity at the national level to support implementation of projects including in relation to modelling and for each of the decentralised monitoring activities. Although the NIPs generally identify areas of human and technical capacity needs there is less focus on what needs to be done to address these needs including consideration of joint activities and country-to-country knowledge sharing where there are common needs or opportunity for sharing lessons learned.

265. Of particular concern is the reporting in some NIP review reports that some (many) line agencies do not believe that what is included in the NIPs aligns with their national mandates. In this case it is clear that line agencies will take less overall responsibility for implementation and regional needs will not be prioritised in budget allocation and work planning decisions. While it may not be the case in all countries, there is a clear need to strengthen the involvement of line agencies in the preparation of NIPs in order to ensure alignment of national and regional objectives and actions. This needs to start at the Basin Development Strategy stage to ensure that the overall strategy appropriately recognises issues and priorities at a sub-basin scale where these have regional relevance. The coordination role of the NMCs is critical at both stages.

8.9.6 Potential solutions

266. Effective use of the NIPs in national planning requires explicit recognition of the role of the NMC both in coordinating preparation of the NIP and in coordinating its implementation over the five year planning period. There would be merit in documenting this responsibility for both stages in handover agreements for this activity. Equally, the role of national line agencies in the preparation of NIPs is critical, both to ensure projects and activities align with national needs but also to enable effective integration of budget preparations and work plans. Handover agreements could also

document the role of each relevant national line agency in preparation and implementation of the NIP and be signed by all parties.

267. Following a review of the NIPs, Viet Nam made some changes to its plan, including removing some activities that were considered to only be of national significance and to reflect the changing policy landscape in relation to management of the Delta region. This is a good example of the NIPs being implemented as flexible, working documents, subject to update and change from time-to-time to ensure they remain relevant. This approach should be continued and indeed extended to the preparation stage by instituting the NIPs as a rolling five year plan that is reviewed and updated annually to accommodate new joint and regional initiatives. This would allow better alignment with national budget processes. A longer horizon to the Basin Development Strategy would also support this approach.

268. One of the biggest challenges for the NIPs is the identification of projects that fail to attract funding support. Addressing this is in part about greater line agency responsibility for projects and activities, but also about more explicit identification of funding options and a strategy for exploiting those options. One way to address this could be for each NIP to have an associated funding mobilisation strategy prepared alongside it to identify how any funding gaps will be filled over the planning cycle. Such a strategy would seek to align NIP projects and activities with either national priorities or the priorities of different development partners. The NMCs are likely to have to play an important coordination role in the promotion of projects and activities to funding partners and so greater support for them to undertake this outreach and engagement role may be useful.

269. Even with a decentralisation of this activity to Member Countries, an active coordination role for the MRCS will remain important in ensuring coherence between the NIPs of each country, and with the BDS and the MRC Strategic Plan.

270. A summary of the status of the handover of this activity, the issues that require resolution and the proposed options to resolve them are described in Table 21.

Table 21: Summary of the status of preparation and coordination of NIPs for basin planning and description of the key issues and potential solutions

Preparation and coordination of NIPs for basin planning	
No handover agreements have been signed for this activity. The planned transition schedule involves Member Countries contributing 50% of the costs of this activity in 2020 with full handover by 2025.	
Overall Performance	
Financial handover	
	Key issues to be resolved • Handover documents need to be prepared and signed
Technical handover	
	Key issues to be resolved • The timeliness of NIP preparation relative to national budget processes • Effective coordination of preparation and implementation of the NIPs to ensure line agency ownership in supporting integrated water resource management in the LMB
Summary of key issues and causes	
1. The timeliness of NIP preparation relative to national budget processes There is often a two year lag between the finalisation of NIPs and Government approval of national budgets to undertake activities. As a result the first two years in any strategic plan period cannot be utilised for the activities identified in the plan that is finalised at the start of the period. The time required to secure budgets needs to be taken into consideration in the preparation and coordination of the next round of NIPs including with regard to the funding of decentralised monitoring activities. 2. A need for strong national line agency ownership in preparation and implementation of NIPs The quality and usefulness of the NIPs is questionable to the extent they consist of a list of unfunded projects and without sufficient line agency ownership. Effective coordination across all relevant line agencies in budget development and with other countries in relation to joint projects is critical in this regard. This coordination from NMCs is important in ensuring line agencies appropriately integrate NIP projects and activities into their annual and multi-annual work plans.	
Actions to support implementation of the overall recommendations	
• Review lessons learned from implementing the current NIPs and how they have influenced planning and investment decisions within each country and contributed to the objectives of the Basin Development Strategy. Revise the approach and guidelines for NIP preparation and proposed content accordingly. • Implement a rolling preparation and implementation process for NIPs such that they are reviewed and updated every year to accommodate new joint and regional initiatives. • Change the description of this activity to recognise that it involves coordination in the implementation phase as well in the preparation phase of the NIP (e.g. Coordination of the preparation and ongoing implementation of NIPs for basin planning). • Include measures to enhance technical capacity for implementation in addition to the necessary financial resources and prepare a funding mobilisation strategy to accompany each NIP. • Prepare handover documents that include the role of the NMCs and all relevant line agencies in preparation and implementation of the NIPs and which are signed by all parties.	

Attachment A

Stakeholders consulted for this review

Consultations for this *Review of the decentralisation of Core River Basin Management Function activities* were undertaken in conjunction with the *Mid-Term Review of the Mekong River Commission's Strategic Plan 2016-2020*. The meetings and discussions held with stakeholders on the Mid-Term Review for the most part included participants views on decentralisation. The list of participants to these meetings is attached the MTR report. In addition, dedicated meetings on the decentralised activities involved the organisations listed below.

Cambodia

- Cambodia National Mekong Committee Secretariat, Ministry of Water Resources and Meteorology
- Department of Hydrology and River Works, Ministry of Water Resources and Meteorology
- Department of Meteorology, Ministry of Water Resources and Meteorology
- Ministry of Environment
- Ministry of Mines and Energy
- Ministry of Foreign Affairs and International Cooperation
- Department of Water Resource Management and Conservation, Ministry of Water Resources and Meteorology
- Fisheries Administration, Ministry of Agriculture, Forestry and Fisheries
- Tonle Sap Authority, Ministry of Water Resources and Meteorology
- National Institute of Statistics, Ministry of Planning

Lao PDR

- Lao National Mekong Committee Secretariat, Ministry of Natural Resources and Environment
- Department of Meteorology and Hydrology, Ministry of Natural Resources and Environment
- Lao Statistics Bureau, Ministry of Planning and Investment
- Living Aquatic Resources Research Centre, Ministry of Agriculture and Forestry
- Department of Environment, Ministry of Natural Resources and Environment

Thailand

- Thailand National Mekong Committee Secretariat, Ministry of Natural Resources and Environment
- Department of Water Resources, Ministry of Natural Resources and Environment
- Pollution Control Department, Ministry of Natural Resources and Environment
- Department of Fisheries, Ministry of Agriculture and Cooperatives
- Legal and Treaty Department, Ministry of Foreign Affairs
- Department of International Organisations, Ministry of Foreign Affairs

Viet Nam

- Standing Office of the Viet Nam National Mekong Committee, Ministry of Natural Resources and Environment
- Department of Water Resources Management, Ministry of Natural Resources and Environment
- Institute of Water Resources, Ministry of Natural Resources and Environment
- National Hydro-Meteorological Service, Ministry of Natural Resources and Environment
- General Statistics Office of Viet Nam, Ministry of Planning and Investment
- National Centre of Water Resources Investigation and Planning, Ministry of Natural Resources and Environment
- Southern Region Hydro-Meteorological Centre, Ministry of Natural Resources and Environment

- Southern Institute for Ecology, Viet Nam Academy of Science and Technology
- Southern Institute for Water Resource Planning, Ministry of Agriculture and Rural Development
- Research Institute of Aquaculture, Ministry of Agriculture and Rural Development
- National Disaster Management Authority, Ministry of Agriculture and Rural Development
- Viet Nam Inland Waterway Administration, Ministry of Transport
- Electricity of Viet Nam, Ministry of Trade and Industry
- Department of International Organisations, Ministry of Foreign Affairs

Mekong River Commission Secretariat

- Office of the Chief Executive Officer
- Environment Division
- Planning Division
- Technical Division, including the Regional Flood Mitigation and Management Centre

Attachment B

Lists of monitoring stations and sampling locations

1) MRC hydro-meteorological network
2) List of additional hydro-meteorological stations identified by RFMMC as necessary to improve river flood forecasting and flash flood guidance, based on 2015 data
3) List of additional hydro-meteorological stations in Viet Nam including some funded by the World Bank
4) Map of hydro-meteorological stations in Viet Nam
5) List of additional hydro-meteorological stations in Lao PDR funded by ADB and China
6) List of additional hydro-meteorological stations in Cambodia funded by UNDP
7) Map of hydro-meteorological stations in Cambodia
8) MRC discharge measurement and sediment monitoring sampling locations
9) MRC water quality sampling locations
10) MRC ecological health monitoring sampling locations
11) MRC fisheries abundance and diversity monitoring sampling locations

Additional known stations where details are not yet available:

12) List of new hydro-meteorological stations in Lao PDR funded by ADB
13) List of new hydro-meteorological stations in Cambodia funded by JICA (as mapped)
14) List of new hydro-meteorological stations in Lao PDR funded by JICA
15) List of any new hydro-meteorological stations in Thailand

The lists of monitoring stations and sampling locations in this attachment are not complete. They are based on information which was available to the MTR team at the time of this review. In addition to the missing stations identified above, location information and station ID codes were not available for all stations provided. It is possible there are some duplicate entries in these lists, particularly where different spellings and multiple station codes have been used for the same stations.

The MRC is advised to develop a master database of all existing monitoring stations and sampling locations across the LMB. The MTR understands this work has commenced as part of the upgrade of the MRC Information System. This should include cross-checking all monitoring stations and sampling locations, deciding on the definitive list and preparing a master file of stations including GIS layers and all relevant information to support the kind of network analysis referred to in Recommendation D.5. The minimum required information in both table and shape file format includes:

- The location of all stations (digital & DMS format) and their unique regional identification code
- The location of key mainstream and tributary development projects (hydropower and agriculture) as well as the extent of backwater effects and potential volumetric water use
- Location of key flood zones and the area of inundation under different return interval floods
- The monitoring parameters collected, the frequency of transmission and the unit of measurement
- The sampling/sensing technology including automatic or manual operation
- The data collection and transmission systems used and the station/data owner
- The magnitude of annual and seasonal passing water flows and sediment transport, particularly in relation to the contribution of each of the mainstream tributaries

