



Mekong River Commission
Cambodia • Lao PDR • Thailand • Viet Nam
For sustainable development

*The Procedures for
the Maintenance of Flows on the Mainstream (PMFM)*

Implementation Report

2011-2015

A report of the PMFM Technical Review Group that summarises the results and experiences of implementing the PMFM in a learning-by-doing approach during 2011-2015. The report will inform the finalization and adoption of the draft Technical Guidelines for the implementation of the PMFM.

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EXECUTIVE SUMMARY

Background of the PMFM

The intent of the **1995 Mekong Agreement** is to promote cooperation among the riparian countries on the sustainable development and management of the Mekong water and related resources. The main instruments for that cooperation are a rolling Basin Development Plan and Mekong River Commission (MRC) Procedures. Currently, the MRC Procedures are an integral part of MRC's five-year planning cycle.

The MRC initiated the Water Utilisation Programme (WUP) in 1999 to develop sets of rules for water utilisation in the Lower Mekong Basin (LMB). The following are the five MRC Procedures:

- Procedures for Data and Information Exchange and Sharing (PDIES) – 2001,
- Procedures for Water Use Monitoring (PWUM) – 2003,
- Procedures for Notification, Prior Consultation and Agreement (PNPCA) – 2003,
- Procedures for the Maintenance of Flows on the Mainstream (PMFM) – 2006,
- Procedures for Water Quality (PWQ) – 2011.

The intent of the PMFM is to cooperate on the maintenance of an acceptable hydrological flow regime on the mainstream to optimise the multiple uses and mutual benefits of all riparian countries and to minimise the harmful effects. In **Article 6** of the 1995 Mekong Agreement, the LMB countries agreed “to cooperate in the maintenance of the flows on the mainstream from diversions, storage releases, or other actions of a permanent nature, except in the cases of historically severe droughts and/or floods:

- **Article 6A:** *Of not less than the acceptable minimum monthly natural flow during each month of the dry season;*
- **Article 6B:** *To enable the acceptable natural reverse flow of the Tonle Sap River to take place during the wet season; and*
- **Article 6C:** *To prevent average daily peak flows greater than what naturally occur on the average during the flood season.”*

The principles of the PMFM as described in the 1995 Mekong Agreement do not include essential information such as the acceptable water flows to be maintained and how this will be done. To produce this information, the MRC Joint Committee established in 2003 the regional **Technical Review Group (TRG)**.

The TRG prepared the **Procedures for the Maintenance of Flows on the Mainstream** (adopted by the MRC Council in June 2006) and the current **draft Technical Guidelines on the PMFM** (October 2011) that provide, inter alia, the flow frameworks and the hydrological stations that are required for the implementation of the Procedures.

The draft Technical Guidelines provide flow frameworks for planning purposes and monitoring purposes for Articles 6A, 6B and 6C:

- **Planning purposes:** flow frameworks against which future basin-wide development scenarios or projects can be assessed; and
- **Monitoring purposes:** flow frameworks that can be used to validate the predictions made for the PMFM for planning purposes and to raise awareness of daily flows and to discuss coordinated action by the Member Countries whenever needed.

The Member Countries have reached a working consensus on five of the six required flow frameworks that are required for the implementation of the PMFM for both planning and monitoring purposes (see the table below). The main pending issue is a four-country agreement on a minimum flow framework for planning purposes.

PMFM principles	Purpose	Status
Article 6A: Maintain minimum flows during the dry season	For planning purposes	Pending
	For monitoring purposes	Working consensus
Article 6B: Maintain reverse flow to the Tonle Sap River during the wet season	For planning purposes	Working consensus
	For monitoring purposes	Working consensus
Article 6C: Prevent greater than natural peak flows in the flood season	For planning purposes	Working consensus
	For monitoring purposes	Working consensus

Purpose of this report

In 2011, the Technical Review Group for the PMFM agreed to implement the draft Technical Guidelines for the PMFM in a learning-by-doing approach, with a view to testing the flow frameworks set out in the draft Technical Guidelines. This includes the analysis and testing of the considered alternative flow frameworks for the pending issue as confirmed by the MRC Joint Committee in April 2012.

This report informs government officials and water managers of the main results, lessons learnt and experiences of implementing the PMFM in a learning-by-doing approach during 2011-2015. The discussion of this report during the 13th TRG Meeting will pave the way for the updating and finalization of the draft Technical Guidelines and their subsequent implementation during the 2016-2020 planning cycle.

Results, findings and lessons

The PMFM Comprehensive Information Report prepared. With support from National PMFM Experts, and feedback from the TRG and staff of the NMC Secretariats, three successive drafts of the PMFM Comprehensive Information Report have been prepared for PMFM practitioners and new members of the TRG. The report provides an informative overview of: (1) the **entire PMFM process** including a factual record of researches, events and agreements; (2) the **key aspects of the hydrology of the Mekong and Tonle Sap system**, and the potential future changes in mainstream flows as a result of basin development and climate change; (3) the **analysis and discussion of the pros and cons of the considered alternative minimum flow frameworks for planning purposes** (main pending issue); (4) the

proposed **steps towards building consensus** on a single minimum flow framework for planning purposes; and (5) the **near and longer term implementation modalities** of the PMFM.

Application of the draft Technical Guidelines for planning purposes. The existing scenarios that are based on the national water resources development plans of the Member Countries (formulated in 2008) have been used to analyse the pros and cons of the considered alternative minimum flow frameworks for planning purposes. No new development scenarios have been formulated and forwarded for PMFM compliance assessment during 2011-2015. Two hydropower projects of **Xayaburi** and **Don Sahong** on the mainstream were submitted for prior consultation (through the Procedures for Notification, Prior Consultation and Agreement – PNPCA). For each of these projects, PMFM compliance assessment has been carried out as part of the project review by the MRCS, and reported in the MRCS technical review report. For both projects, it was generally concluded that the **flow frameworks in the draft Technical Guidelines will not be transgressed** as a result of the project due to their limited storage capacity.

Application of the draft Technical Guidelines for monitoring purposes. Several **minimum** flow transgressions were observed during the dry season. They generally occurred before the flow augmentation started in December 2012. **The assessment of these transgressions showed that they were generally associated by weather conditions.** In the future, instances where low flow frameworks will be transgressed in the dry season will likely become rare. There have been also a few instances where the **maximum** flow frameworks for the flood season have been transgressed. Also these transgressions were traced back to climatic events. It can therefore be generally concluded that these transgressions were not human made and did not violate the PMFM.

Review of the draft Technical Guidelines. The application of the draft Technical Guidelines for planning purposes revealed several cases of unclear wording in the current text of the draft Technical Guidelines. These have been clarified with the National PMFM Experts and the TRG members. These include:

- The **data of the graphically presented flow frameworks** for Article 6A for monitoring purposes needs to be added to the draft Technical Guidelines. Additionally, zero gauge of the selected hydrological stations needs to be added to water level presentation for Article 6A for monitoring purposes.
- For Article 6B, the **methodology for calculating the accumulated reverse flow volume** to the Tonle Sap Lake needs to be included in the draft Technical Guidelines.
- **Phnom Penh Port** station should be also added to the list of the selected hydrological stations.

Clarity is essential, otherwise the interpretation of how the draft Technical Guidelines is to be applied may differ between Member Countries, which could lead to paralysis in decision-making on development plans. The TRG is now in the position to update the draft Technical Guidelines.

Review of alternative minimum flow frameworks for planning. Extensive testing of the considered alternative minimum flow frameworks (ARI 1:4, ARI 1:5, FDC 80%, and FDC 90%) and their application for planning purposes during the past five years demonstrated that the **difference between these flow frameworks is small and within the error margin of the accuracy with which scenarios or projects can be modelled and assessed.** The testing also showed that one

straightforward minimum flow framework is the ‘mean’, which is an average of the 15 monthly mean flows – one for each year during the 1985-2000, derived from the simulated daily flows in the DSF. Experience shows that any of these five alternative minimum flow frameworks can be chosen. **The outcomes in terms of basin planning and mainstream flow conditions will be the same.** During the 12th TRG Meeting, Cambodia and Viet Nam supported the ‘mean’ for setting minimum monthly flow framework for the Article 6A for planning purposes. Additionally, Lao PDR agreed that there was no need for a range of flow frameworks. Also, Lao PDR supported a simpler method.

Change in the natural flow regime of the Mekong mainstream. As predicted for the Definite Future Scenario in 2009, the natural flow regime of the Mekong mainstream has been changed as a result of the flow redistribution from the wet season to the dry season by the new storage dams in the Upper Mekong Basin (especially Xiaowan and Nuozhadu) and the increasing number of storage dams on the tributaries in the Lower Mekong Basin in order to maximise hydro-electricity. As a result, **since the dry season of 2012/2013, monitoring shows the dry season flows have been close to or above the historically observed maximum levels for major parts of the dry season at most hydrological stations down to Kratie.** The flow augmentation downstream of Kratie has not yet been visible due to the interplay of the Mekong mainstream, the Tonle Sap Lake and water use in the Tonle Sap Basin. Further assessments in this area could be useful.

Inadequate PMFM monitoring downstream of Kratie. PMFM monitoring and annual reporting has been hampered by the absence of a PMFM monitoring station at Phnom Penh. The last data on the webpage for Chrouy Changvar Station date from 2008. This hydrological station is critical to monitor hydrological conditions downstream of Kratie and condition of the reverse flow to the Tonle Sap Lake. At the 12th TRG Meeting (April 2015), Cambodia announced that this hydrological station is again operational and hydrological data from the station will be shared with the MRCS.

Hydro-meteorological data and information sharing from China. Provision of hydro-meteorological data and early warning during the dry season in the Upper Mekong Basin would build trust and confidence among the downstream countries that the potential benefits of increased flows as a result of re-regulation by the Lancang Hydropower Cascade can be secured and potential impacts from sudden flow changes mitigated.

Annual reporting and regular consultations. Until 2013, annual reports on the PMFM have been prepared for the MRC Joint Committee in the form of 4 to 8-page ‘Notes for Information’. Since then, the reporting on the PMFM to the MRC Joint Committee became part of a report on all five MRC Procedures. During 2011-2015, **three TRG Meetings**, up to **four national consultations**, and **four meetings with the National PMFM Experts** have been held. The 12th TRG Meeting (April 2015) discussed the possible solutions for the main pending issue. The meeting also agreed to update the draft Technical Guidelines (October 2011) in 2015, and aimed to finalise it in the next TRG meeting and submit to the MRC Joint Committee for consideration and endorsement.

Synergy between the Annual PMFM, Hydrological Condition Report and Flood Reports. In the short term, the **annual PMFM reporting to the MRC Joint Committee can be merged with the conventional Hydrological Condition reporting** to the MRC Joint Committee. In the medium term, the new Annual Hydrological Condition Report (with PMFM flow frameworks) may be merged with the Annual Flood Report, but this would require significant work and further consultations.

Knowledge transfer and capacity building. The four meetings with the **National PMFM Experts** (who were engaged in 2012) and **MRCS staff focused on the exchange of knowledge and experience, and joint learning.** The meetings were also useful for the preparation of the national consultations and TRG Meetings. The **national consultations and TRG Meeting focused on awareness raising and capacity building** on the PMFM, including possible solutions for the pending issues. Since 2012, the PMFM expertise within the MRCS has been strengthened (with a staff member) for supporting and improving PMFM implementation, and maintaining PMFM knowledge base and website.

PMFM webpage launched. In 2014, the PMFM webpage was launched in support of the implementation of the PMFM, including the exchange of information with stakeholders on emerging and sudden flow changes. Among other things, the webpage shows the historical and current daily water flow observations, flags (emerging) transgressions of agreed flow frameworks and identifies the likely cause(s). The webpage also maintains information how the PMFM is being used to support the Basin Development Planning and implementation of the PNPCA. The **webpage visualizes the changes in flow patterns in the Upper Mekong Basin and capture how the patterns propagate along the mainstream.**

Lessons learned. A range of PMFM experiences and lessons learnt have been identified, with a view to: (1) **supporting the updating of the draft Technical Guidelines** including the PMFM implementation arrangements and (2) **identifying issues that need to be addressed by the ‘MRC Joint Platform to review and improve the implementation of the MRC Procedures.’** One of the issues where the MRC Joint Platform could add value is the harmonization and integration of the hydrological, flood and PMFM reporting. These annual reports are currently partly overlapping and not always consistent.

Benefits of implementation of the PMFM

Improved basin-scale planning. Use of the PMFM flow frameworks ensures that a comprehensive basin-wide planning approach is adopted in light of the national development plans of the Member Countries. The Member Countries are able to better monitor the predicted impacts of their plans with those that subsequently materialise, thus improving national planning, implementation and adaptive management.

Better informed relevant stakeholders and decision makers. With PMFM monitoring webpage, the broader public, relevant stakeholders and decision-makers are timely and comprehensively informed of development opportunities and (potential) critical flow situations on the Mekong mainstream.

Better rationale for data collection and monitoring requirements. The PMFM process provides a transparent and confident rationale as to what data/information is needed by the MRC and for what purpose (reducing data/information collection burden under the PDIES).

More accountable integrated water resources management-based MRC. The PMFM and other procedures, especially PWUM and PNPCA, underpins efforts to broaden and deepen understanding of basin issues in the context of promoting integrated water resources management.

1 INTRODUCTION

1.1 Background to the PMFM process

In their **1995 Mekong Agreement**, the Lower Mekong Basin (LMB) Countries of Cambodia, Lao PDR, Thailand and Viet Nam established the Mekong River Commission (MRC) and agreed to “*cooperate in all fields of sustainable development, utilisation, management and conservation of the water and related resources of the Mekong River Basin.*” Primary instruments for that cooperation are a rolling Basin Development Plan and the MRC Procedures. Currently, the procedures are an integral part of MRC’s five-year planning cycle.

The MRC initiated the Water Utilisation Programme (WUP) in 1999, to develop sets of rules for water utilisation in the LMB. The following are the five MRC Procedures:

- Procedures for Data and Information Exchange and Sharing (PDIES) – 2001,
- Procedures for Water Use Monitoring (PWUM) – 2003,
- Procedures for Notification, Prior Consultation and Agreement (PNPCA) – 2003,
- Procedures for the Maintenance of Flows on the Mainstream (PMFM) – 2006,
- Procedures for Water Quality (PWQ) – 2011.

The Procedures for the Maintenance of Flows on the Mainstream (PMFM) aim at protecting the natural flow regime. In **Article 6** of the 1995 Mekong Agreement, the LMB Countries agreed “*to cooperate in the maintenance of the flows on the mainstream from diversions, storage releases, or other actions of a permanent nature, except in the cases of historically severe droughts and/or floods:*

- **Article 6A:** *Of not less than the acceptable minimum monthly natural flow during each month of the dry season;*
- **Article 6B:** *To enable the acceptable natural reverse flow of the Tonle Sap River to take place during the wet season; and*
- **Article 6C:** *To prevent average daily peak flows greater than what naturally occur on the average during the flood season.”*

The principles of the PMFM as described in the 1995 Mekong Agreement cannot be fully implemented right away. They lack essential information such as the acceptable water flows to be maintained and how this will be done. This information has been developed by expert groups with members of the LMB Countries. They studied and discussed a range of implementation options that resulted in two negotiated documents:

- Procedures for the Maintenance of Flows on the Mainstream (PMFM); and
- Draft Technical Guidelines on Implementation of the PMFM.

The Procedures for the Maintenance of Flows on the Mainstream were adopted by the MRC Council on 22nd June 2006. They have the central objective of providing *a framework for technical guidelines, institutional arrangements, directions and information to enable the MRC and its Member Countries to maintain the flows of the Mekong River mainstream as required by the 1995 Mekong Agreement*. The Procedures are presented in seven main sections (Box 1) and are to be applied to diversions, storage releases, or other actions of a permanent nature undertaken by the Member Countries, which may have a significant impact on the flows of the mainstream during the wet and dry seasons in accordance with Article 6 of the 1995 Mekong Agreement.

The Procedures reaffirm the requirements of Article 6 and confirm that separate Technical Guidelines are to be prepared to, inter alia: determine the levels of the flows to be maintained and to establish criteria for selection of hydrological stations required for the implementation of the Procedures.

The draft Technical Guidelines on the PMFM have been developed after extensive consultation between representatives of the Member Countries within the Technical Review Group (TRG), established by the MRC Joint Committee for this purpose in 2003. The TRG has met 12 times in the intervening period from 2004 to 2015.

It is clear that the TRG made considerable progress on the drafting of the Technical Guidelines for the PMFM. The first draft Technical Guidelines were prepared based on the 2004 hydrological assessment and MRC Integrated Basin Flow Management (IBFM) completed in September 2006. In particular, an acceptable flow frameworks¹ has been determined for:

- **Planning purposes:** flow frameworks against which future basin-wide development scenarios or projects can be assessed; and
- **Monitoring purposes:** flow frameworks that can be used to validate the predictions made for the PMFM for planning purposes and to raise awareness of daily flows and to discuss coordinated action by the Member Countries whenever needed.

By the end of 2006, the TRG had reached a working agreement on five of the six flow frameworks that are required for the implementation of the PMFM, as shown in Table 1. In the following years, the PMFM activities focussed on the discussions of possible flow frameworks for the implementation of Article 6A for planning purposes, which constitutes the main pending issue. In parallel, successive drafts of the Technical Guidelines were prepared and discussed.

Box 1. Contents of the Procedures for the Maintenance of Flows on the Mainstream.

Preamble

1. Definitions

2. Objectives

3. Principles

4. Scope

5. Maintenance of flows on the mainstream

- Flows to be maintained
- Hydrological stations
- Preparation, review and revision of the Technical Guidelines

6. Institutional arrangements

- MRC Council
- MRC Joint Committee
- MRC Secretariat
- National Mekong Committees

7. Final provisions

- Amendments or modifications
- Entry into force

¹ Flow frameworks can be seen in the current draft Technical Guidelines of the PMFM.

Table 1. Status of flow frameworks for implementation of the PMFM.

PMFM principles	Purpose	Status
Article 6A: Maintain minimum flows during the dry season	For planning purposes	Pending
	For monitoring purposes	Working consensus
Article 6B: Maintain reverse flow to the Tonle Sap River during the wet season	For planning purposes	Working consensus
	For monitoring purposes	Working consensus
Article 6C: Prevent greater than natural peak flows in the flood season	For planning purposes	Working consensus
	For monitoring purposes	Working consensus

The current draft Technical Guidelines are presented in three main chapters accompanied by three Annexes (Box 2). Chapter 2 provides the flow frameworks for the implementation of the PMFM and Chapter 3 is the implementation arrangements.

The 10th TRG Meeting (5 October 2011), whilst recognising that differences of opinion remained amongst the Member Countries with respect to the definition of a minimum flow framework for planning purposes (the pending issue), agreed to implement the draft Technical Guidelines on an interim basis by testing the flow frameworks as set out in the draft Technical Guidelines of October 2011. They further agreed to implement the draft Technical Guidelines in a learning-by-doing approach. For the pending issue, the draft Technical Guidelines provide four alternative flow frameworks.