Lists of monitoring stations and sampling locations

Table B1: Stations providing telemetry rainfall and water level data to MRC

No	Station Code	Station Name	River/Basin	Country	Lat.	Long.	Para-meter[23]	Type of Station[24]
1	092500	Jinghong	Mekong	China			WL,R	T (Other)
2	092980	Manan	Manan	China			WL,R	T (Other)
3	350101	Ban Kengdone	Se Bang Hieng	Lao PDR	16.187	105.313	WL,R	M,T (HYCOS)
4	120101	Ban Mixai	Nam Khan	Lao PDR	19.786	102.183	WL,R	M,T (HYCOS)
5	270502	Ban Nape	Nam Phao	Lao PDR			WL,R	T (HYCOS)
6	430106	Ban Veunkhen	Se Kong	Lao PDR	14.819	106.806	WL,R	M,T (HYCOS)
7	390102	Khongsedone	Nam Sedone	Lao PDR	15.575	105.815	WL,R	M,T (HYCOS)
8	011201	Luang Prabang	Mekong	Lao PDR	19.893	102.134	WL,R	M,T (HYCOS)
9	320107	Mahaxai	Se Bang Fai	Lao PDR	17.418	105.198	WL,R	M,T (HYCOS)
10	260101	Muang Kao	Nam Sane	Lao PDR	18.562	103.737	WL,R	M,T (HYCOS)
11	100102	Muang Ngoy	Nam Ou	Lao PDR	20.572	102.617	WL,R	M,T (HYCOS)
12	013901	Pakse	Mekong	Lao PDR	15.100	105.813	WL,R	M,T (HYCOS)
13	350102	Phalane	Se Sangsoy	Lao PDR			WL,R	T (HYCOS)
14	230113	Phiengluang	Nam Ngum	Lao PDR	19.568	103.071	WL,R	M,T (HYCOS)
15	270101	Phonesy	Nam Kading	Lao PDR	18.302	104.098	WL,R	M,T (HYCOS)
16	320101	Se Bangfai	Se Bang Fai	Lao PDR			WL,R	T (HYCOS)
17	350106	Senuane	Sebangnuane	Lao PDR	16.697	106.220	WL,R	M,T (HYCOS)
18	350105	Sopnam	Se Bang Hieng	Lao PDR			WL,R	T (HYCOS)
19	011901	Vientiane KM4	Mekong	Lao PDR	17.931	102.616	WL,R	M,T (HYCOS)
20	050106	Ban Doi Hang	Nam Mae Kok	Thailand	19.918	99.850	WL,R	T (HYCOS)
21	290113	Ban Had Paeng	Nam Sonkhran	Thailand	17.675	104.286	WL,R	M,T (HYCOS)
22	290102	Ban Tha Kok Doeng	Nam Sonkhran	Thailand	17.866	103.774	WL,R	M,T (HYCOS)
23	011903	Chiang Khan	Mekong	Thailand	17.900	101.670	WL,R	M,T (HYCOS)
24	010501	Chiang Saen	Mekong	Thailand	20.274	100.089	WL,R	M,T (HYCOS)
25	013801	Khong Chiam	Mekong	Thailand	15.322	105.493	WL,R	M,T (HYCOS)
26	013402	Mukdahan	Mekong	Thailand	16.583	104.733	WL,R	M,T (HYCOS)
27	013101	Nakhon Phanom	Mekong	Thailand	17.425	104.774	WL,R	M,T (HYCOS)
28	012001	Nong Khai	Mekong	Thailand	17.881	102.732	WL,R	M,T (HYCOS)
29	070103	Thoeng	Nam Mae lng	Thailand	19.688	100.187	WL,R	M,T (HYCOS)
30	150101	Wang Saphung	Nam Loei	Thailand	17.300	101.776	WL,R	M,T (HYCOS)
31	680103	Angkorborey	Stung Takeo	Cambodia			WL,R	T (HYCOS)
32	550102	Battambang	Sangker	Cambodia			WL,R	T (HYCOS)
33	590101	Boribo	Stung Boribo	Cambodia			WL,R	T (HYCOS)
34	033401	Chaktomuk	Bassac	Cambodia	11.563	104.935	WL,R	M,T (HYCOS)
35	019905	Kampong Ampil	Tonle Touch	Cambodia			WL,R	T (HYCOS)
36	020106	Kompong Luong	Tonle Sap	Cambodia	12.577	104.208	WL,R	M,T (HYCOS)
37	640102	Kompong Speu	Prek Thnot	Cambodia			WL,R	T (HYCOS)
38	610101	Kompong Thom	Stung San	Cambodia			WL,R	T (HYCOS)
39	014901	Kratie	Mekong	Cambodia	12.481	106.018	WL,R	M,T (HYCOS)
40	450101	Lumphat	Sre Pok	Cambodia	13.501	106.971	WL,R	M,T (HYCOS)
41	020102	Prek Kdam	Tonle Sap	Cambodia	11.811	104.807	WL,R	M,T (HYCOS)
42	430102	Siempang	Sekong	Cambodia			WL,R	T (HYCOS)
43	530101	Sisophon	Stung Mongkolborey	Cambodia			WL,R	T (HYCOS)
44	014501	Stung Treng	Mekong	Cambodia	13.533	105.950	WL,R	M,T (HYCOS)
45	440102	Voeun Sai	Sesan	Cambodia	13.969	106.885	WL,R	M,T (HYCOS)
46	451305	Ban Don	Se Re Pok	Viet Nam	12.898	107.783	WL,R	M,T (HYCOS)
47	039803	Can Tho	Bassac	Viet Nam	10.027	105.769	WL,R	M,T (HYCOS)
48	039801	Chau Doc	Bassac	Viet Nam	10.705	105.134	WL,R	M,T (HYCOS)
49	908001	Cho Lach	Ham Luong	Viet Nam			WL,R	T (HYCOS)
50	450701	Duc Xuyen	Krong Kno	Viet Nam	12.297	107.976	WL,R	M,T (HYCOS)
51	450502	Giang Son	Krong Ana	Viet Nam			WL,R	T (HYCOS)
52	440201	Kontum	Dak Bla	Viet Nam	14.347	108.034	WL,R	M,T (HYCOS)
53	901503	Long Dinh	Xang	Viet Nam			WL,R	T (HYCOS)
54	908002	My Hoa	Ham Luong	Viet Nam			WL,R	T (HYCOS)
55	019804	My Thuan	Mekong	Viet Nam	10.275	105.926	WL,R	M,T (HYCOS)
56	902601	Phung Hiep	Cai Con	Viet Nam			WL,R	T (HYCOS)
57	019803	Tan Chau	Mekong	Viet Nam	10.801	105.248	WL,R	M,T (HYCOS)
58	985203	Vam Kenh	Mekong	Viet Nam	10.274	106.737	WL,R	M,T (HYCOS)
59	980601	Vam Nao	Vam Nao	Viet Nam	10.579	105.363	WL,R	M,T (HYCOS)
60	902602	Vi Thanh	Xa No	Viet Nam			WL,R	T (HYCOS)

[23] WL = Water Level; R = Rainfall; T = Tide

[24] M = Manual; T = Telemetry

Table B2: Stations providing manual water level data to RFMMC

No	Station Code	Station Name	River/Basin	Country	Lat.	Long.	Para-meter	Type of Station
1	014501	Stung Treng	Mekong	Cambodia	13.533	105.950	WL	M,T (HYCOS)
2	014901	Kratie	Mekong	Cambodia	12.481	106.018	WL	M,T (HYCOS)
3	019802	Kompong Cham	Mekong	Cambodia	11.909	105.388	WL	M
4	033401	Chaktomuk	Bassac	Cambodia	11.563	104.935	WL	M,T (HYCOS)
5	020101	Phnom Penh Port	Tonle Sap	Cambodia	11.575	104.923	WL	M
6	019806	Neak Loung	Mekong	Cambodia	11.261	105.284	WL	M
7	033402	Koh Khel	Bassac	Cambodia	11.240	105.040	WL	M
8	020102	Prek Kdam	Tonle Sap	Cambodia	11.811	104.807	WL	M,T (HYCOS)
9	020106	Kompong Loung	Tonle Sap Lake	Cambodia	12.577	104.208	WL	M,T (HYCOS)
10	440102	Voeunsai	Sesan	Cambodia	13.969	106.885	WL	M,T (HYCOS)
11	600101	Kompong Chen	Stung Stong	Cambodia	12.937	104.583	WL	M
12	020103	Kompong Chhnang	Tonle Sap	Cambodia	12.251	105.686	WL	M
13	570101	Kompong Kdei	Stung Chikreng	Cambodia	13.127	104.339	WL	M
14	620101	Kompong Thmar	Stung Chinit	Cambodia	12.501	105.131	WL	M
15	450101	Lumphat	Srepork	Cambodia	13.501	106.971	WL	M,T (HYCOS)
16	010402	Xieng Kok	Mekong	Lao PDR			WL	M
17	010901	Pak Beng	Mekong	Lao PDR	19.858	101.115	WL	M
18	011201	Luang Prabang	Mekong	Lao PDR	19.893	102.134	WL	M,T (HYCOS)
19	011401	Paklay	Mekong	Lao PDR	18.208	101.413	WL	M
20	011901	Vientiane KM4	Mekong	Lao PDR	17.931	102.616	WL	M,T (HYCOS)
21	012703	Paksane	Mekong	Lao PDR	18.372	103.667	WL	M
22	013102	Thakhet	Mekong	Lao PDR	17.393	104.807	WL	M
23	013401	Sovannaket	Mekong	Lao PDR	16.562	104.747	WL	M
24	013901	Pakse	Mekong	Lao PDR	15.100	105.813	WL	M,T (HYCOS)
25	230101	Ban Pak Kanhoung	Nam Ngum	Lao PDR	18.418	102.550	WL	M
26	250101	Muong Mai	Nam Nhiep	Lao PDR	18.505	103.658	WL	M
27	270101	Ban Phone Si	Nam Cadin	Lao PDR	18.302	104.098	WL	M,T (HYCOS)
28	260101	Muong Kao	Nam Sane	Lao PDR	18.562	103.737	WL	M,T (HYCOS)
29	320107	Mahaxai	Se Bangfai	Lao PDR	17.418	105.198	WL	M,T (HYCOS)
30	390102	Khong Sedone	Se Done	Lao PDR	15.575	105.815	WL	M,T (HYCOS)
31	390103	Saravanne	Se Done	Lao PDR	15.710	106.450	WL	M
32	430106	Veun Khen	Se Kong	Lao PDR	14.819	106.806	WL	M,T (HYCOS)
33	430105	M.May (Attopeu)	Se Kong	Lao PDR	14.807	106.843	WL	M
34	100102	Muong Ngoy	Nam Ou	Lao PDR	20.572	102.617	WL	M,T (HYCOS)
35	120101	Ban Mixay	Nam Khan	Lao PDR	19.786	102.183	WL	M,T (HYCOS)
36	180207	Vang Vieng	Nam Ngum	Lao PDR	18.923	102.450	WL	M
37	230113	Phiengluang	Nam Ngum	Lao PDR	19.568	103.071	WL	M,T (HYCOS)
38	350101	Ban Keng Done	Se Banhieng	Lao PDR	16.187	105.313	WL	M,T (HYCOS)
39	350106	Highway Bridge/Senuane	Sebangnuane	Lao PDR	16.697	106.220	WL	M,T (HYCOS)
40	390104	Souvanna Khill	Se Done	Lao PDR	15.397	105.825	WL	M
41	150609	Sekong	Se Kong	Lao PDR	15.083	106.850	WL	M
42	010501	Chiang Saen	Mekong	Thailand	20.274	100.089	WL	M,T (HYCOS)
43	010801	Chiang Khong	Mekong	Thailand			WL	M
44	011903	Chiang Khan	Mekong	Thailand	17.900	101.670	WL	M,T (HYCOS)
45	012001	Nong Khai	Mekong	Thailand	17.881	102.732	WL	M,T (HYCOS)
46	013101	Nakhon Phanom	Mekong	Thailand	17.425	104.774	WL	M,T (HYCOS)
47	013402	Mukdahan	Mekong	Thailand	16.583	104.733	WL	M,T (HYCOS)
48	013801	Khong Chiam	Mekong	Thailand	15.322	105.493	WL	M,T (HYCOS)
49	050115	Ban Mai Bua Daeng	Nam Kok	Thailand	20.023	99.959	WL	M
50	070103	Thoeng	Nam Mae Ing	Thailand	19.688	100.187	WL	M,T (HYCOS)
51	150101	Wang Saphung	Nam Loei	Thailand	17.300	101.776	WL	M,T (HYCOS)
52	290102	Ban Tha Kok Doeng	Nam Sonkhran	Thailand	17.866	103.774	WL	M,T (HYCOS)
53	290113	Ban Had Paeng	Nam Sonkhran	Thailand	17.675	104.286	WL	M,T (HYCOS)
54	050104	Chiang Rai	Nam Mae Kok	Thailand	19.918	99.850	WL	M
55	019803	Tan Chau	Mekong	Viet Nam	10.801	105.248	WL	M,T (HYCOS)
56	039801	Chau Doc	Bassac	Viet Nam	10.705	105.134	WL	M,T (HYCOS)
57	980601	Vam Nao	Van Nao	Viet Nam	10.579	105.363	WL	M,T (HYCOS)
58	019804	My Thuan	Mekong	Viet Nam	10.275	105.926	WL	M,T (HYCOS)
59	039803	Can Tho	Bassac	Viet Nam	10.027	105.769	WL	M,T (HYCOS)
60	985203	Vam Kenh	Vinh Te	Viet Nam	10.274	106.737	WL	M,T (HYCOS)
61	451305	Ban Don	Srepok	Viet Nam	12.898	107.783	WL	M,T (HYCOS)
62	440201	Kon Tum	Sesan	Viet Nam	14.347	108.034	WL	M,T (HYCOS)
63	450701	Duc Xuyen	Krong Kno	Viet Nam	12.297	107.976	WL	M,T (HYCOS)

Table B3: Stations providing manual rainfall data to RFMMC

No	Station Code	Station Name	River/Basin	Country	Lat.	Long.	Para-meter	Type of Station
1	130501	Stung Treng	Mekong	Cambodia	13.533	105.950	R	M,T (HYCOS)
2	120603	Kratie	Mekong	Cambodia	12.481	106.018	R	M,T (HYCOS)
3	120504	Kompong Cham	Mekong	Cambodia	11.909	105.388	R	M
4	033401	Chaktomuk	Bassac	Cambodia	11.563	104.935	R	M,T (HYCOS)
5	019806	Neak Loung	Mekong	Cambodia	11.261	105.284	R	M
6	033402	Koh Khel	Bassac	Cambodia	11.240	105.040	R	M
7	020102	Prek Kdam	Tonle Sap	Cambodia	11.811	104.807	R	M,T (HYCOS)
8	450101	Lumphat	Srepork	Cambodia	13.501	106.971	R	M,T (HYCOS)
9	130322	Banteay Srey	Stung Siem Reap	Cambodia	13.598	103.965	R	M
10	130505	Sadan	Stung Sen	Cambodia	13.100	105.250	R	M
11	120505	Sambor	Mekong	Cambodia	12.780	105.977	R	M
12	120606	Snoul	Prek Chhlong	Cambodia	12.075	106.426	R	M
13	130326	Srey Snam	Stung Sreng	Cambodia	13.843	103.523	R	M
14	120309	Talo	Stung Pursat	Cambodia	12.519	103.659	R	M
15	130309	Sre Noy	Stung Siem Reap	Cambodia	13.950	103.583	R	M
16	130202	Sisophon	St.Mongkul Borey	Cambodia	13.609	102.971	R	M,T (HYCOS)
17	130200	Okrieng	Prek Krieng	Cambodia	13.133	106.183	R	M
18	134010	O Yadav	Se San	Cambodia			R	M
19	130220	Koh Gneak	Sre Pok	Cambodia			R	M
20	134910	Koulen	Stung Sen	Cambodia			R	M
21	134813	Tbeng Meanchey	Stung Sen	Cambodia			R	M
22	141112	Oudor Meanchey	Stung Sreng	Cambodia			R	M
23	110404/ 640102	Kompong Speu	St.Prek Thnot	Cambodia	11.344	104.056	R	M,T (HYCOS)
24	110433	Oral	St.Prek Thnot	Cambodia	11.688	104.138	R	M
25	110434	O Taroat	St.Prek Thnot	Cambodia	11.537	104.424	R	M
26	110445	Trapeang	St.Prek Thnot	Cambodia	11.817	104.137	R	M
27	120202	Pailin	Stung Sangker	Cambodia	12.859	102.618	R	M
28	120302	Pursat	Stung Pursat	Cambodia	12.550	103.900	R	M
29	120303	Mung Russey	Stung Dauntry	Cambodia	12.771	103.450	R	M
30	120304	Dap Bat	Stung Pursat	Cambodia	12.343	103.787	R	M
31	120312	Kravanh	Stung Pursat	Cambodia	12.675	103.648	R	M
32	120420	Tuk Phos	Stung Boribo	Cambodia	12.055	104.528	R	M
33	120423	Stung Chinit	Stung Chinit	Cambodia	12.510	105.147	R	M
34	120520	Cham Bac	Mekong	Cambodia	12.281	105.827	R	M
35	120602	Peam Te	Prek Te	Cambodia	12.453	106.038	R	M
36	120607	Svay Chreas	Prek Chhlong	Cambodia	12.283	106.283	R	M
37	120611	Kantout	Prek Te	Cambodia	12.467	106.176	R	M
38	130506	Seam Bork	Mekong	Cambodia	13.390	105.939	R	M
39	130507	Tala Boriwat	Mekong	Cambodia	13.546	105.955	R	M
40	130605	Sesan	Se San	Cambodia	13.552	106.096	R	M
41	140603	Seam Pang	Sekong	Cambodia	14.133	106.367	R	M
42	130208	Bovel	St.Mongkul Borey	Cambodia	13.253	102.877	R	M
43	010901	Pak Beng	Mekong	Lao PDR	19.858	101.115	R	M
44	190202	Luang Prabang	Mekong	Lao PDR	19.893	102.134	R	M,T (HYCOS)
45	180101	Paklay	Mekong	Lao PDR	18.208	101.413	R	M
46	170203	Vientiane	Mekong	Lao PDR	17.931	102.616	R	M
47	180303	Paksane	Mekong	Lao PDR	18.372	103.667	R	M
48	170404	Thakhet	Mekong	Lao PDR	17.393	104.807	R	M
49	160405	Sovannaket	Mekong	Lao PDR	16.562	104.747	R	M
50	150504	Pakse	Mekong	Lao PDR	15.100	105.813	R	M,T (HYCOS)
51	190203	Ban Pak Kanhoung	Nam Ngum	Lao PDR	18.418	102.550	R	M
52	180308	Muong Mai	Nam Nhiep	Lao PDR	18.505	103.658	R	M
53	270101	Ban Phone Si	Nam Cadin	Lao PDR	18.302	104.098	R	M,T (HYCOS)
54	180307/ 260101	Muong Kao (Borikhane)	Nam Sane	Lao PDR	18.562	103.737	R	M,T (HYCOS)
55	170502	Mahaxai	Se Bangfai	Lao PDR	17.418	105.198	R	M,T (HYCOS)
56	150506	Khong Sedone	Se Done	Lao PDR	15.575	105.815	R	M
57	150602	Saravanne	Se Done	Lao PDR	15.710	106.450	R	M
58	430106	Veun Khen	Se Kong	Lao PDR	14.819	106.806	R	M,T (HYCOS)
59	140705	M.May (Attopeu)	Se Kong	Lao PDR	14.807	106.843	R	M
60	200201	Muong Ngoy	Nam Ou	Lao PDR	20.572	102.617	R	M,T
61	190103	Sayaboury	Nam Houng	Lao PDR	19.233	101.367	R	M
62	180207	Vang Vieng	Nam Ngum	Lao PDR	18.923	102.450	R	M
63	190303	Phiengluang	Nam Ngum	Lao PDR	19.568	103.071	R	M,T
64	200204	Oudomxay	Nam Ou	Lao PDR	20.680	102.000	R	M
65	210201	Moung Namtha	Nam Tha	Lao PDR	20.930	101.400	R	M
66	190302	Xiengkhouang	Nam Nhiep	Lao PDR	19.333	103.367	R	M
67	350106	Highway Bridge	Se Banhieng	Lao PDR	16.697	106.220	R	M

68	160505	Ban Kengkok	Se Banhieng	Lao PDR	16.433	105.200	R	M,T
69	160601	Muong Techpon	Se Done	Lao PDR	16.033	106.233	R	M
70	150609	Sekong	Se Kong	Lao PDR	15.083	106.850	R	M
71	200002	Chiang Saen	Mekong	Thailand	20.274	100.089	R	M,T (HYCOS)
72	200001	Chiang Khong	Mekong	Thailand			R	M
73	170105	Chiang Khan	Mekong	Thailand	17.900	101.670	R	M,T (HYCOS)
74	170206	Nong Khai	Mekong	Thailand	17.881	102.732	R	M,T (HYCOS)
75	170403	Nakhon Phanom	Mekong	Thailand	17.425	104.774	R	M,T (HYCOS)
76	160401	Mukdahan	Mekong	Thailand	16.583	104.733	R	M,T (HYCOS)
77	150503	Khong Chiam	Mekong	Thailand	15.322	105.493	R	M,T (HYCOS)
78	050115	Ban Mai Bua Daeng	Nam Kok	Thailand	20.023	99.959	WL	M
79	070103	Thoeng	Nam Mae Ing	Thailand	19.688	100.187	R	M,T (HYCOS)
80	170102	Wang Saphung	Nam Loei	Thailand	17.300	101.776	R	M,T (HYCOS)
81	290102	Ban Tha Kok Doeng	Nam Songkhram	Thailand	17.866	103.774	R	M,T (HYCOS)
82	290113	Ban Had Paeng	Nam Sonkhran	Thailand	17.675	104.286	R	M,T (HYCOS)
83	199907	Chiang Rai	Nam Mae Kok	Thailand	19.918	99.850	R	M
84	100513	Tan Chau	Mekong	Viet Nam	10.801	105.248	R	M,T (HYCOS)
85	100505	Chau Doc	Bassac	Viet Nam	10.705	105.134	R	M,T (HYCOS)
86	980601	Vam Nao	Van Nao	Viet Nam	10.579	105.363	R	M,T (HYCOS)
87	985203	Vam Kenh	Vinh Te	Viet Nam	10.274	106.737	R	M,T (HYCOS)
88	170601	Ban Don	Srepok	Viet Nam	12.898	107.783	R	M,T (HYCOS)
89	140704	Kon Tum	Sesan	Viet Nam	14.347	108.034	R	M,T (HYCOS)
90	450701	Duc Xuyen	Krong Kno	Viet Nam	12.297	107.976	R	M,T (HYCOS)
91	220201	Muong Te		Viet Nam	22.370	102.830	R	M
92	220303	Tam Duong		Viet Nam	22.420	103.480	R	M
93	220302	Sin Ho		Viet Nam	22.370	103.230	R	M
94	220301	Lai Chau		Viet Nam	22.070	103.150	R	M
95	210305	Tuan Giao		Viet Nam	21.580	103.420	R	M
96	210301	Dien Bien		Viet Nam	21.370	103.000	R	M
97	210303	Quynh Nhai		Viet Nam	21.850	103.570	R	M
98	160611	Khe Sanh		Viet Nam	16.630	106.730	R	M
99	210304	Son La		Viet Nam	21.330	103.900	R	M
100	180505	Huong Khe		Viet Nam	18.180	105.700	R	M
101	180504	Ha Tinh		Viet Nam	18.350	105.900	R	M
102	180601	Ky Anh		Viet Nam	18.100	106.270	R	M
103	170603	Tuyen Hoa		Viet Nam	17.880	106.020	R	M
104	170602	Dong Hoi		Viet Nam	17.480	106.600	R	M
105	160607	Dong Ha		Viet Nam	16.850	107.080	R	M
106	160705	A Luoi	Sekong	Viet Nam	16.220	107.280	R	M
107	160704	Hue		Viet Nam	16.430	107.580	R	M
108	140715	Dak To	Sesan	Viet Nam	14.650	107.830	R	M
109	140703	Pleiku	Sesan	Viet Nam	14.017	107.900	R	M
110	130803	An Khe	Sesan	Viet Nam	13.950	108.650	R	M
111	130804	Ayunpa	Srepok	Viet Nam	13.380	108.450	R	M
112	120801	Buon Me Thuoc	Srepok	Viet Nam	12.600	108.083	R	M
113	120806	Mdrak	Srepok	Viet Nam	12.730	108.750	R	M
114	120712	Dak Nong	Srepok	Viet Nam	12.000	107.680	R	M
115	120805	Buon Ho	Srepok	Viet Nam	12.920	108.270	R	M
116	180506	Huong Son		Viet Nam			R	M
117	220401	Pha Din		Viet Nam			R	M
118	220402	Yen Chau		Viet Nam			R	M
119	220403	Mai Chau		Viet Nam			R	M
120	220404	Tuong Duong		Viet Nam			R	M
121	220405	Con Cuong		Viet Nam			R	M
122	220406	Tay Ninh		Viet Nam			R	M
123	220407	Phuoc Long		Viet Nam			R	M
124	220408	Dong Xoai		Viet Nam			R	M
125	220409	Ialy		Viet Nam			R	M

Red = Telemetry station, but not part of MRC-HYCOS network

Blue = Station with multiple identification codes

Table B4: List of additional stations identified by RFMMC as necessary for improved flood forecasting

B4.1 List of stations from Lao PDR

N^0	Station ID	Station_Name	Lat	Long	Elevation	Country	RegionDescrptn
1	48921	Phongsali	21.68	102.10	1350.00	Lao PDR	Northern Highland
2	48924	Louangnamtha	20.95	101.40	550.00	Lao PDR	Northern Highland
3	48925	Oudomxai	20.70	101.99	635.00	Lao PDR	Northern Highland
4	48926	Houeixai	20.26	100.44	401.00	Lao PDR	Northern Highland
5	48928	XamNeua	20.42	104.23	1000.00	Lao PDR	High Elev
6	48935	Xiengkhuang	19.44	103.17	1094.00	Lao PDR	High Elev
7	48938	Sayabouly	19.24	101.71	292.00	Lao PDR	High Elev
8	48947	Savanakhet	16.55	104.75	144.00	Lao PDR	Central Plateau
9	48952	Salavan	15.71	106.41	168.00	Lao PDR	Southern inland
10	48957	Attopeu	14.69	106.84	103.00	Lao PDR	Southern inland