The draft Technical Guidelines of October 2011 state that Technical Guidelines will be reviewed every five years and be first updated in 2015, or earlier if the TRG considers that there is clear evidence that the flow frameworks or the implementation arrangements need to be modified. The 35th MRC Joint Committee Meeting (April 2012) acknowledged

Box 2. Content of the Technical Guidelines on the PMFM (draft version of October 2011).

Preamble

Abbreviations and acronyms

Definition of Terms

1. Introduction

1.1. Background

1.2. Objective of the Technical Guidelines

1.3. Flows framework

2. Technical Guidelines

2.1. Selection of hydrological stations

2.2. Flows to be maintained

2.2.1. During the dry Season

A. For planning purposes

B. For monitoring purposes

2.2.2. During the wet season

A. For planning purposes

B. For monitoring purposes

2.2.3. During the flood season

A. For planning purposes

B. For monitoring purposes

2.3. Historically severe droughts and/or floods

3. Implementation and review of the Technical Guidelines

3.1. Implementation mechanisms

3.1.1. MRC Joint Committee

3.1.2. MRC Secretariat

A. For planning purposes

B. For monitoring purposes

C. For annual reporting

3.1.3. National Mekong Committees

3.2. Information exchange with Upper Mekong Countries

3.3. Periodic review and updating

Annex A: The Procedures for the Maintenance of Flow on the Mainstream (PMFM)

Annex B: Example applications of flow framework

Annex C: Terms of Reference of Technical Review Group (TRG)

that the draft Technical Guidelines of the PMFM can be implemented in a learning-by-doing approach, including the testing of the considered alternative flow frameworks for Article 6A for planning purposes.

1.2 Purpose of this report

The purpose of this report is to summarise the main results and experiences of implementing the PMFM in a learning-by-doing approach during 2011-2015. The report integrates and elaborates various information notes that have been prepared for the MRC Joint Committee, the TRG and MRCS management on the implementation of the PMFM. This report will also facilitate the updating and finalisation of the draft Technical Guidelines in the 2nd half of 2015, as envisioned in the current draft Technical Guidelines.

This report is presented in four chapters. After the introductory Chapter, Chapter 2 describes the results and experiences of implementing the PMFM for planning purposes. This includes the testing of the considered alternative minimum flow frameworks and the review of the draft Technical Guidelines. Chapter 3 provides the results and experiences of applying the PMFM for monitoring purposes, including an overview of the PMFM webpage. Chapter 4 summarises the supporting activities of implementation of the PMFM, including the PMFM engagement in the MRC Joint Platform. Relevant supporting information is annexed to the report.

1.3 Benefits of implementation of the PMFM

Effective implementation of the PMFM directly contributes to activities of the MRC and its Member Countries in implementing the 1995 Mekong Agreement. The key benefits are highlighted below:

- **Improved basin-scale planning.** Use of the PMFM flow frameworks ensures that a comprehensive basin-wide planning approach is adopted in light of the national development plans of the Member Countries. The Member Countries are able to better monitor the predicted impacts of their plans with those that subsequently materialise, thus improving national planning, implementation and adaptive management.
- **Better informed relevant stakeholders and decision makers.** With PMFM monitoring webpage, the broader public, relevant stakeholders and decision-makers are timely and comprehensively informed of development opportunities and (potential) critical flow situations on the Mekong mainstream.
- **Better rationale for data collection and monitoring requirements.** The PMFM process provides a transparent and confident rationale as to what data/information is needed by the MRC and for what purpose (reducing data/information collection burden under the PDIES).
- **More accountable integrated water resources management-based MRC.** The PMFM and other procedures, especially PWUM and PNPCA, underpins efforts to broaden and deepen understanding of basin issues in the context of promoting integrated water resources management.

2 IMPLEMENTATION OF THE PMFM FOR PLANNING PURPOSES

This chapter summarises the results and experiences of implementing the PMFM for planning purposes during 2011-2015. The PMFM activities for planning purposes are the application of the draft Technical Guidelines for planning purposes, review of the draft Technical Guidelines, and analysis of the considered alternative minimum flow frameworks for Article 6A for planning purposes.

2.1 Application of the draft Technical Guidelines for planning purposes

During 2011-2015, no new development scenarios have been formulated and forwarded for PMFM compliance assessment (new scenarios are currently being formulated under the MRC Council Study). However, the existing scenarios formulated in 2008 and assessed in 2009-2010 have been used to analyse the advantages and disadvantages of the considered alternative minimum flow frameworks for planning purposes (see Section 2.2). In the process, the current draft Technical Guidelines were reviewed and amendments recommended (see Section 2.3).

In the reporting period, two mainstream hydropower projects of Xayaburi and Don Sahong were notified for prior consultation through the Procedures for Notification, Prior Consultation and Agreement (PNPCA). For each of these projects, PMFM compliance assessment has been carried out in accordance with the current draft Technical Guidelines as part of the project review by the MRCS, and reported in the MRCS technical review report. For both projects it was concluded that the agreed and considered flow frameworks in the draft Technical Guidelines will not be transgressed as a result of the project due to their limited storage capacity.

2.2 Review of the draft Technical Guidelines

For Article 6A (for the dry season from December to May) for planning purposes, the acceptable flow framework is based on the monthly observed flows during 1985-2000, as simulated by the DSF at each of the selected hydrological stations (exclude Kampong Luong and Prek Kdam stations). The following flow frameworks and associated thresholds are to be tested:

- Option 1: a range of the **Annual Recurrence Interval² (ARI)** 1:4 and 1:5.

² Annual Recurrence Interval (ARI) is defined as the average annual rate of occurrence of an event. For example, a ARI 1:5 (equivalent to 20 times in 100 years, meaning 80% probability of exceedence) flow is the monthly mean

- Option 2: a range of the 80-90% time exceedance of **Flow Duration Curve**³ (FDC).

A review has been conducted of the current text of the draft Technical Guidelines of October 2011. Regarding to planning purposes, several cases of unclear wording have therefore been identified. The main ones are related to Article 6A for planning purposes (the pending issue) and these are highlighted below.

Clause 16 in the draft Technical Guidelines (October 2011) states that: *“For each month a range of thresholds is used to consider the year-to-year natural variation of water availability. In case of a **wet year**, the **minimum monthly flows** will be maintained at the upper bound while the lower bound will be applied in case of a **dry year**. In average, the minimum monthly flow should be **maintained between the threshold ranges**.”* This statement is imprecise in a number of respects.

What is meant by **minimum monthly flows**? It could be understood that it is the lowest of the fifteen mean monthly flows predicted for each calendar month within the 15-year (1985-2000) output simulated from the MRC Decision Support Framework (DSF) for the scenario under consideration. In discussions with the National PMFM Experts, it was clarified (and later confirmed by the TRG) that is meant: *‘the mean over 15-year of monthly mean flows’*, resulting in one monthly value for each calendar month within the 15-year period simulated by the DSF whereby the monthly mean flow is the mean of the daily flows within a specific month in a specific year, resulting in 15 monthly values for each calendar month within the 15-year period simulated by the DSF.

The statement that minimum monthly flow should be **maintained between the threshold ranges** considered (Option 1 is ARI 1:4-1:5 and Option 2 is FDC 80-90%) may be interpreted as applying an upper limit to acceptable changes of dry season flows. This appears to be potentially inconsistent with the PMFM, in so far as such a condition may go beyond the requirements of the Procedure (that requires minimum flow thresholds) and inconsistent with the realities in the basin that are leading to increased dry season flows without any needs (and means) to maintain flows between the narrow range of the two options (see Section 2.3). In discussions with the National PMFM Experts and the TRG, it became clear that most see the currently considered alternative minimum flow frameworks as four single sets of minimum flow frameworks: ARI 1:4, ARI 1:5, FDC 80% and FDC 90% instead of ranges.

What is meant by a **wet year** and a **dry year**? These would need to be defined in order to apply the conditions referred to above (so that these can be identified and confirmed in the Baseline Scenario of 1985-2000). This is a non-issue if minimum flow frameworks are considered that consist of a single minimum flow framework instead of range with upper and lower flow frameworks.

flow that is not equalled or exceeded one in five years in the record under consideration. In this case, a Lognormal distribution is used in the calculation of the ARI. In the context of the ARI, the mean flow is equal to the flow of 50% probability of exceedance.

³ Flow Duration Curve (FDC) is a graphical representation of a ranking of all the flows in a given period, from the lowest to the highest, where the rank is the percentage of time the flow value is equalled or exceeded. For instance, the 80% exceedance value is the monthly mean flow in a particular month that is exceeded for 80% of the recorder under consideration. In the context of the FDC, the median flow is the flow corresponding to 50% exceedance.

Clause 17 in the draft Technical Guidelines (October 2011) states that: “A *considered scenario could NOT be deemed acceptable for planning purposes (under the provisions of Section 5.1.1 of the PMFM) if the simulated **monthly flow** by the DSF is below lower bound for one or more months of the dry season at one or more of the selected hydrological station.*” This statement is also imprecise.

The statistics of the simulated scenario flow to be compared with the minimum flow framework(s) is stated only as the **monthly flow**. Is it intended that this should be the mean monthly flow (see previous point) or the statistics equivalent to the minimum flow frameworks in question (i.e. ARI 1:5 or FDC 90%)? In other words, in determining whether a development scenario is acceptable, would the monthly mean simulated scenario flow be compared with the **minimum flow frameworks** (i.e. ARI 1:5 or FDC 90%)? Or would the 1:5 ARI or 90% FDC of the simulated scenario flow be compared with the minimum flow frameworks (ARI 1:5 or FDC 90%)? In discussions with the National PMFM Experts and the TRG members, it was clarified that the monthly mean simulated flow for the 15-year output of the DSF should be compared with the currently considered minimum flow frameworks. The disadvantage, however, is that two different parameters are compared (i.e. the mean with the ARI or FDC).

Clarity is essential, otherwise the interpretation of how the draft Technical Guidelines is to be applied may differ between the Member Countries, which could lead to paralysis in decision-making on development plans.

2.3 Review of alternative minimum flow frameworks for Article 6A for planning purposes

Extensive testing of the considered alternative minimum flow frameworks for Article 6A for planning purposes has been carried out during the last years and reported in the PMFM Supplementary Information Report (June 2011) and the PMFM Comprehensive Information Report (October 2013). The main results are summarized below. Further details can be found in the PMFM Comprehensive Information Report, especially in Chapter 9 and Annex H.

The testing of the considered alternative minimum flow frameworks has been made *with and without the consideration of flow augmentation* by the flow redistribution from the wet season to the dry season. This flow redistribution is believed to be associated with operation of storage dams in the Upper Mekong River and on tributaries of the Lower Mekong River.

Without consideration of flow augmentation from the Upper Mekong River

An assessment has been made of the magnitude of each of the four considered minimum flow frameworks (ARI 1:4, ARI 1:5, FDC 80%, and FDC 90%) compared to the mean monthly flows at each of the mainstream hydrological stations. The results for all of these stations are shown graphically in Annex H of the PMFM Comprehensive Information Report.

At all hydrological stations, it is generally agreed that the ARI 1:4 represents the greatest value of the four frameworks for most of the months in the dry season. The ARI 1:4 varies between 12% at Chiang Saen and 17% at Tan Chau (Chau Doc is in fact higher at 36%) below the mean monthly flow

from the DSF for 1985-2000. As shown in Figure 1, at Kratie, the ARI 1:4 is 12% lower than the mean monthly flow in March (lowest month).

Thus, if the current draft Technical Guidelines for Article 6A for planning purposes were applied in a manner that the **mean monthly simulated flow of the development scenario is compared to one of the four considered minimum flow frameworks**, the implication is that some scenarios that reduced the mean monthly baseline flow would be deemed acceptable. For example, if the selected flow framework was the ARI 1:4, a reduction of 12-17% in mean monthly flows would be considered acceptable. Broadly speaking, if any of the other flow frameworks were selected under this interpretation, then the permissible reduction in mean monthly baseline flows would be somewhat greater.

As noted in the previous Section, it seemingly appears that the intent under the draft Technical Guidelines is not to specifically preserve the mean monthly flows. *If this were to lead to a reduction in the mean monthly flows in the dry season, then the consequences (in the absence of flow augmentation) are two-fold: (1) upstream water users would be able to invest in some new developments that increase abstractions from the mainstream and tributaries and (2) saline intrusion would increase within the Mekong Delta.* Details on the increase of saline intrusion are provided in the PMFM Comprehensive Information Report.

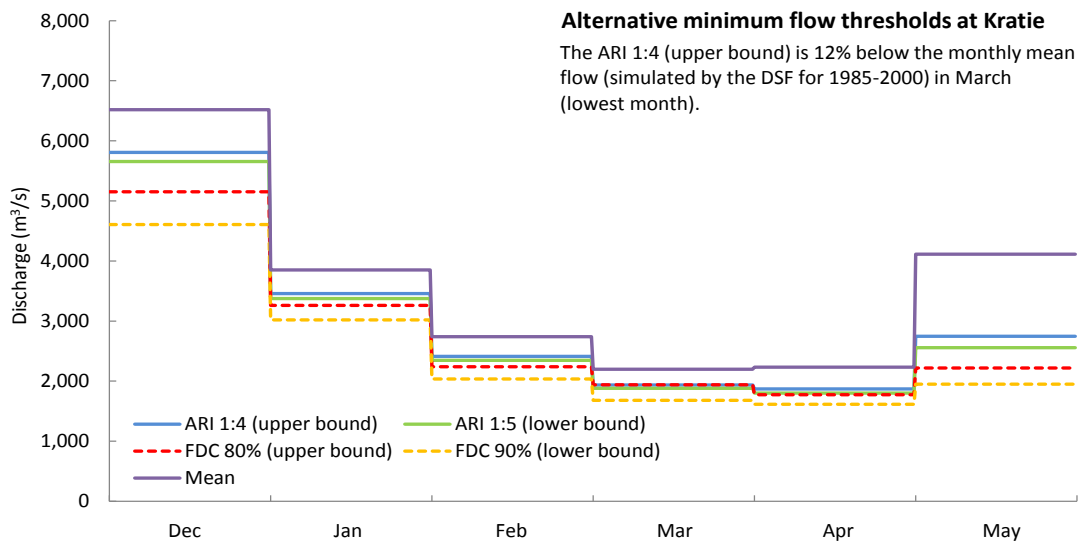


Figure 1. Alternative minimum flow frameworks for Article 6A for planning purposes, compared to the mean monthly flows simulated by the DSF for Baseline Scenario of 1985-2000.

With consideration of flow augmentation from the Upper Mekong River

There is apparently flow augmentation through redistribution of wet season flows to dry season flow by the storage dams on the Lancang Cascade in the Upper Mekong Basin and the increasing number of storage dams on the tributaries in the Lower Mekong River (in order to maximise the generation of hydro-electricity). Since the beginning of the dry season of 2012/2013, flow augmentation has been witnessed in most hydrological stations from Chiang Saen down to Kratie, as described in Chapter 3.

To study the future impact of the flow augmentation, an assessment has been made of three of the existing basin-wide scenarios against the alternative minimum flow frameworks that are being considered for Article 6A for planning purposes. The scenarios used are:

- **The Baseline Scenario**, being conditions related to the reference period for hydrology (1985-2000 and development conditions in 2000);
- **The Definite Future Scenario**, related notionally to 2015 after the two large storage dams in the Upper Mekong Basin have become operational and ongoing tributary dams construction is completed, but with year 2000 water demands (the currently witnessed increases in dry season flow are in line with the assessment of this scenario in 2009-2010); and
- **The 20-Year Plan Scenario (2030)**, including mainstream dams in the LMB, an expansion in tributary dams and increased water supply and irrigation abstraction, all reflecting country perspectives on their development plans within this period.

As depicted in Figure 2 and Figure 3, three sites have been selected to illustrate the assessments, being Chiang Saen (most upstream station of the Lower Mekong Basin), Kratie (upstream of the major floodplains of Cambodia and Viet Nam), and Tan Chau (most downstream station).

For each scenario and at each hydrological station, daily simulated flow from the DSF has been converted to monthly means, resulting in 15 monthly means for each month in the dry season at each station. The minimum of these 15 monthly means was then identified. In addition, the mean of the 15-year of monthly mean flows was also calculated. In conducting these calculations, no years were excluded on grounds of being wet or dry years.

At each hydrological station, the results have been compared with the considered minimum flow frameworks for Article 6A for planning purposes: ARI 1:4, ARI 1:5, FDC 80%, and FDC 90%. The results are shown below in Figure 2 for the Definite Future Scenario (2015) and in Figure 3 for the 20-Year Plan Scenario (2030).

From this analysis and further detailed discussion in Chapter 9 of the PMFM Comprehensive Information Report, the following conclusions have been drawn. They were initially introduced at the 11th TRG Meeting (December 2013) and in more detail discussed during the 12th TRG Meeting (April 2015):

- The difference between the four alternative minimum flow frameworks (ARI 1:4, ARI 1:5, FDC 80%, and FDC 90%) is small. The difference is within the error margin of the accuracy, with which scenarios can be modelled and assessed. Any of the four flow frameworks can be chosen as it will result in similar basin planning decisions and future mainstream flow conditions. Moreover, instances where any of these flow frameworks will be transgressed in the dry season in future will become very rare irrespective of which flow framework is selected.
- The approach based on the monthly Flow Duration Curve (FDC) is the more robust of the two since it is based on the observed data and is simple to replicate. The Annual Recurrence Interval (ARI) requires the fitting of a probability model, in this case a Lognormal distribution, which makes it less straightforward (it requires assumptions and is sometimes subjective). It evidently appears to have no advantage in terms of the

results. Thus, the FDC can be a robust option: either the FDC 80% or FDC 90% can be selected as the difference is relatively small.

- At the 12th TRG Meeting, the testing results were presented and also showed that the mean monthly flow of Baseline Scenario (1985-2000) could also consider as a minimum flow framework: the **mean**, which is the mean monthly flows of the 15-year, simulated by the DSF. As depicted in Figure 2 and Figure 3, the mean (even if higher than the ARI and FDC at all hydrological stations) would be rarely transgressed in the future.

Some members of the TRG noted that **the mean** has the following advantages:

- The mean is *easier to understand and replicate* by relevant stakeholders; and
- The *'like-for-like' comparison* (the mean monthly flows in a given scenario are compared to mean monthly flows in Baseline Scenario) minimises the errors in the assessment.

In conclusion, any of these alternative minimum flow frameworks can be chosen: ARI 1:4, ARI 1:5, FDC 80%, FDC 90% or the mean. The outcomes in terms of basin planning and mainstream flow conditions will generally be the same. During the 12th TRG Meeting, Cambodia and Viet Nam indicated their preference for the 'mean' for setting minimum monthly flow framework for the Article 6A for planning purposes. Additionally, Lao PDR agreed that there was no need for a range of flow frameworks. Also, Lao PDR supported a simpler method.

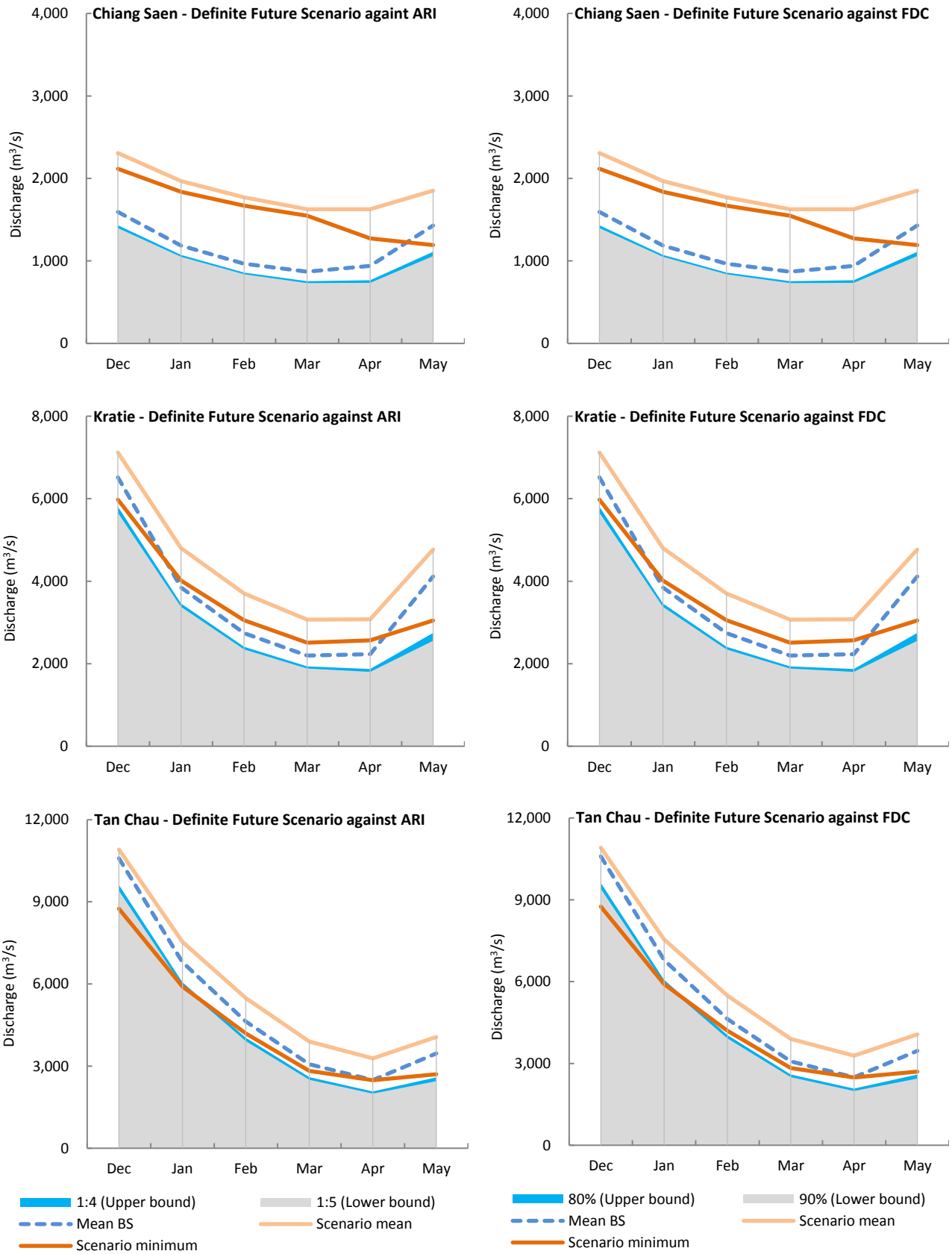


Figure 2. Assessment of Definite Future Scenario (2015) against alternative flow frameworks for Article 6A for planning purposes. It is important to note that vertical scale of Kratie and Tan Chau is 2-time and 3-time higher than that of Chiang Saen, respectively. 'Mean BS' is simulated mean monthly flows of the Baseline Scenario of 1985-2000. 'Scenario mean' and 'Scenario minimum' are simulated mean and minimum monthly flows of the Definite Future Scenario, respectively.

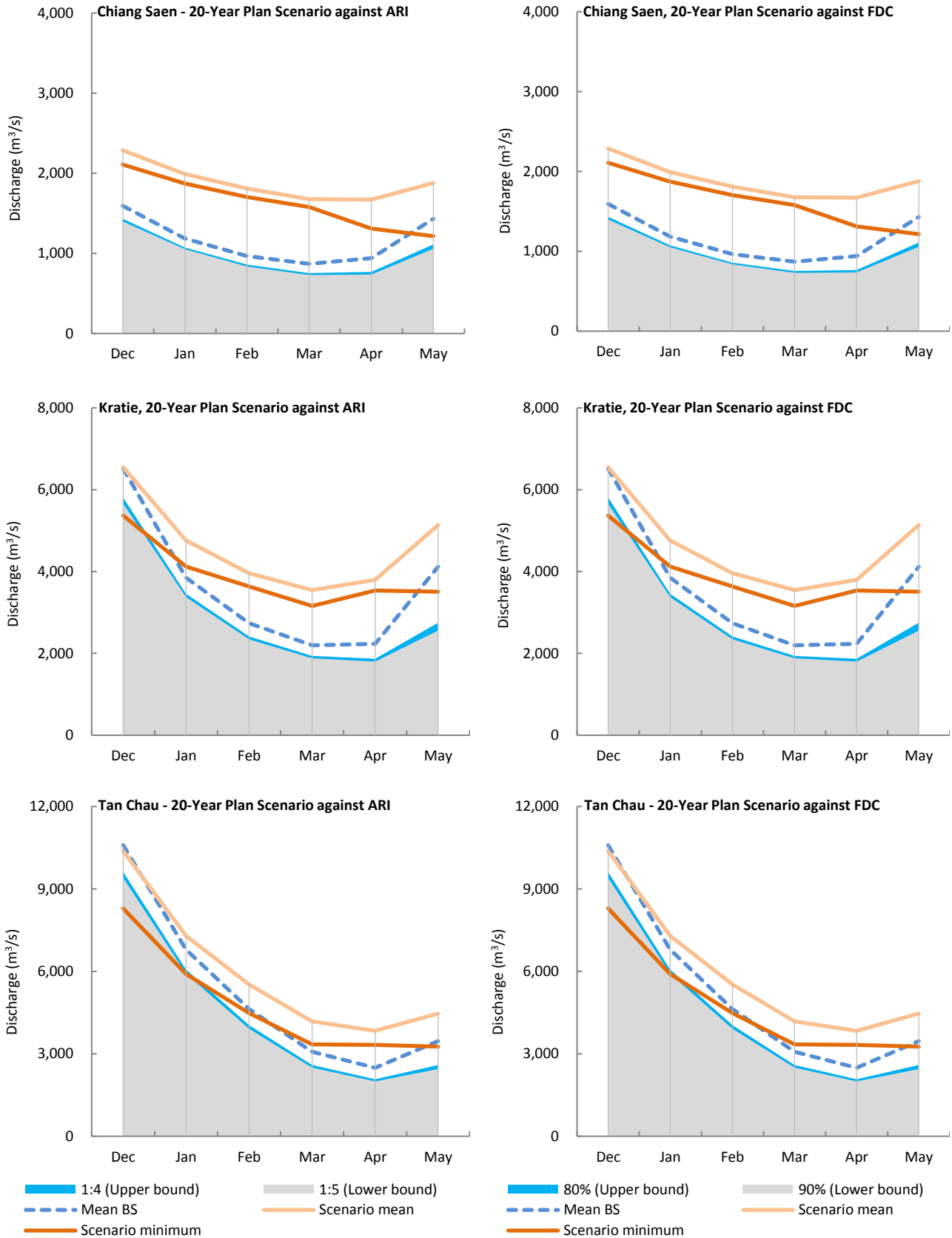


Figure 3. Assessment of 20-Year Plan Scenario (2030) against alternative flow frameworks for Article 6A for planning purposes. It is important to note that vertical scale of Kratie and Tan Chau is 2-time and 3-time higher than that of Chiang Saen, respectively. ‘Mean BS’ is simulated mean monthly flows of the Baseline Scenario of 1985-2000. ‘Scenario mean’ and ‘Scenario minimum’ are simulated mean and minimum monthly flows of the 20-Year Plan Scenario, respectively.

3 IMPLEMENTATION OF THE PMFM FOR MONITORING PURPOSES

This chapter summarises the methodology using in flow monitoring, analysis results and experiences of implementing the PMFM for monitoring purposes during 2011-2015. Several references are made to other documents for further detailed information.

3.1 Application of the draft Technical Guidelines for the monitoring purposes

The PMFM for monitoring purposes requires three flow frameworks (for Articles 6A, 6B and 6C) to enable appropriate actions to be developed and activated during critical periods of flow deficiency and excess. As stipulated in the draft Technical Guidelines (October 2011), eleven⁴ hydrological stations (Table 2) are selected, based on the hydro-geographic reach analysis, for monitoring flow on the Mekong mainstream during the dry season for Article 6A and during the flood season for Article 6C of the 1995 Mekong Agreement. Amongst these hydrological stations, Kampong Luong on the Tonle Sap Lake, Prek Kdam on the Tonle Sap River and Phnom Penh Port on the Tonle Sap River (newly proposed to the list of the selected hydrological stations) are specifically selected for monitoring the acceptable natural flow of the Tonle Sap Lake during the wet season for Article 6B. Location of the selected hydrological stations is illustrated in Figure 4.

Water level of the selected hydrological stations was sent to the MRC Servers (which synchronised between the two offices of the MRCS) on a **weekly basis** (which contains seven-day values of the previous week) during **the dry season monitoring** (Dec to May) and **daily basis** during **the flood season monitoring** (Jul to Oct).

Rated discharge of the monitoring stations are derived from observed water level using newly developed rating curves by taking advantages of ‘*Discharge and Sediment Monitoring Project for 2008-2014*’, implemented by the Information and Knowledge Management Programme (IKMP). The rating curves, their range of applicability and performance analysis are presented in Table 3. Detailed methodology and analysis technique for the rating curves can be found in Someth et al⁵.

⁴ Later in this Chapter, Phnom Penh Port station is proposed to be added to the list of the selected hydrological stations. Therefore, there are in total twelve key hydrological stations.

⁵ Someth P., Seebacher F., Khem S., Kong S., Preap S. (2013). Rating curves for mainstream and tributaries of the Mekong River, Information and Knowledge Management Programme (IKMP), Mekong River Commission Secretariat (MRCS).



Figure 4. Location of the selected hydrological stations.

Table 2. Selected hydrological stations and their hydro-geographical features.

No	Station	Country	Drainage area (km ²)	River	Observed data	Hydro-geographical features
1	Chiang Saen	Thailand	189,000	Mekong River	1962-2014	Recognised as transboundary station
2	Vientiane	Lao PDR	299,000	Mekong River	1962-2014	Key station above the Nam Ngum confluence
3	Khong Chiam	Thailand	419,000	Mekong River	1967-2014	Upstream of Kong-Chi-Mun confluence
4	Pakse	Lao PDR	545,000	Mekong River	1962-2014	Downstream of Kong-Chi-Mun confluence
5	Stung Treng	Cambodia	635,000	Mekong River	1962-2014	Transboundary flow monitoring for Lao PDR and Cambodia
6	Kratie	Cambodia	646,000	Mekong River	1962-2014	Key station for Article 6B
7	Chrouy Changvar	Cambodia	663,000	Mekong River	1969-2008	Key station for Cambodia floodplain
8	Phnom Penh Port ^a	Cambodia	-	Tonle Sap River	1997-2014	Key station for Article 6B
9	Prek Kdam	Cambodia	-	Tonle Sap River	1997-2014	Key station for Article 6B
10	Kampong Luong	Cambodia	-	Tonle Sap Lake	1997-2014	Key station for Article 6B
11	Tan Chau	Viet Nam	760,000	Mekong River	1981-2014	Transboundary flow monitoring for Cambodia and Viet Nam
12	Chau Doc	Viet Nam	760,000	Bassac River	1981-2014	Transboundary flow monitoring for Cambodia and Viet Nam

^a This station is proposed in this report to be included in the list of the selected hydrological stations for monitoring reverse flow to the Tonle Sap Lake for Article 6B.

Table 3. Rating equations for some selected hydrological stations, their range of applicability and performance evaluation.

No	Station name	Rating equation	Water level ^a (m)		Discharge ^a (m ³ /s)		Zero gauge ^b (m msl)	Performance evaluation ^c			
			Max	Min	Max	Min		RMSE	MEPE	NASE	CODE
1	Chiang Sean	$Q = 213.182(H+0.578)^{1.747}$	6.80	1.43	6,977	720	+357.11	158	0.051	0.991	0.991
2	Vientiane ^d	$Q = 71.784(H+3.062)^{1.994}$	11.49	0.54	15,928	884	+158.04	400	0.058	0.989	0.989
3	Khong Chiam	$Q = 376.760(H+1.112)^{1.673}$	15.72	1.54	43,599	2,038	+89.03	880	0.057	0.993	0.993
4	Pakse	$Q = 1141.292(H+0.808)^{1.364}$	12.23	0.60	41,827	1,924	+86.49	907	0.052	0.993	0.994
5	Stung Treng	$Q = 2180.085(H-1.234)^{1.360}$	9.68	2.22	39,971	2,232	+36.79	328	0.021	0.999	0.999
6	Kratie	$Q = 199.671(H-2.658)^{1.835}$	20.44	5.96	41,590	1,638	-1.08	711	0.044	0.996	0.996

^a Range of applicability of the rating equations after being applied the Least Square Fitting technique.

^b Zero gauge above the mean sea level (msl) with different national datum (Hatien for Cambodia and Lao PDR, Hondau for Viet Nam, and Kolak for Thailand).

^c RMSE is Root Mean Square Error (in m³/s); MEPE is Mean Percentage Error; NASE is Nash-Sutcliff Efficiency; CODE is Coefficient of Determination.

^d Rated discharge at Nong Khai (derived from observed water level at Nong Khai) is used to represent discharge at Vientiane as the rating curves at Vientiane cannot comprehensively developed and both hydrological stations are only 30 km apart and there is no obvious inflow to and outflow from the reach.

It is noted that the rating equations presenting in this report is slightly different from the ones developed in Someth et al., as the current analysis of the rating equations (in this report) included the recent discharge measurements of 2012 and 2013.

It is widely accepted that estimation of the rated discharge at Vientiane is not always feasible (since the rating curves at Vientiane cannot be comprehensively developed using observed water level and measured discharge for 2008-2014). Rated discharge at Nong Khai (derived from observed water level at Nong Khai) is consequently used to represent the discharge at Vientiane, since both hydrological stations are only 30 km apart and there is no obvious inflow to and outflow from the reach. Furthermore, simple rating curves at the stations below Kratie cannot be developed as those stations are influenced by tidal effect of the sea.

For the purposes of this report, **flow analysis in the context of the PMFM were conducted for both daily observed water level and rated discharge for 2008-2014**, which is the same period as taken for the rating curves analysis.

To insure a pleasant browsing through this report, especially this Chapter, it is critically important to note the following conventions:

- The dry season is from 1 December to 31 May (6 months). In this case, the dry season of 2008 covers 1 December 2007 to 31 May 2008.
- The wet season is from 1 June to 30 November (6 months). Likewise, the flood season is from 1 July to 31 October (4 months). For example, the wet season of 2010 covers 1 June 2010 to 30 November 2010.
- Daily observed water level at a given year is represented by 'H' with [YEAR], while daily rated discharge is represented by 'Q' with [YEAR]. For instance, 'H2013' means daily observed water level in 2013. Additionally, the water level presented in this report is referenced to the national datum of the Member Countries (Hatien for Cambodia and Lao PDR, Hondau for Viet Nam, and Kolak for Thailand).

3.1.1 *Article 6A – acceptable minimum monthly natural flows during the dry season (December to May)*

Article 6A of the 1995 Mekong Agreement concerns the maintenance of the flows on the mainstream of *not less than the acceptable minimum monthly natural flows during the dry season*. The flow framework for real time monitoring purposes during the dry season comprises of the **ARI 1:5, ARI 1:10 and ARI 1:20 of the historically daily flows (observed water level or rated discharge⁶)**,

⁶ For the tidally influenced **Chrouy Changvar, Tan Chau and Chau Doc** stations, only the **daily observed water level** are used.

usually the period of **1960-2009**, at each of the selected hydrological stations along the mainstream, and using smoothed values⁷.

The daily observed water level and rated discharge from **1 December to 31 May** (the dry season) at the selected hydrological stations are compared with the flow frameworks for monitoring purposes. This flow framework is derived from available observed data in the DSF Knowledge Base, which usually covers a period of 1960-2009. The draft Technical Guidelines (October 2011) states that *“there are four zones in this flow framework of increasing drought severity, each involving specific actions.*

- **Zone 1 (green):** *If the daily updated flow lies **above the ARI 1:5**, it means ‘normal hydrological conditions’; there is **no need for action**.*
- **Zone 2 (yellow):** *If the daily updated flow lies **between the ARI 1:5 and ARI 1:10**, it means that hydrological conditions remain ‘stable’; there is a **need for caution**.*
- **Zone 3 (orange):** *If the daily updated flow lies **between the ARI 1:10 and ARI 1:20**, it means that hydrological conditions are ‘unstable’; investigation should be undertaken to **identify the possible cause(s) and possible mitigation measures**. There is a **need to be on alert**.*
- **Zone 4 (red):** *If the daily updated flow lies **below the ARI 1:20**, it means that hydrological conditions are ‘severe’; the **implementation of mitigating measures** should be considered.”*

As examples of flow monitoring for Article 6A, Figure 5, Figure 6, and Figure 7 depict flow pattern for 2008-2014 observed at Chiang Saen, Pakse and Stung Treng, respectively. Graphical presentation of flow pattern of other selected hydrological stations for Article 6A can be found in Appendix A.

Daily observed water level and rated discharge characteristics of the Mekong mainstream for the dry season between Chiang Saen to Pakse follows the flow pattern observed in Chiang Saen as the flow pattern is not typically perturbed by runoff generated from intense rainfall, which does not usually occur in the basin during the dry season. The pattern becomes smoother and less variable as the Mekong River entering Cambodia, at Stung Treng. A summary of number of days in four zones of flow framework of Article 6A for monitoring purposes of some selected hydrological stations for the dry season of 2008-2014 is presented in Table 4 for observed water level and Table 5 for rated discharge. The hydrological condition of the mainstream applied monitoring flow framework for Article 6A for the dry season can be described as follows.

2008: Hydrological condition of most of the selected hydrological stations was considered normal, as daily observed water level and rated discharge was most of the time in Zone 1, except for a few transgressions into Zone 2 of the observed water level for the stations from Vientiane to Pakse, and of the rated discharge for Stung Treng.

⁷ All curves have been smoothed to produce more useful reference values for indicating the trends in the various thresholds through the dry season. The smoothing was done by taking the 30-day moving average of the daily values, i.e. the value of a given day is the average of the values of the previous 15 days and the next 15 days (including the given day).

2009: There were no flow transgressions. Both observed water level and rated discharge at every hydrological station were most of the time between the historically observed minimum and average.