B4.2 List of stations from Thailand

N^0	Station ID	Station_Name	Lat	Long	Elevation	Country	RegionDescrptn
1	48372	SUKHOTHAI	17.11	99.80	48.29	Thailand	Thailand Central
2	48373	SI SAMRONG AGROMET	17.16	99.86	53.00	Thailand	Thailand Central
3	48378	PHITSANULOK	16.79	100.28	44.02	Thailand	Thailand Central
4	48380	KAM PHAENG PHET	16.49	99.53	80.00	Thailand	Thailand Central
5	48386	PICHIT AGROMET	16.44	100.29	35.95	Thailand	Thailand Central
6	48400	NAKHON SAWAN	15.67	100.13	34.01	Thailand	Thailand Central
7	48401	TAKFA AGROMET	15.35	100.53	91.47	Thailand	Thailand Central
8	48402	CHAI NAT AGROMET	15.15	100.18	15.00	Thailand	Thailand Central
9	48410	UTHAI THANI	15.37	100.04	-999.00	Thailand	Thailand Central
10	48413	WICHIAN BURI	15.66	101.11	68.00	Thailand	Thailand Central
11	48415	AYUTTHAYA AGROMET	14.53	100.73	7.70	Thailand	Thailand Central
12	48418	BUA CHUM	15.27	101.19	49.28	Thailand	Thailand Central
13	48419	PATHUMTHANI AGROMET	14.10	100.62	6.00	Thailand	Thailand Central
14	48420	SAMUTPRAKAN AGROMET	13.52	100.76	1.44	Thailand	Thailand Central
15	48425	SUPHAN BURI	14.47	100.14	7.23	Thailand	Thailand Central
16	48426	LOP BURI	14.80	100.65	10.00	Thailand	Thailand Central
17	48427	U THONG AGROMET	14.30	99.86	6.00	Thailand	Thailand Central
18	48429	SUVARNABHUMI INTERNATIONAL AIRPORT	13.69	100.77	0.96	Thailand	Thailand Central
19	48438	SAMUT SONGKRAM	13.41	100.03	6.00	Thailand	Thailand Central
20	48450	KANCHANA BURI	14.02	99.54	27.53	Thailand	Thailand Central
21	48451	NAKHONPATHOM AGROMET	14.01	99.97	7.46	Thailand	Thailand Central
22	48453	BANGNA AGROMET	13.67	100.61	0.80	Thailand	Thailand Central
23	48454	BANGKOK PORT	13.71	100.57	2.80	Thailand	Thailand Central
24	48455	BANGKOK METROPOLIS	13.73	100.56	3.01	Thailand	Thailand Central
25	48456	DON MUANG / BANGKOK INTL	13.92	100.61	12.00	Thailand	Thailand Central
26	48457	BANGKOK PILOT	13.39	100.60	14.00	Thailand	Thailand Central
27	48464	RATCHA BURI	13.49	99.79	9.01	Thailand	Thailand Central
28	48465	PHETCHABURI	13.00	100.06	1.40	Thailand	Thailand Central
29	48474	NONG PHLUB AGROMET	12.58	99.73	106.00	Thailand	Thailand Central
30	48475	HUA HIN	12.59	99.96	4.73	Thailand	Thailand Central
31	48500	PRACHUAP KHIRIKHAN	11.83	99.83	4.00	Thailand	Thailand Central
32	48300	MAE HONG SON	19.30	97.98	265.41	Thailand	Northern Highland
33	48302	DOI ANG KHANG	19.93	99.05	1529.00	Thailand	Northern Highland
34	48304	CHAING RAI AGROMET	19.87	99.78	402.72	Thailand	Northern Highland
35	48310	PHAYAO	19.13	99.90	401.05	Thailand	Northern Highland
36	48324	THOEN	17.64	99.24	190.89	Thailand	Northern Highland
37	48325	MAE SARIANG	18.17	97.93	211.00	Thailand	Northern Highland
38	48327	CHIANG MAI	18.79	98.98	304.59	Thailand	Northern Highland
39	48328	LAMPANG	18.28	99.52	242.00	Thailand	Northern Highland
40	48329	LAMPHUN	18.57	99.03	296.42	Thailand	Northern Highland
41	48330	PHRAE	18.17	100.17	161.79	Thailand	Northern Highland
42	48334	LAMPANG AGROMET	18.32	99.28	315.00	Thailand	Northern Highland
43	48351	UTTARADIT	17.62	100.10	63.00	Thailand	Northern Highland
44	48374	LOM SAK	16.77	101.25	142.81	Thailand	Northern Highland
45	48375	MAE SOT	16.66	98.55	196.00	Thailand	Northern Highland

Continue B4.2

N^0	Station ID	Station_Name	Lat	Long	Elevation	Country	RegionDescrptn
46	48376	TAK	16.88	99.14	124.12	Thailand	Northern Highland
47	48377	BHUMIBOL DAM	17.24	99.00	143.73	Thailand	Northern Highland
48	48379	PHETCHABUN	16.43	101.15	114.00	Thailand	Northern Highland
49	48385	UMPHANG	16.02	98.86	454.00	Thailand	Northern Highland
50	48387	DOI MU SOE AGROMET	16.75	98.93	863.00	Thailand	Northern Highland
51	48421	THONG PHA PHUM	14.74	98.64	97.36	Thailand	Northern Highland
52	48307	TUNG CHANG	19.41	100.88	333.39	Thailand	High Elev
53	48315	THA WANG PHA	19.11	100.80	234.70	Thailand	High Elev
54	48331	NAN	18.78	100.78	200.00	Thailand	High Elev
55	48333	NAN AGROMET	18.87	100.75	264.03	Thailand	High Elev
56	48350	LOEI AGROMET	17.40	101.73	260.30	Thailand	Central Plateau
57	48353	LOEI	17.45	101.73	252.51	Thailand	Central Plateau
58	48354	UDON THANI	17.38	102.80	315.00	Thailand	Central Plateau
59	48355	SAKON NAKHON AGROMET	17.13	104.06	191.03	Thailand	Central Plateau
60	48356	SAKON NAKHON	17.15	104.13	171.00	Thailand	Central Plateau
61	48358	NAKHON PHANOM AGROMET	17.44	104.77	153.13	Thailand	Central Plateau
62	48360	NONGBUALAMPHU	17.23	102.43	226.81	Thailand	Central Plateau
63	48381	KHON KAEN	16.46	102.79	186.97	Thailand	Central Plateau
64	48382	KOSUM PHISAI	16.25	103.07	152.95	Thailand	Central Plateau
65	48384	THA PHRA AGROMET	16.33	102.82	166.00	Thailand	Central Plateau
66	48390	KAMALASAI	16.33	103.59	138.75	Thailand	Central Plateau
67	48403	CHAIYAPHUM	15.80	102.03	182.15	Thailand	Central Plateau
68	48404	ROI ET AGROMET	16.07	103.61	153.00	Thailand	Central Plateau
69	48405	ROB MUANG	16.02	103.74	140.00	Thailand	Central Plateau
70	48407	UBON RATCHATHANI	15.25	104.87	122.00	Thailand	Central Plateau
71	48408	UBON RATCHATHANI AGROMET	15.24	105.02	129.91	Thailand	Central Plateau
72	48409	SISAKET AGROMET	15.00	104.05	122.87	Thailand	Central Plateau
73	48416	THA TUM	15.32	103.68	127.62	Thailand	Central Plateau
74	48431	NAKHON RATCHASIMA / KHORAT	14.97	102.09	186.60	Thailand	Central Plateau
75	48432	SURIN	14.88	103.50	145.81	Thailand	Central Plateau
76	48433	SURIN AGROMET	14.88	103.45	142.56	Thailand	Central Plateau
77	48434	CHOK CHAI	14.72	102.17	190.34	Thailand	Central Plateau
78	48435	PAKCHONG AGROMET	14.64	101.33	386.12	Thailand	Central Plateau
79	48436	NANG RONG	14.58	102.80	179.00	Thailand	Central Plateau
80	48437	BURERAM	15.23	103.25	182.00	Thailand	Central Plateau
81	48417	NAKHON NAYOK	14.22	101.38	1267.00	Thailand	Southern
82	48430	PRACHIN BURI / KHAO E TO	14.06	101.37	4.15	Thailand	Southern
83	48439	KABIN BURI	13.98	101.71	10.56	Thailand	Southern
84	48440	SRAKAEW	13.79	102.03	40.83	Thailand	Southern
85	48458	CHACHOENGSAO AGROMET	13.52	101.46	69.42	Thailand	Southern
86	48459	CHON BURI	13.37	100.98	0.86	Thailand	Southern
87	48460	KO SICHANG	13.16	100.80	24.85	Thailand	Southern
88	48461	PHATTHAYA	12.92	100.87	58.93	Thailand	Southern
89	48462	ARANYAPRATHET	13.70	102.58	47.00	Thailand	Southern
90	48463	LAEM CHABANG	13.08	100.88	1.20	Thailand	Southern
91	48477	SATTAHIP	12.68	100.98	16.00	Thailand	Southern
92	48478	RAYONG	12.63	101.34	2.60	Thailand	Southern
93	48479	HUAI PONG AGROMET	12.73	101.13	43.00	Thailand	Southern
94	48480	CHANTHA BURI	12.62	102.11	2.86	Thailand	Southern
95	48481	PHLIU AGROMET	12.51	102.17	22.00	Thailand	Southern
96	48501	KHLONG YAI	11.77	102.88	2.00	Thailand	Southern
97	48517	CHUMPHON	10.50	99.19	4.40	Thailand	Southern Peninsula
98	48520	SAWI AGROMET	10.33	99.10	13.00	Thailand	Southern Peninsula
99	48532	RANONG	9.98	98.62	7.00	Thailand	Southern Peninsula
100	48550	KO SAMUI	9.47	100.05	4.00	Thailand	Southern Peninsula
101	48551	SURAT THANI	9.14	99.15	5.00	Thailand	Southern Peninsula
102	48552	NAKHONSI THAMMARAT / CHA IAN	8.54	99.96	4.14	Thailand	Southern Peninsula
103	48554	NAKHONSI THAMMARAT AGROMET	8.36	100.00	1.81	Thailand	Southern Peninsula
104	48555	SURAT THANI AGROMET	9.10	99.63	34.80	Thailand	Southern Peninsula
105	48556	PHRASANG	8.57	99.26	12.08	Thailand	Southern Peninsula

Continue B4.2

N^0	Station ID	Station_Name	Lat	Long	Elevation	Country	RegionDescrptn
106	48557	CHAWANG	8.43	99.51	28.12	Thailand	Southern Peninsula
107	48560	PHATTHALUNG AGROMET	7.58	100.17	2.00	Thailand	Southern Peninsula
108	48561	TAKUA PA	8.68	98.25	5.93	Thailand	Southern Peninsula
109	48563	KRABI	8.10	98.98	29.35	Thailand	Southern Peninsula
110	48564	PHUKET	7.88	98.40	1.83	Thailand	Southern Peninsula
111	48565	PHUKET AIRPORT	8.15	98.31	5.86	Thailand	Southern Peninsula
112	48566	KO LANTA	7.53	99.05	2.00	Thailand	Southern Peninsula
113	48567	TRANG	7.52	99.62	13.97	Thailand	Southern Peninsula
114	48568	SONGKHLA	7.18	100.61	4.57	Thailand	Southern Peninsula
115	48569	HAT YAI AIRPORT	6.92	100.43	27.40	Thailand	Southern Peninsula
116	48570	SATUN	6.65	100.08	4.06	Thailand	Southern Peninsula
117	48571	KHO HONG AGROMET	7.00	100.50	6.96	Thailand	Southern Peninsula
118	48574	SADAO	6.80	100.39	24.70	Thailand	Southern Peninsula
119	48580	PATTANI	6.78	101.15	4.05	Thailand	Southern Peninsula
120	48581	YALA AGROMET	6.52	101.28	30.00	Thailand	Southern Peninsula
121	48583	NARATHIWAT	6.42	101.82	3.57	Thailand	Southern Peninsula