2010: As stipulated in the draft Technical Guidelines, year 2010 can be considered as historically severe drought as daily observed water level and rated discharge were in Zone 4 (less than the ARI 1:20 of the low water level or discharge) for most of the selected hydrological stations, as presented in Table 4 and Table 5, and as depicted in Figure 5, Figure 6 and Figure 7. It is reported that rainfall between January and March, at Chiang Saen, Luang Prabang, Vientiane and Pakse dropped lower than the long term average of 1966-2009⁸. Moreover, the dry period of 2010 was longer than usual as the southwest Monsoon in 2009 withdrew six weeks earlier (further information can be found in flow monitoring in the flood season for Article 6C for 2009) and the southwest Monsoon in 2010 started four weeks later⁹ (further details can be seen in flow monitoring in the flood season for Article 6C for 2010). Severe drought condition was confirmed by an analysis of flow of two major tributaries of the Mekong River in Lao PDR, the Nam Ou and Nam Khan, for January-February. Flows of Nam Ou were the lowest in historically observed records of 1985-2003, while those of Nam Khan were unprecedentedly low for 1960-2005. Low flow situation was consequently observed at most of the selected hydrological stations along the Mekong mainstream. This situation evidently reflected the regional hydrological drought conditions in the Lower Mekong Basin. The sudden drop in the flows at Chiang Saen in mid-February was caused by the sharply reduced releases from Lancang Hydropower Cascade. An assessment reveals that the operators of the cascade used storage to maintain higher than the low natural flows through to mid-February but then had to reduce the releases. This reduction appeared to have further contributed to the regional hydrological drought. Hence, flow transgressions down to Zone 4 at most of the hydrological stations were seen from mid-February to mid-March, which are usually the driest months of the year.

2011: Normal hydrological conditions were observed at most of the hydrological stations. There were few flow transgressions at different hydrological stations: water level transgressions at Vientiane in January and February and discharge transgressions at Stung Treng in early January and early February (as shown in Figure 7). It is suggested that high flows from March to May observed at Chiang Saen were not a common dry season flows and considerably influenced by flows released from the reservoirs in the Upper Mekong Basin¹⁰. Moreover, two rapid fluctuations (similar amplitude rise/fall events of about 1 m or 900 m³/s in 3 days) at Chiang Saen were recorded on 12-19 December 2010 (from 359.54 m or 1,460 m³/s to 360.44 m or 2,306 m³/s) and 11-16 January 2011 (from 359.35 m or 1,303 m³/s to 360.06 m or 1,929 m³/s).

⁸ Mekong River Commission (2010). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Fifteenth Dialogue Meeting, 27 August 2010, Phnom Penh, Cambodia.

⁹ Mekong River Commission (2011). Annual Mekong Flood Report 2010. Mekong River Commission, Vientiane, 76 pages.

¹⁰ Mekong River Commission (2011). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Sixteenth Dialogue Meeting, 29 August 2011, Vientiane, Lao PDR.

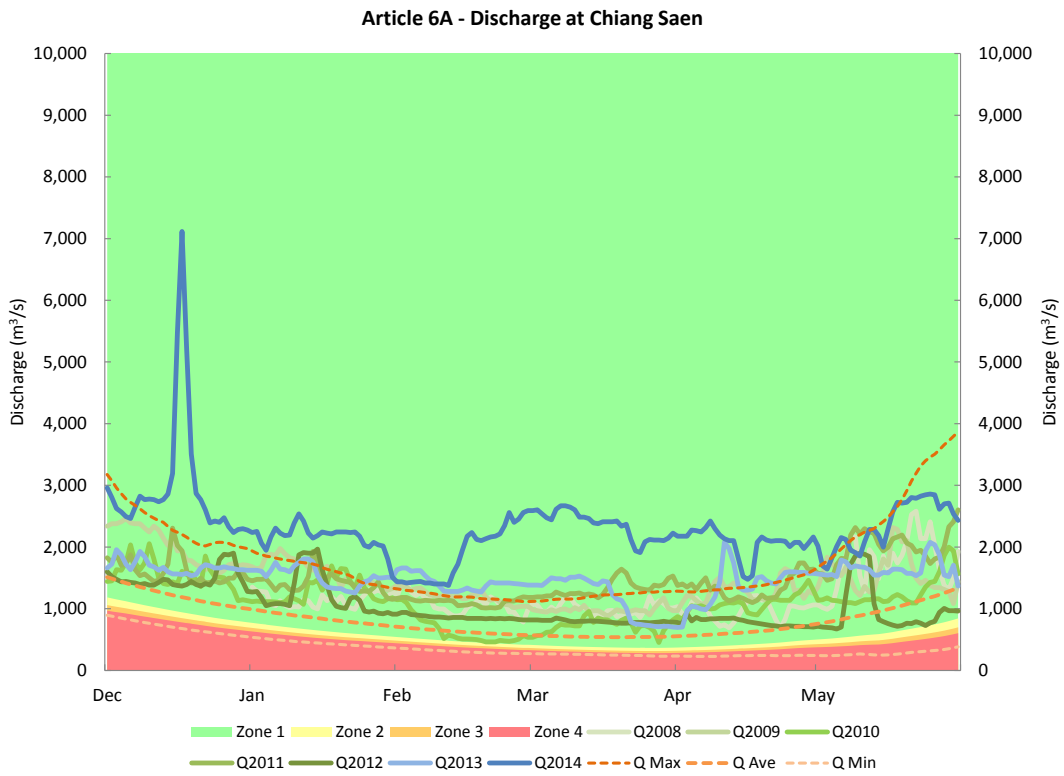


Figure 5. Daily flow monitoring for Article 6A at Chiang Saen for 2008-2014.

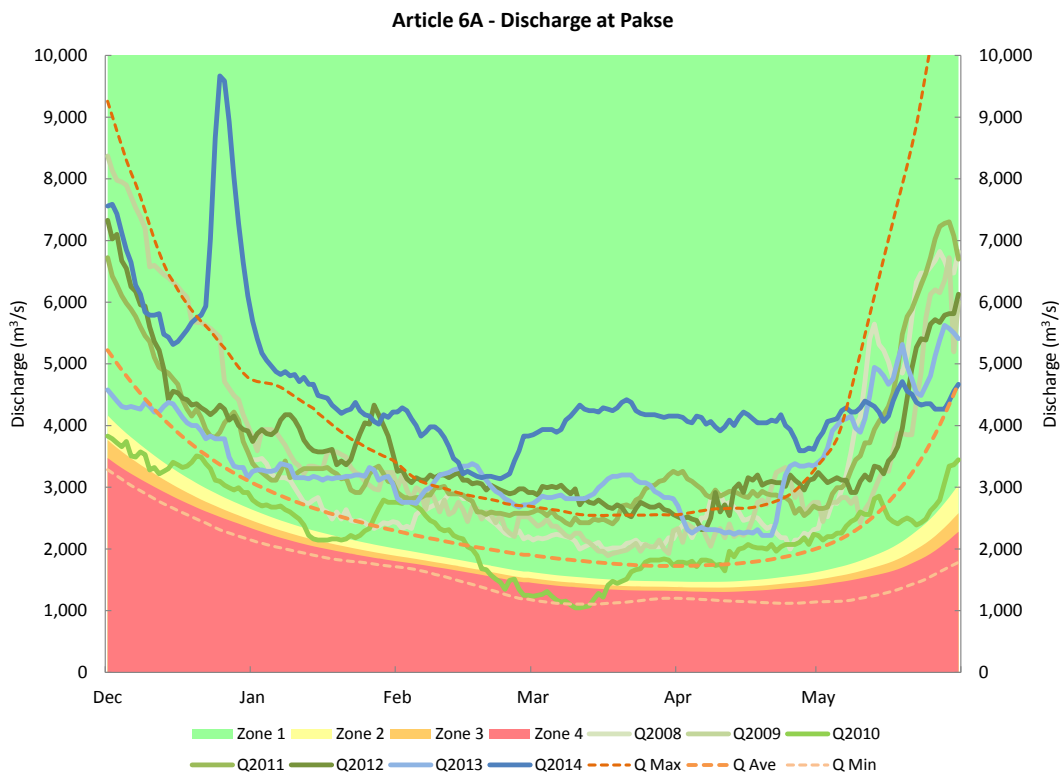


Figure 6. Daily flow monitoring for Article 6A at Pakse for 2008-2014.

2012: Regulation of flow pattern seems obvious from this year as depicted in Figure 5. At Chiang Saen, daily observed water level and rated discharge were almost constant (about 800 m³/s) with three peaks (on 22-30 December 2011 from 359.48 m or 1,409 m³/s to 360.01 m or 1,882 m³/s in 4 days, 9-19 January 2012 from 359.02 m or 1,048 m³/s to 360.00 m or 1,872 m³/s in 2 days, and 6-17 May 2012 from 358.51 m or 702 m³/s to 359.98 m or 1,853 m³/s in 3 days). The three peaks of similar amplitude, which were clearly observed down to Kratie, are widely accepted to be directly associated with the release from the reservoirs in the Upper Mekong Basin. This regulated pattern is not natural and unprecedented in historically observed records at Chiang Saen (1962-2014). The sequence of the events can be found in full details in Appendix A. In addition, both water level and discharge at Chiang Saen were above the historically observed average, while flows at Vientiane followed the pattern at Chiang Saen, but were below the historically observed average most of the time in the dry season and about half of the time below Zone 1. At other stations downstream of Vientiane, flows were above the historically observed average almost all the time and stayed close or even higher than the historically observed maximum almost half of the dry season.

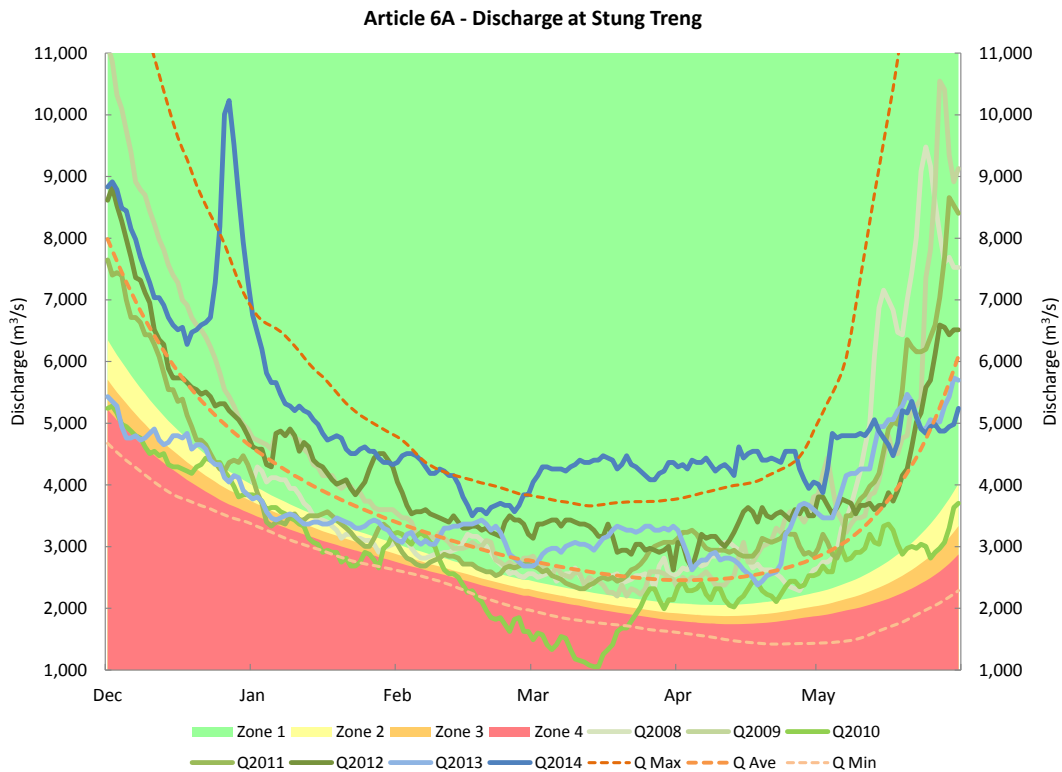


Figure 7. Daily flow monitoring for Article 6A at Stung Treng for 2008-2014.

Table 4. Number of days in the four zones of flow framework of Article 6A for the observed water level in the dry season (Dec-May).

Article 6A	H2008	H2009	H2010	H2011	H2012	H2013	H2014
Chiang Saen							
Zone 1	183	183	170	183	173	183	183
Zone 2	0	0	13	0	10	0	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Vientiane							
Zone 1	170	183	64	122	70	160	183
Zone 2	13	0	29	40	81	14	0
Zone 3	0	0	25	18	13	5	0
Zone 4	0	0	65	3	19	4	0
Khong Chiam							
Zone 1	172	183	83	183	183	178	183
Zone 2	11	0	43	0	0	5	0
Zone 3	2	0	21	0	0	0	0
Zone 4	0	0	36	0	0	0	0
Pakse							
Zone 1	165	183	70	183	183	175	183
Zone 2	18	0	25	0	0	8	0
Zone 3	0	0	27	0	0	0	0
Zone 4	0	0	61	0	0	0	0
Stung Treng							
Zone 1	183	183	154	183	183	174	183
Zone 2	0	0	23	0	0	9	0
Zone 3	0	0	6	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Kratie							
Zone 1	183	183	161	183	183	168	183
Zone 2	0	0	18	0	0	7	0
Zone 3	0	0	4	0	0	8	0
Zone 4	0	0	0	0	0	0	0

Note

Zone 1 (green): If the daily updated flow lies above the ARI 1:5, it means 'normal hydrological conditions'; there is no need for action.

Zone 2 (yellow): If the daily updated flow lies between the ARI 1:5 and ARI 1:10, it means that hydrological conditions remain 'stable'; there is a need for caution.

Zone 3 (orange): If the daily updated flow lies between the ARI 1:10 and ARI 1:20, it means that hydrological conditions are 'unstable', investigation should be undertaken to identify the possible cause(s) and possible mitigation measures. There is a need to be on alert.

Zone 4 (red): If the daily updated flow lies below the ARI 1:20, it means that hydrological conditions are 'severe' and the implementation of mitigating measures should be considered.

Table 5. Number of days in the four zones of flow framework of Article 6A for the rated discharge in the dry season (Dec-May).

Article 6A	Q2008	Q2009	Q2010	Q2011	Q2012	Q2013	Q2014
Chiang Saen							
Zone 1	183	183	183	183	183	183	183
Zone 2	0	0	0	0	0	0	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Vientiane							
Zone 1	183	183	113	183	114	171	183
Zone 2	0	0	23	0	49	1	0
Zone 3	0	0	9	0	6	1	0
Zone 4	0	0	38	0	14	10	0
Khong Chiam							
Zone 1	183	183	132	183	183	183	183
Zone 2	0	0	39	0	0	0	0
Zone 3	0	0	12	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Pakse							
Zone 1	183	183	129	183	183	183	183
Zone 2	0	0	28	0	0	0	0
Zone 3	0	0	3	0	0	0	0
Zone 4	0	0	23	0	0	0	0
Stung Treng							
Zone 1	163	183	62	144	183	139	183
Zone 2	20	0	37	27	0	28	0
Zone 3	2	0	31	10	0	13	0
Zone 4	0	0	53	2	0	3	0
Kratie							
Zone 1	183	183	169	183	183	172	183
Zone 2	0	0	14	0	0	11	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0

Note

Zone 1 (green): If the daily updated flow lies above the ARI 1:5, it means 'normal hydrological conditions'; there is no need for action.

Zone 2 (yellow): If the daily updated flow lies between the ARI 1:5 and ARI 1:10, it means that hydrological conditions remain 'stable'; there is a need for caution.

Zone 3 (orange): If the daily updated flow lies between the ARI 1:10 and ARI 1:20, it means that hydrological conditions are 'unstable', investigation should be undertaken to identify the possible cause(s) and possible mitigation measures. There is a need to be on alert.

Zone 4 (red): If the daily updated flow lies below the ARI 1:20, it means that hydrological conditions are 'severe' and the implementation of mitigating measures should be considered.

2013: Regulated patterns were apparently observed at most of the selected hydrological station and less visible downstream of Stung Treng. Flows were most of the time steady (1,400 m³/s) and higher than the historically observed average and above the historically observed maximum in February and March for the stations upstream of Stung Treng. As clearly observed at Chiang Saen, this steady high flows in February and March, and a large drop in flows between late March and early April, were most likely attributed to operation of the reservoirs in the Upper Mekong Basin, but the water flows remained substantially above the historically observed average flow levels. Specifically, the large drop (change in 1 m or 700 m³/s in 6 days) was recorded on 17-23 March 2013. The flows were kept almost constant for 10 days from 24 March to 2 April 2013, and immediately jumped to a peak (change in 1.3 m or 1,300 m³/s in 4 days) from 3 April to 14 April 2013. Furthermore, downstream of Stung Treng, flows were low at the beginning of December and were between the historically observed average and maximum most of the time of the dry season.

2014: There were no flow transgressions. Both observed water level and rated discharge were most of the time higher than the historically observed maximum at every hydrological station. This elevated flow pattern observed at Chiang Saen (Figure 5) was associated with reservoir operation in the Upper Mekong Basin, which was confirmed by the Chinese Delegation¹¹ in the Second MRC Summit in April 2014. Furthermore, an extreme event (increase in water level of 3 m and discharge of 4,300 m³/s in 4 days) of 13-21 December 2013 was evidently observed at Chiang Saen. The cause of the extreme event was partly attributed to abnormal high rainfall in the northern part of the Lower Mekong Basin, and possibly releases from the reservoirs in the Upper Mekong Basin. Further detailed discussion on the propagation of this extreme peak can be found later in this section. Furthermore, there was a major drop down (0.7 m or 600 m³/s in 3 days) from 29 January to 15 February 2014. Four more drop down periods of the same amplitude as the previous one were also recorded. In addition, a large variation between low and high flows was clearly observed.

Rapid fluctuation events observed in the dry season at Chiang Saen

Being the most upstream hydrological station in the Lower Mekong Basin, Chiang Saen is critically important to capture flow behaviour of the Upper Mekong Basin. Particularly in the dry season, the flow behaviour observed at Chiang Saen can be clearly seen propagating along the mainstream down to Kratie, since rainfall rarely pours down in the Lower Mekong Basin during the dry season to attribute to change in flow pattern downstream of Chiang Saen. Chiang Saen is therefore selected for an analysis of rapid fluctuation of flow characteristics. Remarkable events observed at Chiang Saen for 2008-2014 were specifically discussed above in each year of records.

The extreme event at Chiang Saen on 13-21 December 2013 is unique in historically observed records (1962-2014) of the Mekong River, for at least in December. Using high resolution (15-min) of water level records, the extreme peak was clearly seen until Kratie, as depicted in Figure 8.

The energy of the peak was dissipated by backwater of the Tonle Sap River and tidal effect when approaching the confluence of the Mekong River, Tonle Sap River and Bassac River, at Phnom Penh. The influence of the extreme peak was trivial at Chaktomuk (on the Mekong River) and could not be

¹¹ Mekong River Commission (2014). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Twentieth Meeting of the MRC Council, 26 June 2014, Bangkok, Thailand.

clearly seen at Prek Kdam (on the Tonle Sap River) and at Kampong Luong (on the Tonle Sap Lake). Since the flows from the Tonle Sap Lake dominated the flows in the Mekong River during this period, impact of the extreme peak at Tan Chau and Chau Doc was not visible.