B4.3 List of stations from Cambodia

N^0	Station ID	Station_Name	Lat	Long	Elevation	Country	RegionDescrptn
1	120202	Pailin	12.859	102.618	-999	CAMBODIA	Southern
2	120302	Pursat	12.550	103.900	-999	CAMBODIA	Southern
3	120303	Mung Russey	12.771	103.450	-999	CAMBODIA	Southern
4	120304	Dap Bat	12.343	103.787	-999	CAMBODIA	Southern
5	120309	Talo	12.519	103.659	-999	CAMBODIA	Southern
6	120312	Kravanh	12.675	103.648	-999	CAMBODIA	Southern
7	130202	Sisophon	13.614	102.970	-999	CAMBODIA	Southern
8	130208	Bovel	13.252	102.877	-999	CAMBODIA	Southern
9	130322	Banteay Srey	13.598	103.965	-999	CAMBODIA	Southern
10	130326	Srey Snam	13.843	103.523	-999	CAMBODIA	Southern
11	134813	Tbeng Meanchey	12.877	103.104	-999	CAMBODIA	Southern
12	134910	Koulen	13.580	104.117	-999	CAMBODIA	Southern
13	140603	Seam Pang	14.133	106.367	-999	CAMBODIA	Southern inland
14	14501	Stung Treng	13.519	105.971	-999	CAMBODIA	NorthEast Cambodia
15	14901	Kratie	12.487	106.024	-999	CAMBODIA	NorthEast Cambodia
16	120423	Stung Chinit	12.510	105.146	-999	CAMBODIA	NorthEast Cambodia
17	120505	Sambor	12.779	105.967	-999	CAMBODIA	NorthEast Cambodia
18	120602	Peam Te	12.453	106.038	-999	CAMBODIA	NorthEast Cambodia
19	120606	Snoul	12.075	106.426	-999	CAMBODIA	NorthEast Cambodia
20	120607	Svay Chrea	12.283	106.283	-999	CAMBODIA	NorthEast Cambodia
21	120611	Kantout	12.467	106.176	-999	CAMBODIA	NorthEast Cambodia
22	130200	Okrieng	13.133	106.183	-999	CAMBODIA	NorthEast Cambodia
23	130505	Sadan	13.100	105.250	-999	CAMBODIA	NorthEast Cambodia
24	130506	Seam Bork	13.403	105.940	-999	CAMBODIA	NorthEast Cambodia
25	130507	Tala Boriwat	13.546	105.955	-999	CAMBODIA	NorthEast Cambodia
26	130605	Sesan	13.552	106.096	-999	CAMBODIA	NorthEast Cambodia
27	19802	Kompong Cham	12.002	105.450	-999	CAMBODIA	South Mekong
28	19806	Neak Luong	11.261	105.284	-999	CAMBODIA	South Mekong
29	20102	Prek Kdam	11.811	104.807	-999	CAMBODIA	South Mekong
30	33401	Bassac Chaktomuk	11.563	104.935	-999	CAMBODIA	South Mekong
31	33402	Koh Khel	11.239	105.040	-999	CAMBODIA	South Mekong
32	110404	Kompong Speu	11.344	104.056	-999	CAMBODIA	South Mekong
33	110433	Oral	11.688	104.138	-999	CAMBODIA	South Mekong
34	110434	O Taroat	11.536	104.424	-999	CAMBODIA	South Mekong
35	110445	Trapeang	11.817	104.137	-999	CAMBODIA	South Mekong
36	120420	Tuk Phos	12.055	104.645	-999	CAMBODIA	South Mekong
37	120520	Cham Bac	11.342	104.883	-999	CAMBODIA	South Mekong

B4.4 List of stations from Viet Nam

N^0	Station ID	Station_Na	Lat	Long	Elevation	Country	RegionDescrptn
1	48803	Lao Cai	22.50	103.97	-999.00	Vietnam	NorthWestern Highland
2	48815	Yen Bai	21.70	104.87	-999.00	Vietnam	NorthWestern Highland
3	73016	Tan Lac	20.58	105.28	-999.00	Vietnam	NorthWestern Highland
4	74002	Ta Tong	22.38	102.67	-999.00	Vietnam	NorthWestern Highland
5	74004	Pa Tan	22.45	103.18	-999.00	Vietnam	NorthWestern Highland
6	74006	Muong Mo	22.20	102.92	-999.00	Vietnam	NorthWestern Highland
7	74022	Bat Xat	22.52	103.90	-999.00	Vietnam	NorthWestern Highland
8	74023	Pho Lu	22.30	104.18	-999.00	Vietnam	NorthWestern Highland
9	74102	Nam Giang	22.25	103.25	-999.00	Vietnam	NorthWestern Highland
10	74105	Nam Muc	21.87	103.28	-999.00	Vietnam	NorthWestern Highland
11	74122	Ngoi Nhu	22.13	104.27	-999.00	Vietnam	NorthWestern Highland
12	74127	Ngoi Hut	21.92	104.50	-999.00	Vietnam	NorthWestern Highland
13	74128	Ngoi Thia	21.83	104.65	-999.00	Vietnam	NorthWestern Highland
14	220401	Pha Din	21.57	103.52	-999.00	Vietnam	NorthWestern Highland
15	220402	Yen Chau	21.05	104.30	-999.00	Vietnam	NorthWestern Highland
16	220403	Mai Chau	20.65	105.05	-999.00	Vietnam	NorthWestern Highland
17	48/06	Than Uyen	21.95	103.88	-999.00	Vietnam	NorthWestern Highland
18	48/08	Mu Cang Cl	21.87	104.05	-999.00	Vietnam	NorthWestern Highland
19	48/29	Pho Rang	22.23	104.47	-999.00	Vietnam	NorthWestern Highland
20	48/30	Bac Ha	22.53	104.28	-999.00	Vietnam	NorthWestern Highland
21	48/64	Lac Son	20.45	105.45	-999.00	Vietnam	NorthWestern Highland
22	74/21	Ba Khe	21.26	104.38	-999.00	Vietnam	NorthWestern Highland
23	74/29	Muong Khu	22.80	104.14	-999.00	Vietnam	NorthWestern Highland
24	74/74	Khau Pha	21.75	104.20	-999.00	Vietnam	NorthWestern Highland
25	74/88	Tram Tau	21.45	104.37	-999.00	Vietnam	NorthWestern Highland
26	160705	A Luoi	16.22	107.28	-999.00	Vietnam	NorthWestern Highland
27	170601	Ba Don	17.75	106.42	-999.00	Vietnam	NorthWestern Highland
28	180506	Huong Son	18.52	105.43	-999.00	Vietnam	NorthWestern Highland
29	220404	Tuong Duor	19.28	104.43	-999.00	Vietnam	NorthWestern Highland
30	220405	Con Cuong	19.07	104.85	-999.00	Vietnam	NorthWestern Highland
31	451305	Ban Don	17.75	106.42	-999.00	Vietnam	NorthWestern Highland
32	220409	Ialy	14.70	107.75	-999.00	Vietnam	NorthWestern Highland
33	440201	Kon Tum	14.33	108.00	-999.00	Vietnam	NorthWestern Highland
34	450701	Duc Xuyen	12.28	107.98	-999.00	Vietnam	Central VietNam
35	220406	Tay Ninh	11.33	106.12	-999.00	Vietnam	Central VietNam
36	220407	Phuoc Long	11.83	106.98	-999.00	Vietnam	Central VietNam

Table B5: Additional national hydro-meteorological stations in Viet Nam

No	Station Code	Station Name	River/Basin	Province	Lat.	Long.	Para-meter	Type of Station
1	70601	Go dau ha	Vam Co Tay	Tay Ninh			WL,R	M
2	70600	Can Dang	Ben Da	Tay Ninh			WL,R	M
3	71587	Dau Tieng	Sai Gon	Binh Duong			WL,R	M
4	71586	Thu Dau Mot	Sai Gon	Binh Duong			WL,R	M
5	71591	Ta Lai	Dong Nai	Dong Nai			WL,R	M
6	71594	Bien Hoa	Dong Nai	Dong Nai			WL,R	M
7	71585	Phuoc Hoa	Be	Dong Nai			WL,R	M
8	71595	Phu Hiep	La Nga	Dong Nai			WL,R	M
9	71592	Tri An	Tri An res.	Dong Nai			WL,R	M
10	69731	My Tho	Tien	Tien Giang			T,R	M
11	69732	Hoa Binh	Cua Tieu	Tien Giang			T,R	M
12	69733	Vam Kenh	Cua Tieu	Tien Giang			T,R	M
13	69734	Long Dinh	Kenh Xang	Tien Giang			T,R	M
14	69735	Cai Lay	Ba rai	Tien Giang			T,R	M
15	69759	Tan Chau	Tien	An Giang			T,R	M
16	69760	Chau Doc	Hau	An Giang			T,R	M
17	69762	Long Xuyen	Hau	An Giang			T,R	M
18	66765	Xuan To	Vinh Te	An Giang			WL,R	M
19	66764	Tri Ton	Tri Ton canal	An Giang			WL,R	M
20	66763	Vam Nao	Vam Nao	An Giang			T,R	M
21	66761	Cho Moi	O creak	An Giang			T,R	M
22	71850	Vung Tau	Sea	Ba Ria-Vung Tau			T,R	M
23	70606	Moc Hoa	Vam Co Tay	Long An			T,R	M
24	70607	Tan An	Vam Co Tay	Long An			T,R	M
25	70610	Tuyen Nhon	Vam Co Tay	Long An			T,R	M
26	70608	Ben Luc	Vam Co Dong	Long An			T,R	M
27	70608	Ben Luc	Vam Co Dong	Long An			T,R	M
28	70609	Kien Binh	Vam Co Tay	Long An			T,R	M
29	68738	Cho Lach	Ham Luong	Ben Tre			T,R	M
30	68740	An Thuan	Ham Luong	Ben Tre			T,R	M
31	69741	Binh Dai	Cua Dai	Ben Tre			T,R	M
32	68739	My Hoa	Cua Dai	Ben Tre			T,R	M
33	68742	Ben Trai	Co Chien	Ben Tre			T,R	M
34	69727	Cao Lanh	Tien	Dong Thap			T,R	M
35	69726	Truong Xuan	Kenh	Dong Thap			WL,R	M
36	66768	Can Tho	Hau	Can Tho			T,R	M
37	66769	Phung	Cai Con	Can Tho			T,R	M
38	66770	Vi Thanh	Xa No	Hau Giang			T,R	M
39	69749	My Thuan	Tien	Vinh Long			T,R	M
40	66781	Tan Hiep	Cai San	Kien Giang			T,R	M
41	66782	Rach Gia	Kien	Kien Giang			T,R	M
42	66783	Xeo Ro	Cai Lon	Kien Giang			T,R	M
43	71600	Phu An	Sai Gon	HCM city			T,R	M
44	71601	Nha Be	Sai Gon	HCM city			T,R	M
45	66755	Dai Ngai	Hau	Soc Trang			T,R	M
46	66776	Tran De (My Thanh)	My Thanh	Soc Trang			T,R	M
47	66754	Tra Vinh	Tra Vinh canal	Tra Vinh			T,R	M
48	66790	Ca Mau	Ganh heo	Ca Mau			T,R	M
49	66791	Song Doc	Ong Doc	Ca Mau			T,R	M
50	66797	Nam Can	Cua Lon	Ca Mau			T,R	M
51	66796	Ganh Hao	Ganh Hao	Bac Lieu			T,R	M
52	66798	Phuoc Long	Quan Lo canal	Bac Lieu			T,R	M
53		Chau Doc	Chau Doc					
54		Hau	Hau					
55		Tien	Tien					
56		So Thuong	So Thuong					
57		Long Khot	Long Khot					
58		Vam Co Dong	Cam Co Dong					
59		Dak To	Dak To					
60		Nam Sa Thay	Sa Thay					
61		Ia Drang	Ia Drang					
62		Ya Hleo	Ya Hleo					
63		Sre Pok	Sre Pok					

Stations 53-63: New stations funded by the World Bank for Mekong-Integrated Water Resources Management projects