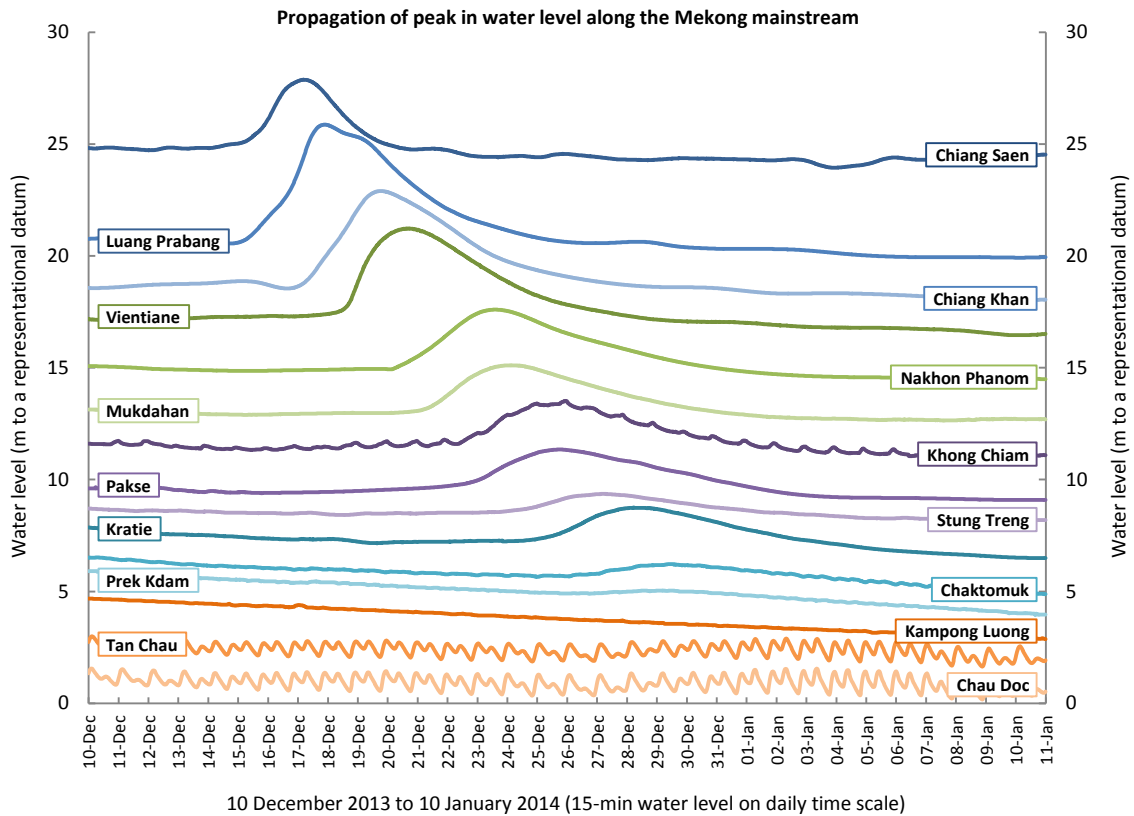


Figure 8. Propagation of peak in water level along the Mekong mainstream from 10 December 2013 to 10 January 2014, using 15-min observed water level. It is critically important to note that water level is referenced to a representational datum for presentation purposes only. Effect of the inflow of the Mun-Chi River on the mainstream flows is observable at Khong Chiam. Regular undulated pattern of water level at Tan Chau and Chau Doc is basically tidal effect of the sea.

It seems that occurrence of rapid fluctuations is increasing since 2012. The change was well associated to the time that the first storage dam of the Lancang Hydropower Cascade, the Xiaowan dam of 4,200 MW with an active storage of 9,800 million m³, was fully in operation, and the Nuazhadu dam of 5,850 MW with an active storage of 12,300 million m³, was in its impoundment period. Provision of hydro-meteorological data and early warning during the dry season in the Upper Mekong Basin would build trust and confidence among the downstream countries that the potential benefits of increased flows as a result of re-regulation by the Lancang Hydropower Cascade can be secured and potential impacts from sudden flow changes mitigated.

Increasing of flow in the dry season

Trends of flow change in the Mekong River have been the interest of the MRC since 1995, when the 1995 Mekong Agreement was signed. Figure 9 presents the trends of flow change in the dry season for 1960-2013 at Chiang Saen, Pakse and Kratie. The figure indicates an increasing trend since 1995¹², which are likely caused by increasing storage volumes behind dams in the Mekong Basin.

More robust increases in dry season flows were apparently observed since the dry season of 2013 at all hydrological stations on the Mekong mainstream every month of the dry season, except for December and May at Stung Treng and Kratie. In the dry season of 2013 and 2014, flows between Chiang Saen and Kratie were above historically observed average levels for a major part of the dry season. At several stations, the flows were above the highest level on record for part of the dry season (as seen Figure 5, Figure 6 and Figure 7). These increases in flows are in line with the flow changes predicted for the Definite Future Scenario in the Assessment of Basin-wide Development Scenarios¹³. The main reason is the reallocation of flows from the wet to dry seasons by the aforementioned two large storage reservoirs on the Lancang Hydropower Cascade, and the filling of the reservoirs in the beginning of the wet season to maximise energy production.

In Figure 10, monthly mean of flows in the dry season of 2013-2014 are compared with those during 2008-2012 and 1960-2009, and with the considered minimum flow frameworks for Article 6A for planning purposes (ARI 1:4, ARI 1:5, FDC 80%, FDC 90% and the mean monthly flows of the Baseline Scenario of 1985-2000). The figure shows that at all stations the observed flows since 2013 are significantly higher than those observed during 2008-2012, which in turn are higher than the flows observed during 1960-2009. The currently considered minimum flow frameworks for Article 6A for planning purposes are generally lower than the historically observed flows of 1960-2009, except for Chiang Saen and Kratie where the observed flows are lower during some dry season months. Furthermore, it can be seen that the 'mean' (an average of the 15 monthly mean flows – one for each year during the 1985-2000, derived from the simulated daily flows in the DSF) is always higher than the ARI and FDC at all stations. Also, the 'mean' would be rarely transgressed in the future due to flow augmentation by the reservoirs in the Upper Mekong Basin, as discussed in Section 2.3.

Hydro-meteorological data and information sharing from China

Provision of hydro-meteorological data and early warning during the dry season in the Upper Mekong Basin would build trust and confidence among the downstream countries that the potential benefits of increased flows as a result of re-regulation by the Lancang Hydropower Cascade can be secured and potential impacts from sudden flow changes mitigated.

¹² Mekong River Commission (2015). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Twenty First Meeting of the MRC Council, 14 January 2015, Hanoi, Viet Nam.

¹³ Mekong River Commission (2011). Assessment of Basin-wide Development Scenarios, Cumulative impact assessment of the riparian countries' water resources development plans including mainstream dams and diversions, Main Report, Mekong River Commission Secretariat (MRCS), Vientiane.

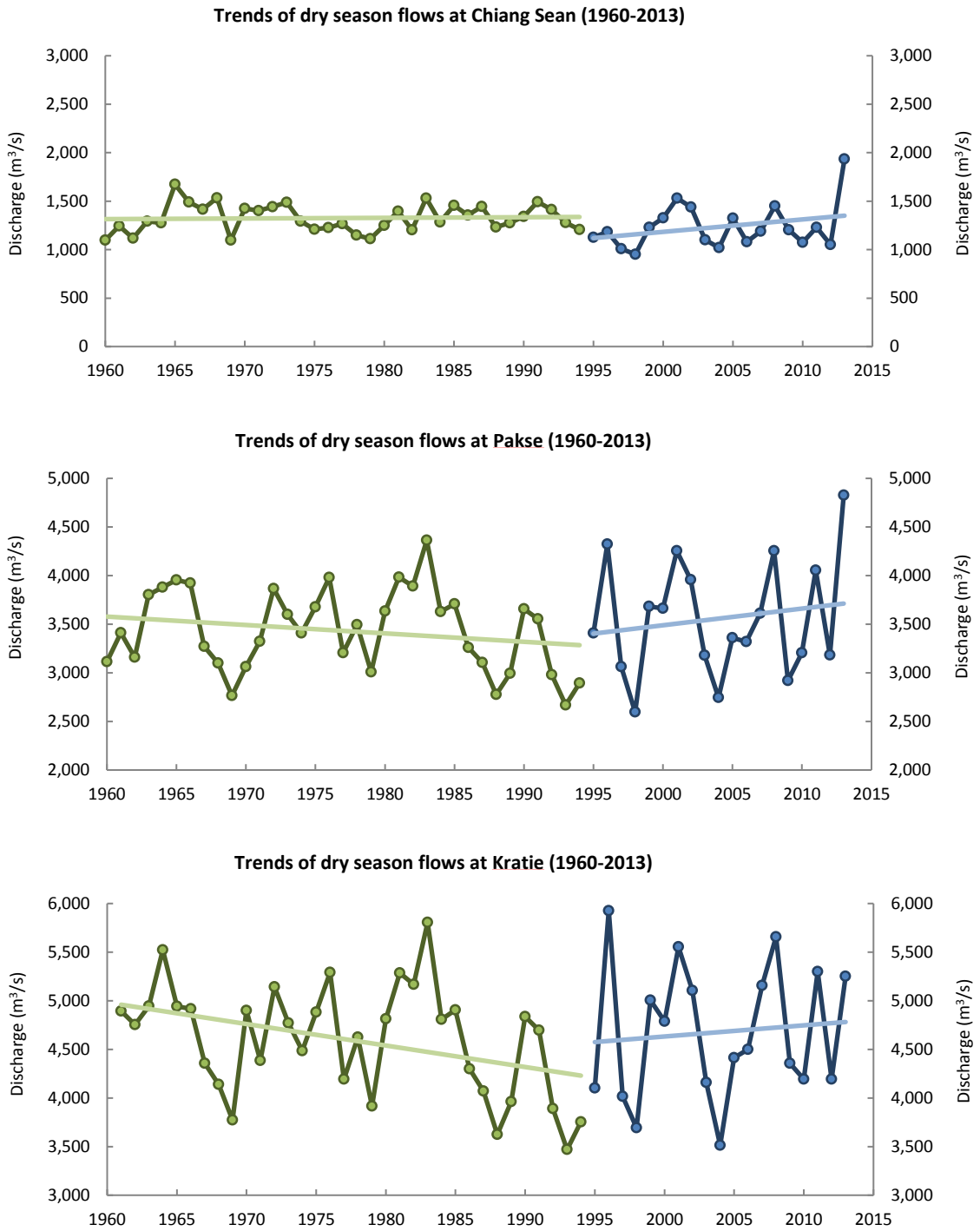


Figure 9. Trends of annual dry season flows at Chiang Saen, Pakse and Kratie for 1960-2013. It is important to note that vertical scale of these graphics is different while its variation range is the same.

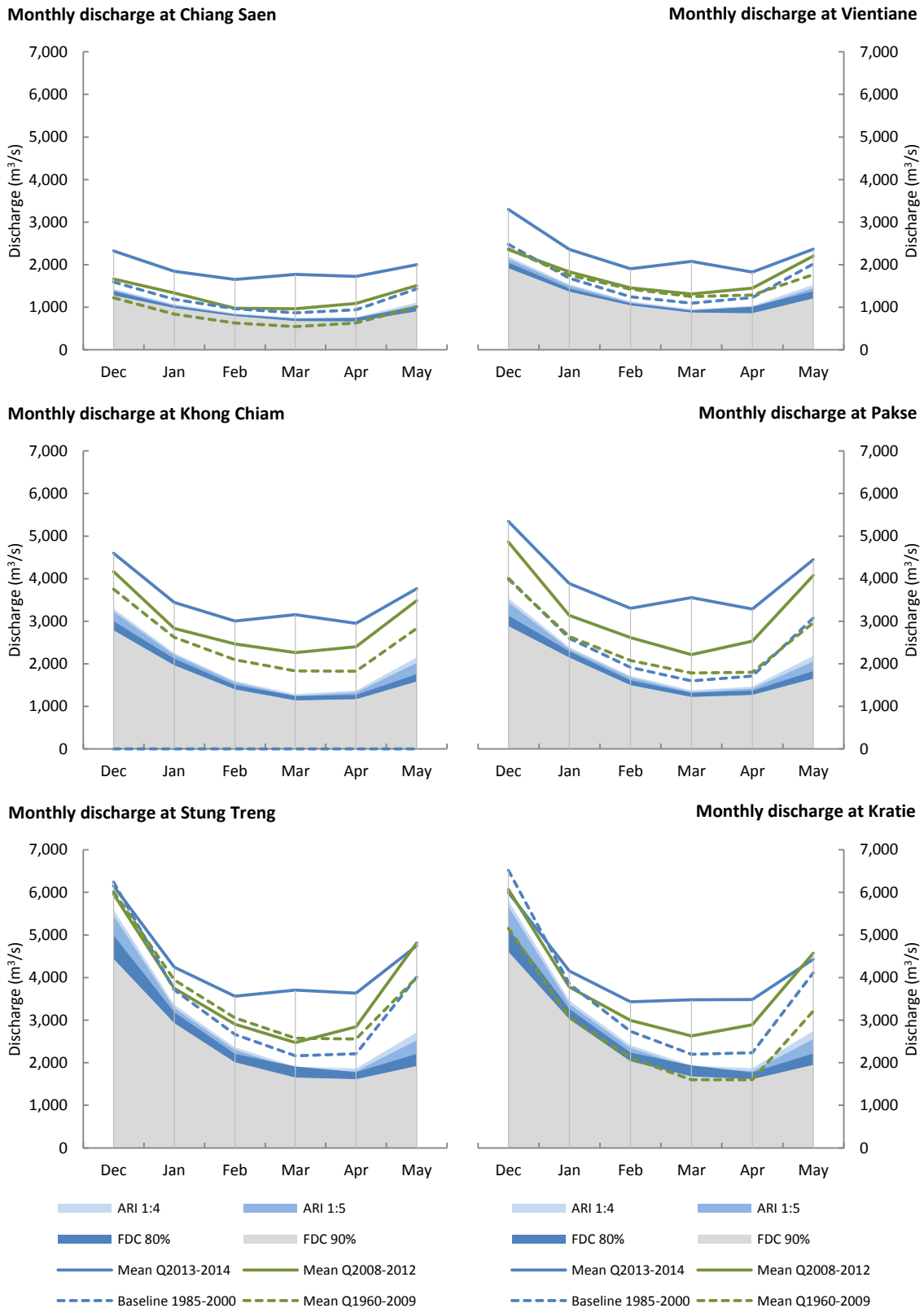


Figure 10. Increasing of flows in the dry season for six hydrological stations along the mainstream, comparing to alternative flow frameworks of Article 6A for planning purposes. ‘Mean Q2013-2014’ and ‘Mean Q2008-2012’ are observed mean monthly flows of 2013-2014 and 2008-2012, respectively. ‘Mean Q1960-2009’ is observed mean monthly flows for long term of 1960-2009, while ‘Baseline 1985-2000’ is simulated mean monthly flows from the Baseline Scenario of 1985-2000.

3.1.2 Article 6B – acceptable natural flows of the Tonle Sap River during the wet season (May to October)

Article 6B of the 1995 Mekong Agreement is to *enable the acceptable natural reverse flows of the Tonle Sap River during the wet season*, which is defined in the 1995 Mekong Agreement as *“the wet season flows in the Mekong River at Kratie that allows the reverse flows of the Tonle Sap River to an agreed upon optimum level of the Tonle Sap Lake.”*

The flow framework for real time monitoring purposes during the wet season is the **historically observed accumulated reverse flows to the Tonle Sap Lake**. The draft Technical Guidelines (October 2011) states that *“the ‘threshold band’ provided by the historically observed maximum and minimum accumulated reverse flow at Prek Kdam will be used as the flow framework to evaluate the daily accumulated reverse flow to the Tonle Sap Lake for monitoring purposes. Furthermore, to determine the accumulated reverse flow volumes at Prek Kdam, the available data at Kampong Luong, Phnom Penh Port and Prek Kdam stations between 1996 and 2005 were used. Although, this period is quite short (10 years) to analyse trend and probability in detail, it included a severe drought event of 1998 as well as a severe flood event of 2000 in Cambodia.”*

As the reserve flow to the Tonle Sap Lake usually occurs from mid-May to mid-October, the accumulated reverse flow is calculated from **1 May to 31 October**, which covers mainly the wet season from June to November, stipulated in the draft Technical Guidelines. In addition, the accumulated reverse flow is computed using a methodology proposed in Background Discussion for the 7th TRG Meeting on the PMFM¹⁴, which was later improved by Kummu et al¹⁵. The calculation methodology is presented below.

Daily accumulated reserve flow to the Tonle Sap Lake is derived from inflow rating equation of the Tonle Sap River at Prek Kdam. The inflow rating equation is based on the index area at Prek Kdam (calculated from observed water level at Prek Kdam) and water level difference between Kampong Luong and Phnom Penh Port referenced to the mean sea level, in this case, to Hatien datum. This hydraulic concept is based on an assumption that water level difference creates a velocity and the velocity is proportional to square root of the water level difference (or hydraulic gradient). Moreover, the inflow rating equation is generated by fitting to a set of 31 discharge measurements between 1998-2006, applied a regression analysis, the Least Square Fitting technique. Finally, the inflow rating equations take form of:

$$Q_{in} = -15.047 \times F^2 + 859.839 \times F - 782.264$$

and

$$F = PKD^{1.2} \times |PPP - KPL|^{0.5}$$

¹⁴ Outlines for the Technical Guidelines of the Procedures for the Maintenance of Flows on the Mainstream (PMFM), Background Discussion for the 7th TRG Meeting on the PMFM, Mekong River Commission Secretariat (MRCS), on 4-5 October 2007, in Vientiane.

¹⁵ Kummu M., Tes S., Yin S., Adamson P., Jozsa J., Koponen J., Richey J., Sarkkula J., (2014). Water Balance Analysis for the Tonle Sap Lake-Floodplain System, Hydrological Processes, Vol 28, p. 1722-1733.

where Q_{in} is inflow to the Tonle Sap Lake in m^3/s ; PKD is the observed water level at Prek Kdam above the mean sea level ($PKD \text{ local datum} + 0.08 \text{ m}$); PPP is the observed water level at Phnom Penh Port above the mean sea level ($PPP \text{ local datum} + 0.07 \text{ m}$); KPL is the observed water level at Kampong Luong above the mean sea level ($KPL \text{ local datum} + 0.64 \text{ m}$).

It is critically important that the inflow rating equations can be only applied when the water level at Phnom Penh Port is higher than that of Kampong Loung.