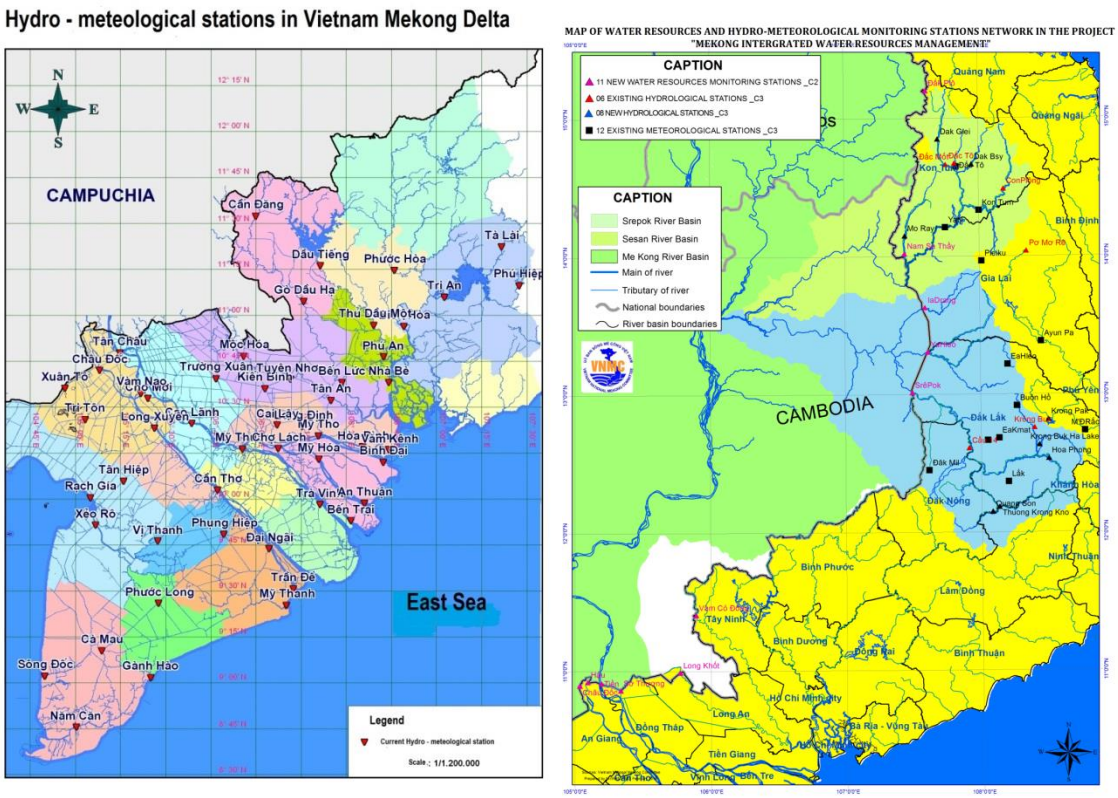


Figure B1: (a) Hydro-met stations in Viet Nam Mekong Delta; and (b) new WB M-IWRM stations in Viet Nam

Table B6: Additional national hydro-meteorological stations in Lao PDR

No	Station Code	Station Name	River/Basin	Country	Lat.	Long.	Para-meter	Type of Station
1		Nakai	Se Bang Fai	Lao PDR			R	AWS
2		Nongbok	Se Bang Hieng	Lao PDR			R	AWS
3		Bou Lapha	Se Bang Fai	Lao PDR			R	AWS
4		Dong hen	Se Bang Hieng	Lao PDR			R	AWS
5		Savan Nakhet	Se Bang Hieng	Lao PDR			R	AWS
6		Phavieng	Se Bang Fai	Lao PDR			WL,R	AHS
7		Sebangfai B	Se Bang Fai	Lao PDR			WL,R	AHS
8		Saang	Se Bang Fai	Lao PDR			WL,R	AHS
9		Ban Dong	Se Bang Hieng	Lao PDR			WL,R	AHS
10		Selanong	Se Bang Hieng	Lao PDR			WL,R	AHS
11		Kengdone	Se Bang Hieng	Lao PDR			WL,R	AHS
12		Sopnam	Se Bang Hieng	Lao PDR			WL,R	AHS
13		Sethamuak	Se Bang Hieng	Lao PDR			WL,R	AHS
14		Xieng Hom	Se Bang Hieng	Lao PDR			WL,R	AHS
15		Mahaxai	Se Bang Fai	Lao PDR			WL,R	AHS
16		Ban Tonhen	Se Bang Fai	Lao PDR			WL,R	AHS
17		Boung Bao	Se Bang Fai	Lao PDR			WL,R	AHS
18		Tad Hai	Se Bang Hieng	Lao PDR			WL,R	AHS
19		Sokbo	Se Bang Fai	Lao PDR			WL,R	AHS
20	10102	Houei Sai	Mekong	Lao PDR	20.270	100.414	WL,R	
21	40801	Ban Hatkham	Nam Tha	Lao PDR	20.149	100.718	WL,R	
22	11201	Luangprabang	Mekong	Lao PDR	19.896	102.132	WL,R	
23	11401	Paklay	Mekong	Lao PDR	18.178	101.391	WL,R	
24		Nam Houng	Nam Houng	Lao PDR	19.263	101.716	WL,R	
25		Ban Tang	Nam OU	Lao PDR	22.030	101.884	WL,R	
26	11502	Sanakham	Mekong	Lao PDR	17.908	101.671	WL,R	
27		Ban Akat	Mekong	Lao PDR	17.969	102.570	WL,R	
28	180207	Vang Vieng	Nam Xong	Lao PDR	18.943	102.443	WL,R	
29		Saysomboun	Nam Cha	Lao PDR	18.911	103.091	WL,R	
30	13401	Paktaphan	Mekong	Lao PDR	18.930	105.351	WL,R	
31	14301	Ban Chan Noy	Mekong	Lao PDR	14.356	105.884	WL,R	
32	14302	Hatsaikhoun	Mekong	Lao PDR	14.118	105.866	WL,R	
33		Muang Khua	Nam Ou	Lao PDR	21.081	102.501	R	
34		Muang Boun Neua	Nam Ou	Lao PDR	21.651	101.909	R	
35		Muang Boun-Tai	Nam Ou	Lao PDR	21.387	101.975	R	
36		Muang Ou-Tai	Nam Ou	Lao PDR	22.129	101.793	R	
37		Muang Xam- Tai		Lao PDR	20.001	104.642	R	
38		Ban Nam Nuern		Lao PDR	20.034	103.715	R	
39		Ban Nam MO		Lao PDR	18.873	102.923	R	
40		Ban NaXon		Lao PDR	18.075	102.981	R	
41		Ban Pakthouay		Lao PDR	18.442	103.442	R	
42		Tadluek		Lao PDR	18.390	103.147	R	
43		Muang Pathoumphone		Lao PDR	14.842	105.949	R	
44		Muang Champasak		Lao PDR	14.898	105.873	R	

Stations 1-19: New stations funded by the Asian Development Bank
Stations 20-44: New stations funded by China

Table B7: Additional national hydro-meteorological stations in Cambodia.

No	Station Code	Station Name	River/Basin	Province	Lat.	Long.	Para-meter	Type of Station
1		Chey Sen	Mekong		11.99467	105.4687		AWS
2		Chroy Thmor	Mekong		11.99023	105.4709		AWS
3		Tasal Dam	Prek Thnot		11.45989	104.5144		AWS
4		Thpong, Anlong Chrey	Tonle Sap		11.75441	104.4016		AWS
5		Phnom Srouch	Bassac		11.34707	104.3287		AWS
6		7 Makara Dam	Bassac		11.46518	104.9343		AWS
7		Koh Tom	Bassac		11.12876	105.0581		AWS
8		Vihear Loung	Tonle Sap		11.81567	104.7676		AWS
9		Tram Kok	Bassac		11.06825	104.522		AWS
10		Kirivong	Bassac		10.79202	104.8187		AWS
11		Sam Roung District	Bassac		11.06687	104.8046		AWS
12		Bati District	Bassac		11.23693	104.8122		AWS
13		Borey Cholsar	Bassac		10.86719	104.9223		AWS
14		Chey Sen	Sen					AHS-S
15		Preah Vihear	Sen					AHS-S, AHS-G
16		Kulen	Sen					AHS-S, AHS-G
17		Santuk	Sen					AWS
18		Kampong Thmar	Sen					AHS-S
19		Chinit Bridge	Sen					AHS-S
20		Santuk	Sen					AWS-S, AHS-G
21		Staung	Sen					AHS-S, AHS-G
22		Kampong Svay	Sen					AHS-S
23		Prasat Sambo	Sen					AHS-S, AHS-G
24		Sandan	Sen					AHS-S
25		Oudong	Prek Thnot					AWS
26		Spean Tasal	Prek Thnot					AHS-S
27		Stung Khliech	Prek Thnot					AHS-S
28		Stung Sva hab	Prek Thnot					AHS-S
29		Spean Kantourt	Prek Thnot					AHS-S
30		Phnom Srouch	Prek Thnot					AHS-S, AHS-G
31		Samrong Toang	Prek Thnot					AHS-S, AHS-G
32		Bosed	Prek Thnot					AHS-S
33		Krang Ponley	Prek Thnot					AHS-S
34		Takhmao	Prek Thnot					AWS, AHS-G
35		Pohnea Leu	Prek Thnot					AWS
36		Kh'am Samnor	Prek Thnot					AHS-S, AHS-G
37		S'ang	Prek Thnot					AHS-S
38		Prek Ho	Prek Thnot					AHS-S
39		Tamouk (P5)	Prek Thnot					AHS-S
40		Wat Kbal Koh	Prek Thnot					AHS-S
41		Kirivong	Slakou					AHS-S, AHS-G
42		Daunkeo	Slakou					AWS
43		Daunkeo	Slakou					AHS-S, AHS-G
44		Bati	Slakou					AWS, AHS-G
45		Prey Kabas	Slakou					AWS
46		Prey Kabas	Slakou					AHS-S
47		Angkor Borei	Slakou					AHS-S
48		Borey Cholsa	Slakou					AHS-S

Stations 1-48: New stations funded by UNDP as part of the *Strengthening Climate Information and Early Warning System* project. Note, this project is also funding further stations in coastal areas outside the LMB

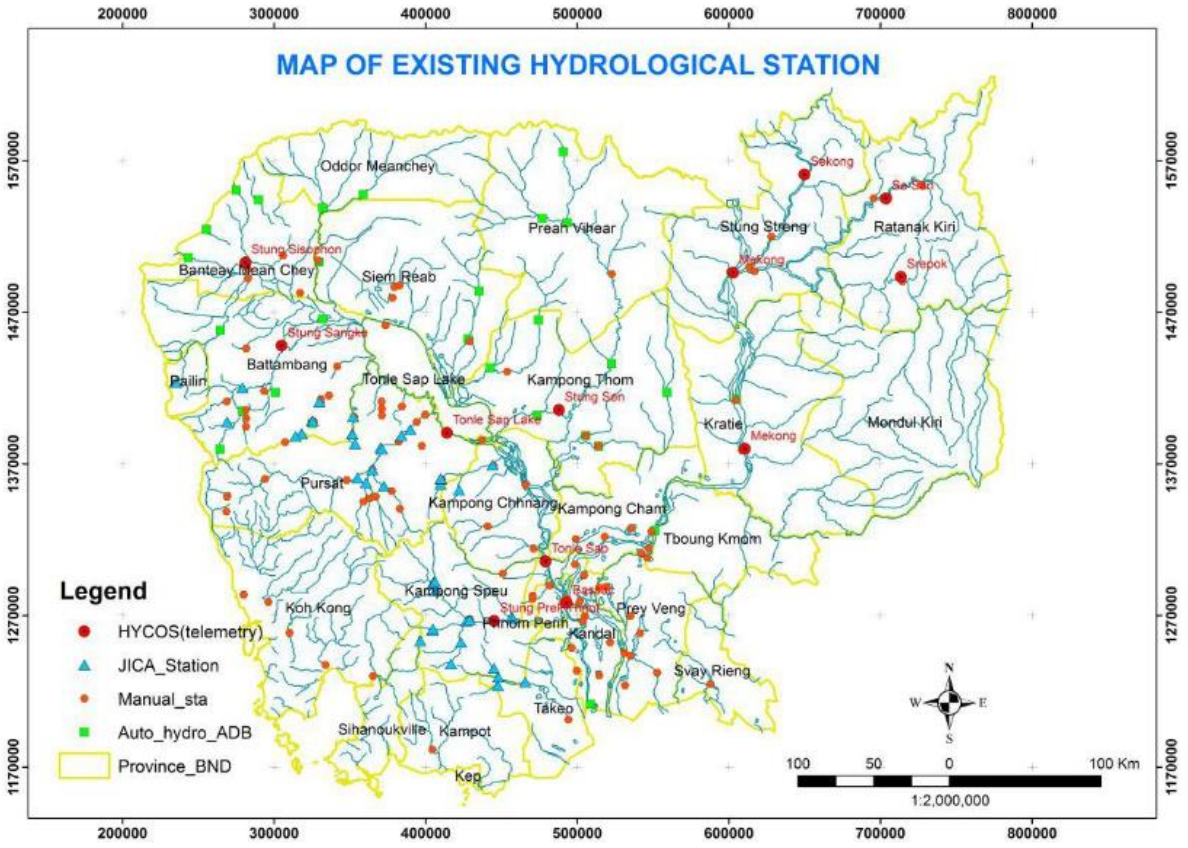


Figure B2: Hydro-meteorological stations in Cambodia

Table B8: MRC discharge measurement and sediment monitoring stations

No	Station Name	River/Basin	Country	Lat.	Long.	Discharge Equipment	Sediment Equipment
1	Chiang Saen	Mekong	Thailand	20.2727	100.0091	CM	D-96
2	Luang Prabang	Mekong	Lao PDR	19˚53'34.2"	102˚08/03.8"	CM	D-96
3	Chiang Khan	Mekong	Thailand	17.9008	101.6638	CM	D-96
4	Nong Khai	Mekong	Thailand	17.8812	102.7163	CM/ADCP	D-96
5	Nathon Phanom	Mekong	Thailand	17.3939	104.7997	CM	D-96
6	Mukdahan	Mekong	Thailand	16.5041	104.7396	CM	D-49
7	Khong Chiam	Mekong	Thailand	15.1906	105.3000	CM	D-49
8	Pakse	Mekong	Lao PDR	15˚04'33.51"	105˚33'06.67"	CM	D-96*
9	Stung Treng	Mekong	Cambodia	13.5217	105.9340	ADCP	D-96
10	Kratie	Mekong	Cambodia	12.4428	106.0239	ADCP	D-96
11	Chroy Chang Var	Tonle Sap	Cambodia	11.3507	104.5633	ADCP	D-96
12	Prek Kdam	Tonle Sap	Cambodia	11.4807	104.4807	ADCP	D-96
13	Koh Norea	Mekong	Cambodia	11.5449	104.9752	ADCP	D-96
14	MRC-OSP	Bassac	Cambodia	11.5164	104.9385	ADCP	D-96
15	Se Kong Bridge	Sekong	Cambodia	13.5341	105.9794	CM/ADCP	VN-5 (SRHMC)
16	Tan Chau	Mekong	Viet Nam	10.8005	105.2479	CM/ADCP	VN-5 (SRHMC)
17	Chau Doc	Bassac	Viet Na,	10.7052	105.1336	ADCP	D-96

* MRC (2018) report sediment sampling equipment at Pakse as D-49/Uppsala. DMH clarified they use the D-96 at each site.
CM: Current Meter; ADCP: Acoustic Doppler Current Profiler.

Figure B3: Map of discharge measurement and sediment monitoring stations

Table B8: MRC water quality monitoring stations

No	Station Code	Station Name	River/Basin	Country	Lat.	Long.
1	H010500	Houa Khong	Mekong	Lao PDR	21.5471	101.1598
2	H010501	Chiang Saen	Mekong	Thailand	20.2674	100.0908
3	H011200	Luang Prabang	Mekong	Lao PDR	19.9000	102.0000
4	H011901	Vientiane	Mekong	Lao PDR	17.9281	102.6200
5	H013101	Nakhon Phanom	Mekong	Thailand	17.4250	104.7744
6	H013401	Savannakhet	Mekong	Lao PDR	16.5583	104.7522
7	H013801	Khong Chiam	Mekong	Thailand	15.3255	105.4937
8	H013900	Pakse	Mekong	Lao PDR	15.1206	105.7837
9	H014501	Stung Treng	Mekong	Cambodia	13.5450	106.0164
10	H014901	Kratie	Mekong	Cambodia	12.4777	106.0150
11	H019802	Kampong Cham	Mekong	Cambodia	11.9942	105.4667
12	H019801	Chrouy Changvar	Mekong	Cambodia	11.5861	104.9407
13	H019806	Neak Loung	Mekong	Cambodia	11.2580	105.2793
14	H019807	Kaorm Samnor	Mekong	Cambodia	11.0679	105.2086
15	H019803	Tan Chau	Mekong	Viet Nam	10.9079	105.1835
16	H019804	My Thuam	Mekong	Viet Nam	10.2727	105.9100
17	H019805	My Tho	Mekong	Viet Nam	10.3430	106.3505
18	H033401	Takhmao	Bassac	Cambodia	11.4785	104.9530
19	H033402	Koh Khel	Bassac	Cambodia	11.2676	105.0292
20	H033403	Koh Thom	Bassac	Cambodia	11.1054	105.0678
21	H039801	Chau Doc	Bassac	Viet Nam	10.9552	105.0867
22	H039803	Can Tho	Bassac	Viet Nam	10.0580	105.7977
23	H020108	Phnom Krom	Tonle Sap	Cambodia		
24	H020106	Kampong Loung	Tonle Sap	Cambodia		
25	H020103	Kampong Chhnang	Tonle Sap	Cambodia		
26	H020102	Prek Kdam	Tonle Sap	Cambodia		
27	H020101	Phnom Penh Port	Tonle Sap	Cambodia		
28	H020107	Back Prea	Sangkeo	Cambodia		
29	H440102	Phum Pi	Sesan	Cambodia		
30	H440103	Angdoung Meas	Sesan	Cambodia		
31	H450101	Lumphat	Srepok	Cambodia		
32	H430102	Siempang	Sekong	Cambodia		
33	H100101	Ban Hatkham	Mekong	Lao PDR		
34	H230103	Ban Hai	Mekong	Lao PDR		
35	H320101	Se Bangfai	Mekong	Lao PDR		
36	H350101	Ban Kengdone	Mekong	Lao PDR		
37	H390105	Sedone Bridge	Mekong	Lao PDR		
38	H910108	Houay Mak Hiao	Mekong	Lao PDR		
39	H050104	Chiang Rai		Thailand		
40	H290103	Ban Chai Buri		Thailand		
41	H310102	Na Kae		Thailand		
42	H380104	Ubon		Thailand		
43	H380128	Mun		Thailand		
44	H440202	Pleiku	Sesan	Viet Nam		
45	H451303	Ban Don	Srepok	Viet Nam		
46	H988114	Tu Thuong	Hong Ngu	Viet Nam		
47	H988115	Thong Binh	Cai Cai	Viet Nam		
48	H988316	Tinh Bien	Vinh Te	Viet Nam		

Figure B4: Map of water quality monitoring stations

Table B9: MRC Ecological Health Monitoring sites

No	Site	Station Name	River/Basin	Country	GPS (X)	GPS (Y)
1	LMX	Ban Xiengkok	Mekong	Lao PDR	670860	2311778
2	LPB	Done Chor	Mekong	Lao PDR	498434	1887920
3	LVT	Huayhome	Mekong	Lao PDR	239871	1989731
4	LBF	Se Bang Fai	Se Bang Fai	Lao PDR	454745	1959958
5	LBH	Songkhone	Se Bang Hieng	Lao PDR	498434	1887920
6	LSD	Ban Hae	Se Done	Lao PDR	587623	1671756
7	LKL	Ban Somsanouk	Se Kong	Lao PDR	670696	1623478
8	LDN	Done Ngiew	Mekong	Lao PDR	596193	1657517
9	TCS	Chian San	Mekong	Thailand	614718	2240109
10	TKO	Chiang Rai	Nam Kok	Thailand	582195	2201793
11	TSM	Mekong Junction	Songkram	Thailand	443775	1951509
12	TNP	Nakorn Phanom	Mekong	Thailand	476094	1926454
13	TNK	Kong Chiam	Nam Mun	Thailand	450496	1874332
14	TUN	Ubon Rachathani	Nam Mun	Thailand	494860	1685056
15	TMU	Kong Chiam	Nam Mun	Thailand	552465	1673182
16	TKC	Kong Chiam	Nam Mun/Mekong	Thailand	552099	1694552
17	CMR	Stung Treng Ramsar site	Mekong	Cambodia	618663	1504098
18	CKM	Kbal Koh, Stung Treng	Se Kong	Cambodia	606331	1539069
19	CUS	Dey It Ratanakiri	Sesan	Cambodia	717794	1490553
20	CSS	Veunsai Ratanakiri	Sesan	Cambodia	695488	1546145
21	CSP	Phik Rattankiri	Srepok	Cambodia	765124	1525674
22	CSJ	DS Srepok junction, stung Treng	Sesan	Cambodia	621744	1498832
23	CKT	Kampi Pool, Kratie	Mekong	Cambodia	610914	1393502
24	CPT	Preh Kanlong, Kratie	Prek Te	Cambodia	613899	1374811
25	CCK	Chong Khnease, Siem Reap	Tonle Sap	Cambodia		
26	CKL	Kampong Luong, Pursat	Tonle Sap	Cambodia		
27	CSN	Kampong Thom	Stung Sen	Cambodia	490998	1401845
28	CSK	Battambang	Stoeng Sangke	Cambodia	357473	1461902
29	CTU	Prek Kdam Ferry, Kandal	Tonle Sap	Cambodia	478364	1307071
30	CPP	Phnom Penh Port	Tonle Sap	Cambodia	491666	1280205
31	CPS	Damnak Ampil, Pursat	Pursat	Cambodia	381258	1382944
32	CNL	Neak Loeung, Prey Veng	Mekong	Cambodia	528321	1250852
33	CKK	Khos Khel, Kandal	Bassac	Cambodia	503786	1245255
34	VTP	Thuong Phuoc, Dong Thap	Mekong	Viet Nam	519830	1205766
35	VTT	Thuong Thoi, Dong Thap	Mekong	Viet Nam	528951	1194447
36	VKB	Khanh Binh, An Giang	Bassac	Viet Nam	509482	1210872
37	VDP	Da Phuoc, An Giang	Bassac	Viet Nam	514690	1188035
38	VCL	Cao Lanh, Dong Thap	Mekong	Viet Nam	563798	1153777
39	VLX	Long Xuyen, An Giang	Bassac	Viet Nam	551897	1143437
40	VVL	My Thuan, Vinh Long	Mekong	Viet Nam	603698	1134514
41	VCT	Phu An, Can Tho	Bassac	Viet Nam	588365	1110673