For the purpose of this report, the daily accumulated reverse flow to the Tonle Sap Lake was computed for the period of available data of 1997-2014 and illustrated in Appendix B. In accordance with the draft Technical Guidelines for the PMFM, the daily reverse flows to the Tonle Sap Lake for 2008-2014 are compared with the historical maximum and minimum band of 1997-2005, which is shown in Figure 11. The draft Technical Guidelines stipulates that *“if the accumulated reverse flow volume at Prek Kdam lies outside of the maximum and minimum thresholds band, it means that hydrological conditions are ‘unstable’, investigation should be undertaken to identify the possible cause(s) and possible mitigation measures. There is a need to be on alert.”*

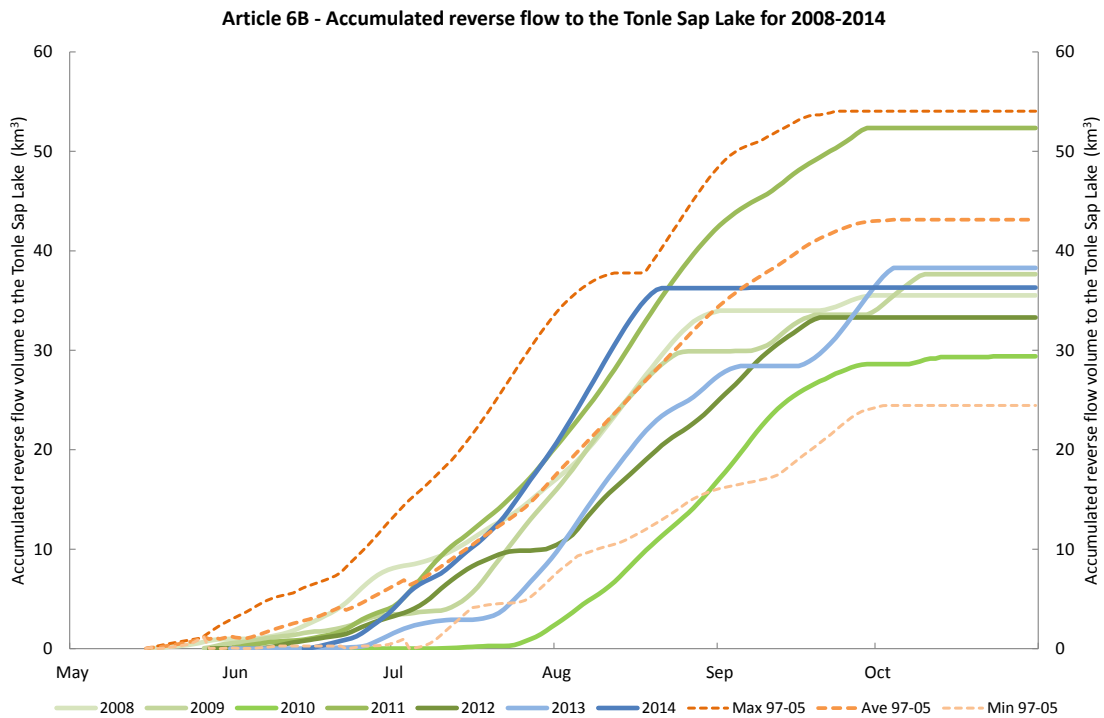


Figure 11. Daily accumulated reverse flows to the Tonle Sap Lake for 2008-2014 comparing to historical maximum and minimum band of 1997-2005.

Figure 11 shows that the accumulated reverse flow to the Tonle Sap Lake for 2008-2014 was usually between the historical maximum and minimum band of 1997-2005 and generally followed the trends of the average. Only in 2010, the flow framework was significantly transgressed in July and August. A summary of the reverse flow characteristics can be seen in Table 6. The main features of the accumulated reserve flow to the Tonle Sap Lake for 2008-2014 are described below.

2008: The reverse flow pattern followed well the trends of the long term average of 1997-2005. The reverse flow to the Tonle Sap Lake started earlier on 16 May and ended on 30 September, with 138 days of reverse flow period, which was considered to be long.

2009: The inflow volume had a shape of increasing three steps, one found in late June and early July, two more between late August and late September. The reverse flow was closely followed the long term average until mid-August and fell below the long term average towards the end of reverse flow season.

2010: The reverse flow started late until 18 June and ended late on 23 October, which was considered to be latest in 18-year calculation. The daily inflow volume was significantly lower than the long term minimum of 1997-2005 till the end of August. The daily inflow volume was then considerably higher than the minimum and followed the shape of the long term average in the rest of the period of the reverse flow. As tabulated in Table 6, the total reverse flow volume is the third smallest in the last 18 years, being 29.40 km³, after the second of 29.23 km³ in 1999, and the first of 24.46 km³ in 1998. This low reserve flow was directly driven by the low flood volume and short period of the flood season at Kratie in 2010 (further details of the low flood volume and short period of the flood season can be seen in flow monitoring in the flood season for Article 6C for 2010).

2011: The daily accumulated flow was most of the time higher than the long term average and approached the long term maximum of 1997-2005 towards the end of the season. The total flow volume is found to be the third largest for 1997-2014, which is 52.36 km³, after the second of 53.72 km³ in 2005 and the first of 54.05 km³ in 2002, as shown in Table 6.

2012: The daily reverse flow volume usually lied between the long term average and minimum and reached to the maximum volume of 33.29 km³, earlier on 20 September.

2013: The daily reverse flow volume was generally between the long term average and minimum until the end of August, except for about a week of mid-July, where the reverse flow was below the long term minimum of 1997-2005. The reverse flow volume was stagnant over two weeks in early September, before continue increasing to the end of the season.

2014: Pattern of the inflow to the lake followed the high inflow pattern of 2011. The period of the reverse flow was shortest, 86 days, in the last 18 years, started late on 14 June and ended early on 7 September. This brought total reverse flow of 36.31 km³.

Absence of hydrological monitoring station around Phnom Penh

There is a need to put Chrouy Changvar Station back online as it is one of the key hydrological stations to monitor hydrological conditions downstream of Kratie and condition of the reverse flow to the Tonle Sap Lake. The hydrological data at the station was interrupted from 2008, because of lack of equipment and a reliable observer. In the 12th TRG Meeting in April 2015, Cambodia announced that the station is again operational and hydrological data from the station will be shared with the MRCS.

Table 6. Summary of accumulated reverse flows to the Tonle Sap Lake for 1991-2014.

Year	Reverse flow duration (days) and inflow volume (km ³)				Lake level (m-msl)			Lake volume (km ³)			Lake area (km ²)		
	Start date	End date	Duration	Inflow	Start level	End level	Amplitude	Starting	Ending	Change	Starting	Ending	Change
1997	03-Jun	18-Sep ^{L*}	108	46.53	1.40	8.77	7.37	1.85	53.99	52.15	2,593	12,615	10,022
1998	04-Jul ^{H***}	03-Oct	92 ^{L**}	24.46 ^{L***}	1.80 ^{H*}	6.70 ^{L***}	4.90 ^{L***}	2.64 ^{H*}	31.33 ^{L***}	28.69 ^{L***}	2,939 ^{H*}	9,324 ^{L***}	6,384 ^{L***}
1999	15-May ^{L***}	01-Oct	140 ^{H**}	29.23 ^{L**}	1.64	8.72	7.08	2.30	53.37	51.08	2,796	12,535	9,739
2000	17-May ^{L**}	20-Sep	127	46.88	1.83 ^{H**}	10.12 ^{H***}	8.29 ^{H**}	2.71 ^{H**}	72.15 ^{H***}	69.44 ^{H***}	2,967 ^{H**}	14,738 ^{H***}	11,771 ^{H***}
2001	29-May	21-Sep	116	49.78	1.58	9.68 ^{H*}	8.10	2.18	65.94 ^{H*}	63.76 ^{H*}	2,744	14,055 ^{H*}	11,310 ^{H*}
2002	27-May	23-Sep	120	54.05 ^{H***}	1.42	9.61	8.19 ^{H*}	1.88	64.98	63.09	2,609	13,945	11,336
2003	01-Jun	01-Oct	123	38.88	1.43	8.11	6.68	1.90	46.09	44.19	2,617	11,560	8,943
2004	02-Jun	27-Sep	118	44.63	1.32 ^{L*}	9.07	7.75	1.72 ^{L*}	57.80	56.08	2,528 ^{L*}	13,092	10,565
2005	22-Jun ^{H**}	04-Oct	105	53.72 ^{H**}	1.49	9.26	7.77	2.01	60.28	58.27	2,668	13,394	10,726
2006	03-Jun	08-Sep ^{L**}	98 ^{L*}	39.29	1.32 ^{L*}	8.38	7.06	1.72	49.25	47.53	2,528	11,992	9,464
2007	17-May ^{L**}	19-Oct ^{H**}	156 ^{H***}	36.66	1.62	8.80	7.18	2.25	54.37	52.11	2,779	12,663	9,884
2008	16-May	30-Sep	138 ^{H*}	35.51	1.59	8.53	6.94	2.19	51.05	48.85	2,753	12,232	9,479
2009	26-May	10-Oct ^{H*}	138 ^{H*}	37.66	1.89 ^{H***}	9.03	7.14	2.85 ^{H***}	57.28	54.43	3,022 ^{H***}	13,029	10,007
2010	18-Jun ^{H*}	23-Oct ^{H***}	128	29.40 ^{L*}	1.31 ^{L**}	7.65 ^{L*}	6.34	1.70 ^{L**}	40.95	39.25	2,520 ^{L**}	10,825	8,305
2011	30-May	29-Sep	123	52.36 ^{H*}	1.53	9.95 ^{H**}	8.42 ^{H***}	2.08	69.71 ^{H**}	67.64 ^{H**}	2,701	14,475 ^{H**}	11,774 ^{H**}
2012	27-May	20-Sep	117	33.29	1.34	7.48	6.14 ^{L**}	1.75	39.14 ^{L**}	37.39 ^{L**}	2,544	10,554 ^{L**}	8,010 ^{L**}
2013	31-May	04-Oct	127	38.29	1.27 ^{L***}	9.09	7.82	1.64 ^{L***}	58.06	56.42	2,488 ^{L***}	13,124	10,637
2014	14-Jun	07-Sep ^{L***}	86 ^{L***}	36.31	1.36	7.60 ^{L**}	6.24 ^{L*}	1.78	40.42 ^{L*}	38.63 ^{L*}	2,560	10,745 ^{L*}	8,185 ^{L*}
Ave	01-Jun	28-Sep	120	40.38	1.51	8.70	7.19	2.06	53.67	51.61	2,686	12,494	9,808
Min	15-May	07-Sep	86	24.46	1.27	6.70	4.90	1.64	31.33	28.69	2,488	9,324	6,384
Max	04-Jul	23-Oct	156	54.05	1.89	10.12	8.42	2.85	72.15	69.44	3,022	14,738	11,774

H*** is the first latest date or highest value; H** is the second latest date or highest value; H* is the third latest date or highest value.

L*** is the first earliest date or lowest value; L** is the second earliest date or lowest value; L* is the third earliest date or lowest value.

3.1.3 Article 6C – average daily peak flows greater than what naturally occur on the average during the flood season (July to October)

Article 6C of the 1995 Mekong Agreement concerns the preservation of the natural flow regime of the Mekong mainstream and the need to “prevent average daily peak flows greater than what naturally occur on the average during the flood season.” This provision seeks to prevent water infrastructure operations that would amplify the natural peak flows and therefore could cause additional downstream damage.

The flow framework for real time monitoring purposes during the flood season is based on the **ARI 1:2, ARI 1:10 and ARI 1:20 of the historically annual daily peak flows (observed peak water level or rated peak discharge¹⁶)**, usually the period of **1960-2009**, at the selected hydrological stations along the mainstream.

The daily observed water level and rated discharge from **1 July to 31 October** (the flood season) at the selected hydrological stations are compared with the flow framework below. The draft Technical Guidelines (October 2011) states that “there are four zones in this flow framework of increasing flood severity, each involving specific actions.

- **Zone 1 (green):** If the daily updated flow lies **below the ARI 1:2**, it means ‘normal hydrological conditions’; there is **no need for action**.
- **Zone 2 (yellow):** If the daily updated flow lies **between the ARI 1:2 and ARI 1:10**, it is greater than what naturally occur but it still means that hydrological conditions remain ‘stable’; there is a **need for caution**.
- **Zone 3 (orange):** If the daily updated flow lies **between the ARI 1:10 and ARI 1:20**, it means that hydrological conditions are ‘unstable’, investigation should be undertaken to **identify the possible cause(s) and possible mitigation measures**. There is a **need to be on alert**.
- **Zone 4 (red):** If the daily updated flow lies **above the ARI 1:20**, it means that hydrological conditions are ‘severe’ and the **implementation of mitigating measures** should be considered.”

These zones are graphically reproduced in Figure 12, Figure 13 and Figure 14, which show the observed flow pattern during the flood season at Vientiane, Khong Chiam and Kratie. The figures indicate a break in the flow pattern in the stretch of the Mekong River between Vientiane and Khong Chiam. The flow pattern in the stretch from Chiang Saen to Vientiane (Figure 12) cannot be recognised in the flow pattern from Khong Chiam to Kratie (Figure 13 and Figure 14), which is different. This is most likely caused by the mid-basin geomorphological and climate conditions, generating large inflows to the Mekong mainstream, which dominate the flow pattern at Khong Chiam. Subsequently, this flow pattern propagates down to Kratie (Figure 14). The graphical

¹⁶ For the tidally influenced **Chrouy Changvar, Tan Chau and Chau Doc** stations, only the **daily observed water level** are used.

presentation of the flow pattern at other selected hydrological stations for Article 6C can be found in Appendix C.

Figure 12, Figure 13 and Figure 14 also show that transgressions of the flow into Zone 3 (to be on alert) and Zone 4 (consideration of mitigating measures) are rare. A summary of the number of days in the four zones of flow monitoring for Article 6C for some selected hydrological stations for the flood season of 2008-2014 is tabulated in Table 7 for observed water level and Table 8 for rated discharge. In the following, the observed flow patterns during the flood seasons of 2008-2014 are assessed against the above flow framework.

2008: There were only few days of flow transgressions (both daily observed water level and rated discharge). They occurred in August at Chiang Saen and Vientiane. These flow transgressions were caused by the tropical cyclone Kammuri. The tropical cyclone hit southern China on 6 August and moved to southern Yunnan Province of China and northern Lao PDR on the following days¹⁷. Rain poured down about 100-150 mm in Jinghong and caused a 2-day peak flow¹⁸ (changing from 365.07 m or 9,035 m³/s on 9 August to 367.68 m or 14,398 m³/s on 12 August) observed at Chiang Saen. Similarly, the 2-day peak flow (varying from 169.31 m or 14,819 m³/s on 10 August to 171.69 m or 19,600 m³/s on 14 August) was also observed at Vientiane in Figure 12 and was amplified by the relentless Kammuri, coming to Luang Prabang. Accumulated rainfall over Luang Prabang for 9-day of 6-14 August was locally observed as high as 200-250 mm. The peak flow pattern moved along the Mekong mainstream, but did not cause any flow transgression at any downstream hydrological stations (Figure 13 and Figure 14).

2009: There were no flow transgressions. Both daily observed water level and rated discharge lied in Zone 1 for normal hydrological conditions. However, there was one fairly noticeable event at Vientiane in early July, due to heavy rainfall over northern Lao PDR¹⁹. Daily observed water level at Vientiane varied from 161.50 m (3,742 m³/s) on 4 July, to 163.39 m (6,104 m³/s) on 7 July and to 167.27 m (12,248 m³/s) on 9 July. Furthermore, the tropical cyclone Ketsana passed through central Lao PDR from the east to west direction in late September and generated an obvious peak flow in middle reach of the mainstream from Khong Chiam down to Kratie (Figure 13 and Figure 14). On the other hand, the flood season ended almost six weeks earlier at Vientiane, Khong Chiam, Pakse and Kratie²⁰. This reflected earlier withdrawal of the southwest Monsoon and led to a longer dry period of 2010, which emphasised the severe hydrological drought of 2010 (further information on this severe drought can be found in flow monitoring in the dry season for Article 6A for 2010).

¹⁷ Mekong River Commission (2009). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Twenty Nine Meeting of the MRC Joint Committee, 25 March 2009, Nonthaburi, Thailand.

¹⁸ Mekong River Commission (2015). Annual Flood Report 2013, Mekong River Commission, Vientiane, 102 pages.

¹⁹ Mekong River Commission (2010). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Thirty First Meeting of the MRC Joint Committee, 28 January 2010, Luang Prabang, Lao PDR.

²⁰ Mekong River Commission (2010). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Fifteenth Dialogue Meeting, 27 August 2010, Phnom Penh, Cambodia.

Table 7. Number of days in the four zones of flow framework of Article 6C for the observed water level in the flood season (Jul-Oct).

Article 6C	H2008	H2009	H2010	H2011	H2012	H2013	H2014
Chiang Saen							
Zone 1	119	123	123	123	123	123	123
Zone 2	4	0	0	0	0	0	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Vientiane							
Zone 1	108	123	123	123	123	123	123
Zone 2	9	0	0	0	0	0	0
Zone 3	0	0	0	0	0	0	0
Zone 4	6	0	0	0	0	0	0
Khong Chiam							
Zone 1	123	123	123	120	123	123	123
Zone 2	0	0	0	3	0	0	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Pakse							
Zone 1	123	123	123	105	123	121	123
Zone 2	0	0	0	18	0	2	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Stung Treng							
Zone 1	123	122	123	112	123	113	115
Zone 2	0	1	0	11	0	4	3
Zone 3	0	0	0	0	0	3	3
Zone 4	0	0	0	0	0	3	2
Kratie							
Zone 1	123	123	123	117	123	115	115
Zone 2	0	0	0	6	0	8	8
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0

Note

Zone 1 (green): If the daily updated flow lies below the ARI 1:2, it means 'normal hydrological conditions'; there is no need for action.

Zone 2 (yellow): If the daily updated flow lies between the AIR 1:2 and ARI 1:10, it is greater than what naturally occur but it still means that hydrological conditions remain 'stable'; there is a need for caution.

Zone 3 (orange): If the daily updated flow lies between the ARI 1:10 and ARI 1:20, it means that hydrological conditions are 'unstable', investigation should be undertaken to identify the possible cause(s) and possible mitigation measures. There is a need to be on alert.

Zone 4 (red): If the daily updated flow lies above the ARI 1:20, it means that hydrological conditions are 'severe' and the implementation of mitigating measures should be considered.

Table 8. Number of days in four zones of flow framework of Article 6C for the rated discharge in the flood season (Jul-Oct).

Article 6C	Q2008	Q2009	Q2010	Q2011	Q2012	Q2013	Q2014
Chiang Saen							
Zone 1	119	123	123	123	123	123	123
Zone 2	2	0	0	0	0	0	0
Zone 3	1	0	0	0	0	0	0
Zone 4	1	0	0	0	0	0	0
Vientiane							
Zone 1	114	123	123	123	123	123	123
Zone 2	9	0	0	0	0	0	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Khong Chiam							
Zone 1	123	123	123	97	123	121	123
Zone 2	0	0	0	23	0	2	0
Zone 3	0	0	0	1	0	0	0
Zone 4	0	0	0	2	0	0	0
Pakse							
Zone 1	123	123	123	114	123	123	123
Zone 2	0	0	0	9	0	0	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Stung Treng							
Zone 1	123	123	123	123	123	122	123
Zone 2	0	0	0	0	0	1	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Kratie							
Zone 1	123	123	123	119	123	119	118
Zone 2	0	0	0	4	0	4	5
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0

Note

Zone 1 (green): If the daily updated flow lies below the ARI 1:2, it means 'normal hydrological conditions'; there is no need for action.