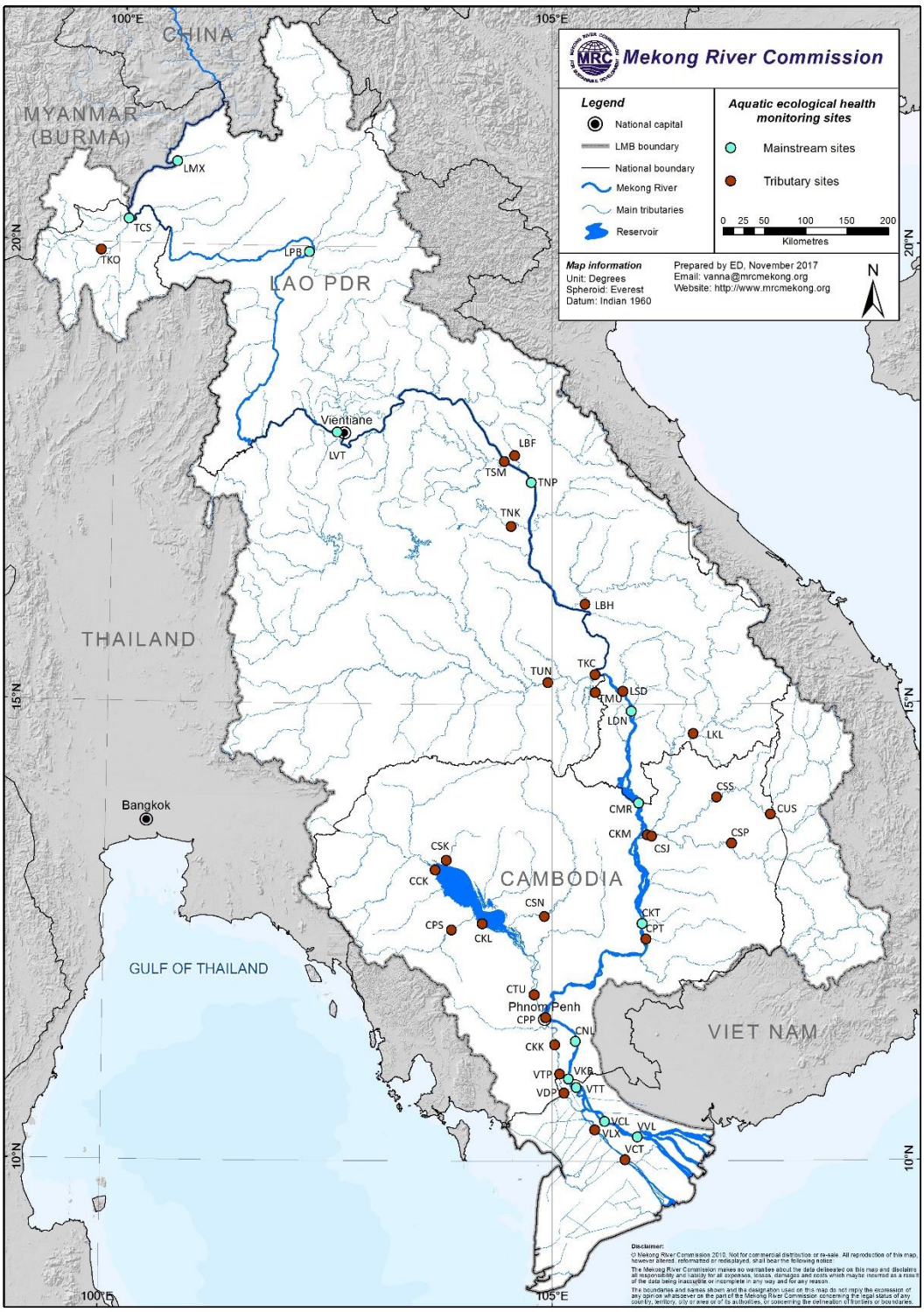


Figure B5: Map of Ecological Health monitoring sites

Table B1: MRC Fish Abundance and Diversity monitoring sites

No	Country	Province/City	District	Commune	Village	Standard habitat	Latitude (N)	Longitude (E)	Number of fishers	Agency	Remark
1	Cambodia	Stung Treng	Siem Pang	Tmar Keo	Pres Bang	Tributaries	14° 7'0.43"	106°23'23.99"	3	IFReDI	2003-2014
2	Cambodia	Ratanakkiri	Lumpat district	Chey Udom	Day Lo	Tributaries	13°28'18.08"	106°59'16.26"	3	IFReDI	2003-2014
3	Cambodia	Ratanakkiri	Veunsai	Banpong	Fang	Tributaries	13°57’43.14”	106°48’7.11”	3	IFReDI	2003-2014
4	Cambodia	Stung Treng	Talaborivat	Ou Svay	Ou Run	Mekong mainstream	13°52'0.13"	105°59'53.91"	3	IFReDI	2003-2014
5	Cambodia	Kratie	Sambo	Ou Krieng	Koh Khne	Mekong mainstream	13°08’9.15”	106°03’51.75”	3	IFReDI	2003-2014
6	Cambodia	Kandal	Ponhe Leu	Kampong Luong	Sang Var	Tributaries	11°49’9.52”	104°48’16.54”	3	IFReDI	2003-2014
7	Cambodia	Kampong Chhnang	Boribo	Chhnouk Trou	Chhnouk Trou	Floodplain/swamp/Lake/tributaries	12°30'55.10"	104°27'26.91"	3	TSA	2011-2014
8	Cambodia	Pursat	Kor Kor	Kompong Loung	Ti 2	Floodplain/swamp/Lake/tributaries	12°36'21.09"	104°13'27.44"	3	TSA	2011-2014
9	Cambodia	Battambong	Ek Phnom	Prek Torl	Prek Torl	Floodplain/swamp/Lake/tributaries	13° 6'1.48"	103°44'36.37"	3	TSA	2011-2014
10	Cambodia	Siem Reap	Siem Reap	Chong Khneas	Ti 3,4,5	Floodplain/swamp/Lake/tributaries	13°12'54.07"	103°48'45.29"	3	TSA	2011-2014
11	Cambodia	Kampong Thom	Kompong Svay	Phat Sanday	Neang Sav	Floodplain/swamp/Lake/tributaries	12°43'1.52"	104°25'45.64"	3	TSA	2011-2014
12	Lao PDR	Luangprabang	Luangprabang		Pha Oh village	Mekong mainstream	19°56'4.39"	102°12'21.97"	3	LARReC	2003-2014
13	Lao PDR	Vientiane Capital	Hatsaifong		Tha Mouang	Mekong mainstream	17°53'26.87"	102°44'45.86"	3	LARReC	2003-2014
14	Lao PDR	Bolikhamxay	Paksan		Sinxay	Mekong mainstream	18°20'51.40"	103°45'9.42"	3	LARReC	2003-2014
15	Lao PDR	Champasack	Phonthong		Hatsalao	Mekong mainstream	15° 4'28.16"	105°49'38.79"	3	LARReC	2003-2014
16	Lao PDR	Champasack	Khong		Hat	Mekong mainstream	14° 5'2.67"	105°50'42.54"	3	LARReC	2003-2014
17	Lao PDR	Bokeo	Houaysai		Houay Tab	Mekong mainstream	20°19'38.88"	100°22'51.08"	3	LARReC	New (2013-14)
18	Lao PDR	Bokeo	Houaysai		Donkhoun	Tributaries	20°22'3.73"	100°22'22.02"	3	LARReC	New (2013-14)
19	Lao PDR	Oudomxay	Pakbeng		Pak Ngeuy	Mekong mainstream	19°53'20.84"	101° 7'18.29"	3	LARReC	New (2013-14)
20	Lao PDR	Oudomxay	Pakbeng		Beng	Tributaries	19°53'29.72"	101° 8'17.65"	3	LARReC	New (2013-14)
21	Lao PDR	Luangprabang	Xieng Ngeung		Pha Nom	Tributaries	19°53'9.14"	102° 9'34.41"	3	LARReC	New (2013-14)*
21	Lao PDR	Xekong	Lamam		Gnai Nava	Tributaries	15°20'49.42"	106°44'29.17"	3	LARReC	New (2017)**
22	Lao PDR	Luangprabang	Pak Ou		Hat Nga	Tributaries	20° 5'6.33"	102°15'41.98"	3	LARReC	New (2013-14)
23	Lao PDR	Xayaboury	Xayaboury		Tha Dua	Mekong mainstream	19°25'52.93"	101°50'20.32"	3	LARReC	New (2013-14)
24	Lao PDR	Xayaboury	Xayaboury		Na Sam	Tributaries	19°13'47.50"	101°42'28.24"	3	LARReC	New (2013-14)
25	Lao PDR	Bolikhamxay	Paksan		Posy	Tributaries	18°25'29.64"	103°37'5.49"	3	LARReC	New (2013-14)*
25	Lao PDR	Attapeu	Samakhixay		Saphaothong	Tributaries	14°48'33.98"	106°47'18.35"	3	LARReC	New (2017)**
26	Lao PDR	Champasack	Pakse		Hae	Tributaries	15° 8'34.40"	105°48'7.43"	3	LARReC	New (2013-14)*
26	Lao PDR	Champasak	Khong		Hangsadam	Mekong mainstream	13°56'8.04"	105°57'31.84"	3	LARReC	New (2017)**
27	Thailand	Loei				Mekong mainstream	17°54'38.64"	101°41'45.81"	3	DoF	2003-2014
28	Thailand	Nong Khai				Tributaries	17°53'10.62"	102°34'1.32"	3	DoF	2003-2014
29	Thailand	Nakhon Phanom				Mekong mainstream	17°37'25.67"	104°31'2.71"	3	DoF	2003-2014
30	Thailand	Nakhon Phanom				Floodplain/swamp	17°39'21.42"	104°13'5.80"	3	DoF	2003-2014

31	Thailand	Ubon Ratchathani				Mekong mainstream	16° 1'39.51"	105°21'0.17"	3	DoF	2003-2014
32	Viet Nam	Vinh Long	Vung Liem	Thanh Binh	Lang	Mekong mainstream	10°05’ 57.7	106°13’ 38.5	3	RiA2	2003-2014
33	Viet Nam	An Giang	Toai Son	Nui Sap	Tay Son	Floodplain/swamp	10°11'21.30"	105°15'27.62"	3	RiA2	2003-2014
34	Viet Nam	An Giang	Cho Moi	My Hoi Dong	My Thuan	Mekong mainstream	10°32’ 49.5	105°20’ 06.6	3	RiA2	2003-2014
35	Viet Nam	An Giang	An Phu	Phu Hoi	Ap 2	Canal	10°47'55.73"	105°04'46.79"	3	RiA2	2003-2014
36	Viet Nam	Tra Vinh	Tieu Can	Cau Quang	Khom 3	Esturine	09°45'15.46"	106°07'09.88"	3	RiA2	2003-2014
37	Viet Nam	Can Tho	Phong Dien	My Khanh	My Thuan	Floodplain/swamp	10°00'27.82"	105°42'20.70"	3	RiA2	2003-2014
38	Viet Nam	Tra Vinh	Tra Vinh city	Long Duc	Long Trị	Esturine	09°59’ 24.4"	106°21’ 11.7"	3	RiA2	2003-2014

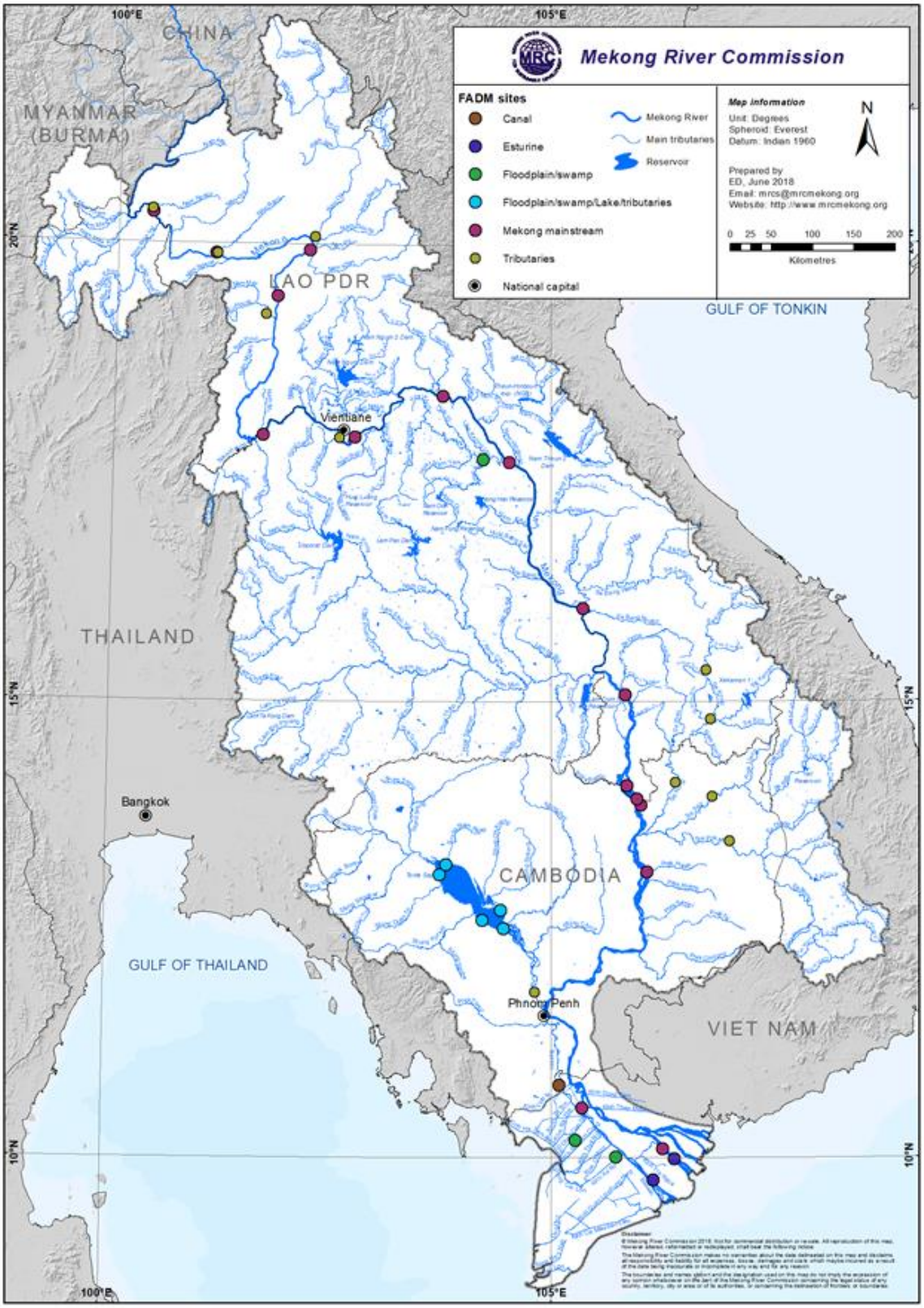


Figure B6: Map of Fish Abundance and Diversity monitoring sites