Zone 2 (yellow): If the daily updated flow lies between the AIR 1:2 and ARI 1:10, it is greater than what naturally occur but it still means that hydrological conditions remain 'stable'; there is a need for caution.

Zone 3 (orange): If the daily updated flow lies between the ARI 1:10 and ARI 1:20, it means that hydrological conditions are 'unstable', investigation should be undertaken to identify the possible cause(s) and possible mitigation measures. There is a need to be on alert.

Zone 4 (red): If the daily updated flow lies above the ARI 1:20, it means that hydrological conditions are 'severe' and the implementation of mitigating measures should be considered.

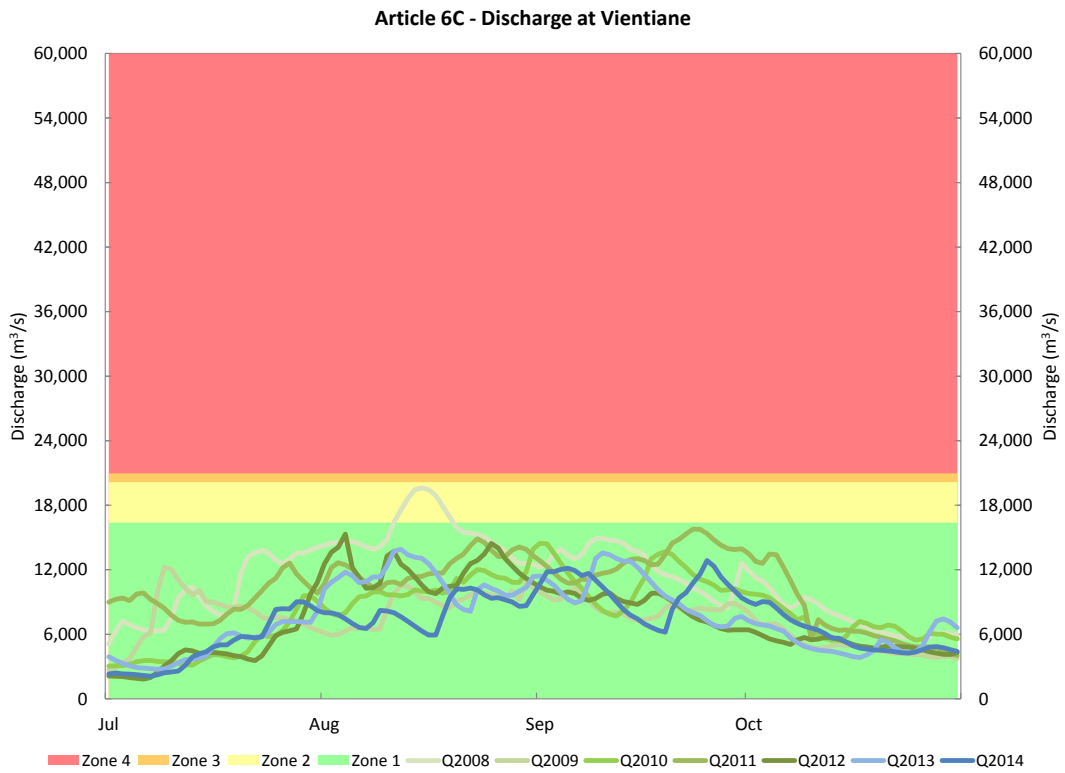


Figure 12. Daily flow monitoring for Article 6C at Vientiane for 2008-2014.

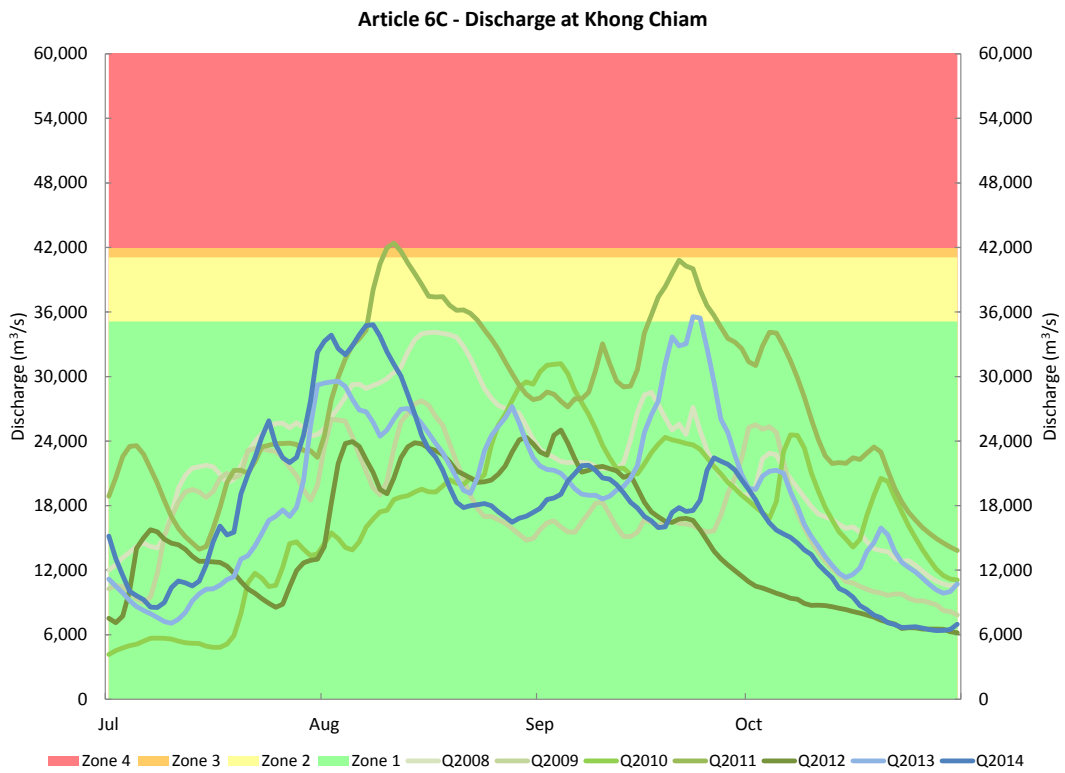


Figure 13. Daily flow monitoring for Article 6C at Khong Chiam for 2008-2014.

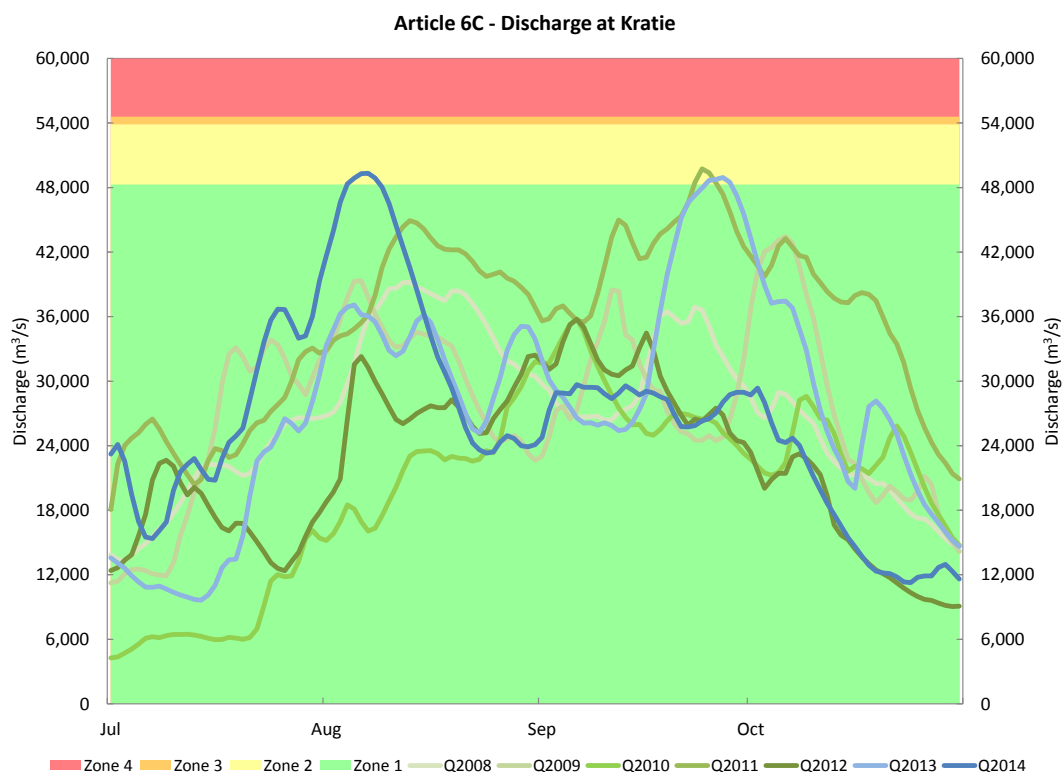


Figure 14. Daily flow monitoring for Article 6C at Kratie for 2008-2014.

2010: There were no flow transgressions. Both daily observed water level and rated discharge lied in Zone 1 for normal hydrological condition. Comparing to historically observed records at the selected hydrological stations, flows in the flood season of 2010 were considered to be low. Four comparable events occurred in 1988, 1992, 1998 and 2004, giving an estimated recurrence interval of such conditions of one in ten years. An analysis of accumulated flood season volume at Kratie reveals that the volume of 2010 (193.1 km³) is lower than that of 1992 (195.4 km³) and widely regards as the most severe regional drought of the last 90 years²¹ (1924-2014). Equally, the southwest Monsoon of 2010 started later than usual with a delay of 27 days in Chiang Saen and 24 days in Vientiane, which prolonged the dry season period of 2010 (further information on the severe drought of 2010 can be found in flow monitoring in the dry season for Article 6A for 2010). The period of the flood season of 2010 is therefore the second shortest in historically observed records, lasting only 97 days (the first shortest is 93 days in 1998) and 40 days (or about 6 weeks) shorter than the average duration of 137 days (1924-2014). This low flood volume and short period of the flood season result to the low reverse flow to the Tonle Sap Lake in 2010 (further details can be seen in flow monitoring in the wet season for Article 6B for 2010).

2011: Flow transgressions with two major peaks were observed at Khong Chiam. The peaks propagated downstream and caused flow transgression at all the stations down to Kratie (Figure 14). The cause of the flow transgression is believed to be associated to intense rainfall in August and

²¹ Mekong River Commission (2011). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Thirty Third Meeting of the MRC Joint Committee, 23-24 March 2011, Sihanoukville, Cambodia.

September²² over the drainage area of the stretch between Vientiane and Khong Chiam. Comparing to monthly long term average rainfall (1990-2005) over the Lower Mekong Basin, flows in this flood season were generally considered to be high at most of the selected hydrological stations as the southwest Monsoon arrived earlier and generally brought high rainfall for July-October²³.

2012: There were no flow transgressions. Both daily observed water level and rated discharge lied in Zone 1 for normal hydrological condition (Table 7 and Table 8). Flows at most of the selected hydrological stations in the flood season of 2012 were moderately high since the southwest Monsoon started late and overall rainfall on the Lower Mekong Basin in June and August²⁴ was only about 60% of the long term average of 1990-2005²⁵.

2013: There were no flow transgressions upstream of Pakse. Peak of water level was observed in Zone 4, at Stung Treng. As an overall climate condition in the Lower Mekong Basin, the southwest Monsoon arrived with bi-modal pattern of rainfall with peaks in July and September. This was clearly reflected in flow pattern from Khong Chiam to Kratie (Figure 13 and Figure 14). The tropical cyclone Usagi brought torrential rain to the region in September, which made monthly rainfall in September twice the long term average²⁶ of 1990-2009. This intense rainfall generated high flow in the mainstream, which caused flow transgressions from Khong Chiam to Kratie.

2014: Flow transgressions were only recorded at Stung Treng and Kratie. It is widely accepted that flows at Chiang Saen and Vientiane in the flood season of 2014 are the sixth year in a row of low flows. This pattern reflects storage activities of the reservoirs of the Lancang Hydropower Cascade in the Upper Mekong Basin, which was confirmed by the Chinese Delegation²⁷ in the Second MRC Summit in April 2014. This pattern is changed in the stretch downstream of Vientiane as the contribution from the Mekong tributaries becomes more significant. The observed major flow peaks from Khong Chiam to Kratie in early August were evidently caused by abnormal heavy rainfall over Lao PDR in late July. The falling limb of flow hydrograph of the Mekong River downstream Khong Chiam in October (Figure 13 and Figure 14) appeared natural and reflected the withdrawal of the southwest Monsoon in October.

²² Mekong River Commission (2014). Annual Mekong Flood Report 2011. Mekong River Commission, Vientiane, 72 pages.

²³ Mekong River Commission (2012). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Thirty Fifth Meeting of the MRC Joint Committee, 24-26 April 2012, Nha Trang, Viet Nam.

²⁴ Mekong River Commission (2013). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Thirty Seventh Meeting of the MRC Joint Committee, 25-26 April 2013, Bangkok, Thailand.

²⁵ Mekong River Commission (2015). Annual Mekong Flood Report 2012. Mekong River Commission, Vientiane, 84 pages.

²⁶ Mekong River Commission (2014). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Thirty Ninth Meeting of the MRC Joint Committee, 14-15 March 2014, Pakse, Lao PDR.

²⁷ Mekong River Commission (2015). Report on the hydrological conditions in the Lower Mekong Basin, Note for information in the Twenty First Meeting of the MRC Council, 14 January 2015, Hanoi, Viet Nam.

3.2 Review of the draft Technical Guidelines

Zero gauges should be added to implementation of Article 6A and Article 6C for monitoring purposes

Zero gauge (above the mean sea level) is already added to the observed water level at the selected hydrological stations for Article 6C for monitoring purposes in the draft of the Technical Guidelines, while the observed water level for Article 6A for monitoring purposes is still referenced to a local datum. For example, at Chiang Saen, the observed water level for Article 6A for monitoring purposes varies from 2 to 5 m, while the observed water level for Article 6C for monitoring purposes ranges from 358 to 368 m (with a zero gauge of 357.11 m above the mean sea level at Kolak datum). It is generally agreed that there is not yet a common datum for the Lower Mekong countries. Currently, Hatien datum is used in Cambodia and Lao PDR, Hondau datum in Viet Nam and Kolak datum in Thailand. However, it should note that conversions between the national datum are not officially available at the MRCS.

Table of daily values of flow thresholds for Article 6A for monitoring purposes should be integrated into the draft Technical Guidelines

Daily values of the flow thresholds for Article 6A for monitoring purposes are not currently attached in the draft Technical Guidelines (but the flow thresholds are presented in graphical formats). Adding comprehensive tabulated figures of the daily flow thresholds for both water level and discharge to the draft Technical Guidelines would help in a quick reproduction of daily flow hydrograph with the flow thresholds. This would indisputably increase confidence, trust and transparency in the implementation of the PMFM.

Calculation method of the accumulated reverse flow to the Tonle Sap Lake in Article 6B for monitoring purposes should be comprehensively presented in the draft Technical Guidelines

The calculation method (developed in Background Discussion for the 7th TRG Meeting on the PMFM²⁸, and later improved by Kummu et al²⁹), which was presented earlier in this Chapter, should be described in the draft Technical Guidelines. This would unquestionably help (new) members of the TRG and MRCS staff in updating the calculation of the accumulated reverse flow. Moreover, Phnom Penh Port station (on the Tonle Sap River) should be included to the list of the selected hydrological stations, since this hydrological station together with Prek Kdam (on the Tonle Sap River) and Kampong Luong (on the Tonle Sap Lake) are needed to calculate the reverse flow to the Tonle Sap Lake.

²⁸ Outlines for the Technical Guidelines of the Procedures for the Maintenance of Flows on the Mainstream (PMFM), Background Discussion for the 7th TRG Meeting on the PMFM, Mekong River Commission Secretariat (MRCS), on 4-5 October 2007, in Vientiane.

²⁹ Kummu M., Tes S., Yin S., Adamson P., Jozsa J., Koponen J., Richey J., Sarkkula J., (2014). Water Balance Analysis for the Tonle Sap Lake-Floodplain System, Hydrological Processes, Vol 28, p. 1722-1733.

3.3 Webpages for PMFM implementation

In 2014, the PMFM webpage was launched in support of the implementation of the PMFM, with aims of engaging relevant stakeholders on emerging and sudden flow changes. Among other things, the webpage shows the historical and current daily water flow observations, flags (emerging) transgressions of agreed flow frameworks and identifies the likely cause(s). The webpage also maintains information how the PMFM is being used to support basin development planning and the implementation of the PNPCA. The webpage visualizes the change in flow patterns in the Upper Mekong Basin and capture how the patterns propagate along the Mekong mainstream.


The webpage is continuously improved by adding fresh content and relevant documents, maintaining mechanism of hydrological data flowing from monitoring stations, technically updating rating curves of the hydrological station, improving calculation of accumulated reverse flow to the Tonle Sap Lake, and including comments and user experience from the public.

Link to the Webpage: <http://pmfm.mrcmekong.org/>

The following are some of the main features of the webpage (version 2015). The number corresponds to functionality illustrated in Figure 15, Figure 16, Figure 17, and Figure 18.

1. Information relating to the PMFM is organised in six main menu tabs: Home, About PMFM, Flow Thresholds, Glossary, FAQ and Contact.
2. Homepage of the webpage is designed with dynamic content, which changes according to seasons. Link on the name of hydrological stations provides direct access the current hydrological condition at the stations.
3. This field gives overview of the last update data available at every hydrological station.
4. This field informs users the current river condition in brief. Detailed hydrological conditions can be further browse through link to each hydrological station.
5. This feature appears on every page of the webpage, allowing user to provide feedback on the display information and comments on the webpage. The webpage is committed to perfection of hydrological information and user friendly content.
6. Under menu of 'Flow framework', this section outlines flow framework for the PMFM for planning and monitoring purposes.
7. The webpage is designed to provide cross-reference to other pages in the webpage for further information relating the topic. In this case, this command button links to further detailed flow framework for Article 6A for planning purposes.
8. This text box provides additionally detailed definition of some immediate technical term used in this page. The technical terms are usually listed and explained under menu tab of 'Glossary'.
9. This figure comes with mouse over feature that user can display detailed data when moving mouse over a time series.
10. In addition to the figure, the webpage also presents the data in tabulated format for user to better capture the overall situation of each hydrological station.

11. This feature allows user to download or save the figure (even a customised/specific figure with preferred period) in various picture formats (.png, .jpeg, .pdf, or .svg).
12. This text box explains flow framework considerations for implementation of the PMFM.
13. This table provides a cross reference to different hydrological stations in the same flow framework.
14. This table has dynamic content whenever hydrological data coming to the webpage. It gives a quick view on the current situation at a selected hydrological station.
15. The figures of water level and discharge can be switched for viewing purpose and figure downloading.
16. Mouse over feature on the figure gives an interactive content, which allows a comprehensive overview of water level and discharge at certain period of time.
17. User can select dataset of different years in hydrological database to compare with current year situation. The available dataset of each hydrological station can be also found in Table 2.
18. This legend explains different types and colours used in the figure. It also explains definition of the zoning and action needed to be taken when flow is in a particular zone.
19. This feature shows geographical location of a selected hydrological station. It is based on Google Map, therefore, user can benefit from several features embedded in Google Map, including zoom in and zoom out, selection of base map as terrain or satellite imagery, and Street View (wherever available). In addition, user can also view all locations of hydrological stations in the Lower Mekong Basin on introduction page of flow framework for monitoring and planning purposes.
20. This feature presents flow at a selected hydrological station in a last five-year time series. User also can zoom in to certain period of interest within the last five years.



MRC Procedures - PMFM
Procedures for Maintenance of Flows on the Mainstream

Logout CMS MRC Home Page


PMFM webpage - Public Preview

Post comments, issues and feedback here

1

Home About PMFM Flow Thresholds Glossary FAQ Contact

5



Cooperation on the maintenance of an acceptable flow regime on the Mekong mainstream

The purpose of this webpage is to communicate to the public and Mekong water users the work of the MRC in implementing the Procedures for the Maintenance of Flow on the Mainstream (PMFM) of the Mekong River. It displays daily water flows during the wet and dry seasons at each of the selected 11 hydrological stations along the mainstream. It is part of an information system for flood and drought monitoring and the implementation of actions related to emerging flow situations that are critical.

The intent of the 1995 Mekong Agreement of the four lower Mekong countries is to promote cooperation on the sustainable development and management of the Mekong River Basin's water and related resources. The intent of the PMFM is to cooperate on the maintenance of a mutually acceptable hydrological flow regime on the mainstream to optimize the multiple uses and mutual benefits of all riparian countries and to minimize the harmful effects.

Under Article 6, the countries are committed to cooperate to maintain mainstream flows, "from diversions, storage releases, or other actions of a permanent nature, except in the cases of historically severe droughts and/or floods", to be:

(A) above an acceptable minimum in the dry season

(B) such that acceptable reverse flow of the Tonle Sap continues to occur

(C) within average conditions in the flood season

Maintenance of Flow on the Mainstream overview				
Name	Station ID	Country	Last observation date	Last observed Flow Threshold Zone
Click on station name to see flow graph and details associated station				
Wang Saen	010501	Thailand	2nd Mar 2015	ABOVE UPPER 1:5 ARI
Vientiane	011901	Lao PDR	2nd Mar 2015	NORMAL
Khong Chiam	013801	Thailand	2nd Mar 2015	ABOVE UPPER 1:10 ARI
Pakse	013901	Lao PDR	2nd Mar 2015	ABOVE UPPER 1:10 ARI
Stung Treng	014501	Cambodia	2nd Mar 2015	ABOVE UPPER 1:20 ARI
Kratie	014901	Cambodia	2nd Mar 2015	ABOVE UPPER 1:20 ARI
Phnom Penh (Chrouy Changvar)	019801	Cambodia	31st May 2008	
Tan Chau	019803	Viet Nam	2nd Mar 2015	ABOVE AVERAGE
Chau Doc	039801	Viet Nam	2nd Mar 2015	ABOVE UPPER 1:10 ARI

Figure 15. Features of the PMFM webpage (1 of 4).

The screenshot shows the MRC Procedures - PMFM webpage. At the top, there is a navigation bar with links: Home, About PMFM, Flow Thresholds, Glossary, FAQ, and Contact. Below this is a section titled 'Flow Thresholds'. The main content is a table with columns for 'Article reference' and 'Flow framework' (subdivided into 'For planning purposes' and 'For monitoring purposes').

Article reference	Flow framework	
	For planning purposes	For monitoring purposes
<p>6A - Acceptable minimum monthly natural flow during each month of the dry season</p> <p>Applied at all stations except Kampong Luong and Prek Kdam</p>	<p>6</p> <p>Options for agreed for testing:</p> <ul style="list-style-type: none"> • <u>Option1</u>; a range of the 1.4-1.5 years Annual Recurrence Interval (ARI)* • <u>Option2</u>; a range of the 80- 90% time exceedance of Flow Duration Curve (FDC)** 	<p>Actions determined in relation to:</p> <ul style="list-style-type: none"> • 1:5 Annual Recurrence Interval (ARI) • 1:10 ARI • 1:20 ARI
<p>6B - Acceptable natural reverse flow of the Tonle Sap taking place during the wet season</p> <p>Applied at Kratie and Prek Kdam as shown (but using data from Kampong Luong also)</p>	<p>7</p> <p>Probability of exceedance of total wet season flow volumes (June - November) at <u>Kratie</u> within the upper and lower 90% confidence interval of the <u>Baseline Scenario</u></p>	<p>Historically observed maximum and minimum accumulated reverse flow volume at Prek Kdam</p>
<p>6C - Preventing average daily peak flows greater than what naturally occur on the average during the flood season</p> <p>Applied at all stations except Kampong Luong and Prek Kdam</p>	<p>Average daily peak flow during the flood season (July-October)</p>	<p>Actions determined in relation to:</p> <ul style="list-style-type: none"> • 1:2 Annual Recurrence Interval (ARI) • 1:10 ARI • 1:20 ARI

8

Annual recurrence interval (ARI) is defined as the average annual rate of occurrence of an event. In this instance, a 1:5 ARI flow is the mean monthly flow that is NOT equalled or exceeded one year in five in the record under consideration; a lognormal distribution is used to calculate the ARIs.
 **: A Flow Duration Curve (FDC) is a plot of flows ranked from highest to lowest. In this instance the 80% exceedance value is the mean monthly flow in a particular month that is exceeded for 80% of the record under consideration.

Figure 16. Features of the PMFM webpage (2 of 4).

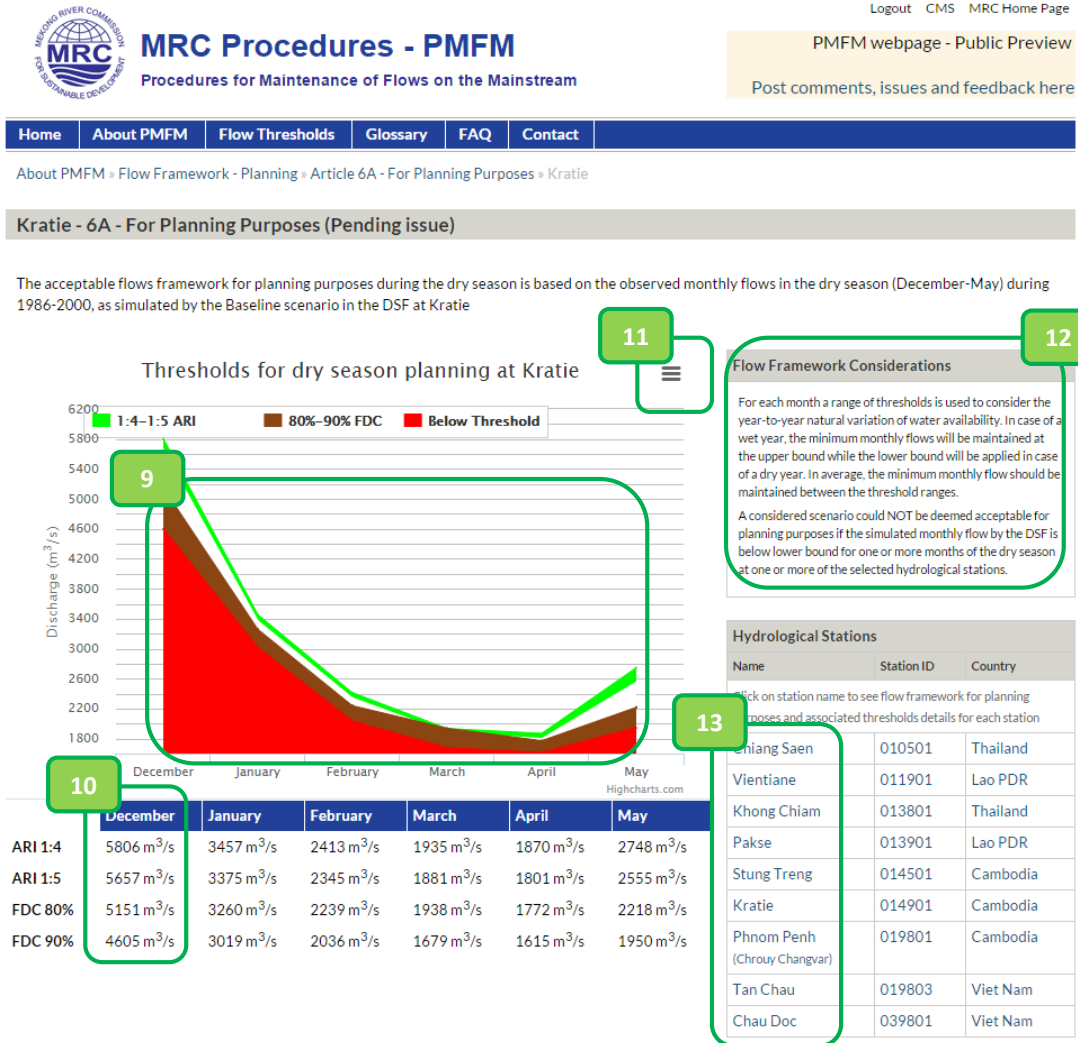


Figure 17. Features of the PMFM webpage (3 of 4).

MRC Procedures - PMFM
Procedures for Maintenance of Flow on the Mainstream

Home | About PMFM | Flow Thresholds | Glossary | FAQ | Contact

About PMFM | Flow Framework - Monitoring | Article 6A - For Monitoring Purposes | Vientiane

Vientiane - 6A - For Monitoring Purposes

Observed daily water level and discharge from 1 December 2014 to 31 May 2015 at Vientiane. The flows are compared against the 1.5, 1.10 and 1.20 ARI of the observed flows (1961-2010) at Vientiane.

Water Level | Discharge

6A - Observed Water Level during the Dry Season at Vientiane

Water Level (in Meter)

Zone 4 | Zone 3 | Zone 2 | Zone 1 | Avg. Water Level

Min | Max | 1.5 ARI | 1.10 ARI | 1.20 ARI

Water Level 2014/2015 | Water Level 2013/2014

Observation Period (1 December to 31 May)

Situation on 2nd Mar 2015:
NORMAL

Values of 2nd Mar 2015:

Water Level	0.83 m
MSL Water Level	158.97 m-MSL
Discharge	1128.8 m ³ /s

data values of period:
December 2014 - 31 May 2015

2014/2015 Water Level
2013/2014 Water Level
Minimum / maximum Water Level (1961-2010)
Average Water Level (1961-2010)
1.5 ARI High Water Level
1.10 ARI High Water Level
1.20 ARI High Water Level

Zone 1: If the daily updated actual flow lies above the 1.5 year ARI, it means "normal hydrological conditions"; there is no need for action.

Zone 2: If the daily updated actual flow lies between 1.5 year ARI and 1.10 year ARI, it means that hydrological conditions remain "stable"; there is a need for caution.

Zone 3: If the daily updated actual flow lies between 1.10 year ARI and 1.20 year ARI, it means that hydrological conditions are "unstable"; investigation should be undertaken to identify the possible cause(s) and possible mitigation measures. There is a need to be on alert.

Zone 4: If the daily updated actual flow lies below the 1.20 year ARI, it means that hydrological conditions are "severe" and the implementation of mitigating measures should be considered.

Station Location
Laos

Hydrological Stations

Name	Station ID	Country
Chiang Saen	010901	Thailand
Vientiane	011901	Lao PDR
Khong Chiam	013801	Thailand
Pakse	013901	Lao PDR
Stung Treng	014501	Cambodia
Kratie	014901	Cambodia
Phnom Penh (Chroux Chhangier)	019801	Cambodia
Tan Chau	019803	Viet Nam
Chau Doc	009801	Viet Nam

Notes & Activities
No notes nor activities have been added yet to this monitoring station.

Feedback & Comments
Submit your feedback, comments and questions

Observed Water Level at Vientiane over the past year

Water Level at Vientiane over the past 5 years
Click and drag in the plot area to zoom in

Water Level

Water Level (in Meter)

Observed Date

Figure 18. Features of the PMFM webpage (4 of 4).

4 SUPPORTING ACTIVITIES OF PMFM IMPLEMENTATION

This Chapter summarises the supporting activities of PMFM implementation, including the preparation of the PMFM Comprehensive Information Report, annual reporting, capacity building, and engagement of the PMFM in the MRC Joint Platform.

4.1 Preparation of PMFM Comprehensive Information Report

Since 1995, many analyses have been made and several documents have been prepared in support of the implementation of Article 6 of the 1995 Mekong Agreement. It has been a challenge for (new) MRCS staff and TRG members to search and comprehend the entire PMFM knowledge base in a short time. Therefore, the 10th TRG Meeting in October 2011 recommended the preparation of a comprehensive information report on the PMFM with the following aims:

- To provide an informative overview of the entire PMFM process for new members of the TRG and other stakeholders involved in the implementation of the PMFM;
- To describe the methods and alternative minimum flow frameworks that are considered for planning purposes (the main pending issue) and a detailed analysis of their advantages and disadvantages for the Mekong Basin and each of the MRC Member Countries; and
- To describe the near and longer term implementation modalities of the PMFM.

With support from National PMFM Experts and feedback from the TRG members, and staff of the NMC Secretariats, three successive drafts of the PMFM Comprehensive Information Report have been prepared. The outline of the current draft is provided Box 3. Within less than 300 pages, the PMFM Comprehensive Information Report consolidates the relevant information related to the PMFM process to date, and within the broader context of the implementation of the 1995 Mekong Agreement. The report is prepared in two parts.

Part 1 of the Comprehensive Information Report reviews the PMFM process to date. It begins with considering the role of the MRC Procedures in implementing the 1995 Mekong Agreement and reflects on the relationship between the Procedures and the Basin Development Strategy. It then describes the PMFM process and its current status, provides a factual record of researches, events and decisions since the adoption of the 1995 Mekong Agreement, and provides an overview of the PMFM and the draft Technical Guidelines.

Part 2 of the Comprehensive Information Report looks forward to implementation of the PMFM and provides guidance on how the pending issues may be addressed. It provides the data and information needed to support consensus building on the main pending issue and to finalise the draft Technical Guidelines, including the key aspects of the hydrology of the Mekong and Tonle Sap system, the potential future changes in mainstream flows as a result of basin development and

climate change, the analysis and discussion of the pros and cons of the considered alternative minimum flow frameworks for planning purposes, and the proposed steps towards building consensus on a single minimum flow framework for planning purposes. Part 2 is concluded with guidance and a road map for implementing the PMFM.

The PMFM Comprehensive Information Report is currently being finalised for publication and distribution among PMFM practitioners. A PMFM brochure will be prepared for a wider audience. The report is already supporting the consensus building process towards a single minimum flow framework for planning purposes, as well as the preparatory work for the finalisation of the draft Technical Guidelines. The subsequent adoption by the Member Countries of the finalised Technical Guidelines would make the Mekong River Basin unique among most other large river basins, where the natural flow regime has been altered considerably.

4.2 Annual reporting, meetings, and capacity building

Until 2013, annual reports on the PMFM have been prepared for the MRC Joint Committee in the form of 4 to 8-page 'Notes for Information'. Since then the reporting on the PMFM to the MRC Joint Committee became part of an annual report on all five MRC Procedures. The contribution on the PMFM in these reports was reduced to less than a page. This report is therefore an addition to the existing reporting on the PMFM to decision-makers.

Box 3. Outline of the PMFM Comprehensive Information Report (draft version of October 2013).

Preamble

Abbreviations and acronyms

Definition of terms used in this report

Part 1 – The PMFM process and current status

1. *Introduction to Part 1*
2. *Context of the PMFM*
3. *The PMFM process to date*
4. *Overview of the PMFM and the Technical Guidelines*
5. *Agreed next steps*

Part 2 – Implementing PMFM through learning by doing

6. *Introduction to Part 2*
7. *Understanding the hydrology of the Mekong River*
8. *Potential future changes in mainstream flows*
9. *Building consensus on minimum flows for basin planning*
10. *Management and operational aspects of the PMFM for monitoring purposes*
11. *Implementation of PMFM through learning by doing*
12. *Road map*

Appendix A	PMFM bibliography
Appendix B	Summary of MRC Joint Committee meeting outcomes related to PMFM
Appendix C	Summary of Technical Review Group meetings
Appendix D	Summary of supporting analyses undertaken to date
Appendix E	The Procedures for Maintenance of Flows on the Mainstream (PMFM)
Appendix F	Technical Guidelines on Implementation of the PMFM
Appendix G	Summary of scenarios assessed by BDP2
Appendix H	Supplementary data and information
Appendix I	Examples of MRCS online flow monitoring
Appendix J	Extracts related to PMFM from the BDP Inception Report and Programme Implementation Plan
Appendix K	Participation from the MRC Member Countries in TRG Meetings
Appendix L	List of staff and experts that provided inputs to this report

During 2011-2015, three TRG Meetings, up to four national consultations, and four meetings with the National PMFM Experts have been held. The 10th TRG Meeting (October 2011) paved a way for the ongoing PMFM implementation in a learning-by-doing approach. The meeting also advised to prepare the PMFM Comprehensive Information Report and to engage National PMFM Experts (one for each Member Country) in its preparation and the assessment of the considered alternative flow frameworks for planning purposes.

The 11th PMFM Meeting (December 2013) discussed the draft PMFM Comprehensive Information Report, including the intermediate PMFM implementation results. The 12th TRG Meeting (April 2015) discussed the possible solutions for the main pending issue in greater detail and reached the following agreements.

- **Review of PMFM implementation.** The main results, experiences and lessons learnt from implementing the PMFM in a learning-by-doing approach will be consolidated in a concise PMFM implementation report for 2011-2015 (this report).
- **Regarding a solution for the main pending issue.** Cambodia and Viet Nam supported the ‘mean’ (which is an average of the 15 monthly mean flows – one for each year during the 1985-2000, derived from the simulated daily flows in the DSF) for setting a single minimum flow framework for Article 6A for planning purposes. Lao PDR agreed that there was no need for a range of the flow frameworks and supported a simpler method than the currently considered technical ARI and FDC, i.e. the mean. Thailand will consider the mean in addition to the ARI 1:4 and 1:5 and FDC 80% and 90%.
- **The current draft of the Technical Guidelines will be updated in 2015.** Amongst others, the identified unclear language will be clarified, the section related to minimum flow frameworks for planning purposes will be updated reflecting the previous points, the data of the graphically presented flow frameworks for PMFM monitoring will be added, and the methodology for calculating the accumulated reverse flow volume at Prek Kdam (for Article 6B for monitoring purposes) will be added. Equally, zero gauge of the selected hydrological stations needs to be added to water level presentation for Article 6A for monitoring purposes. An update of the draft Technical Guidelines will be prepared by taking advantage of findings in the PMFM implementation report for 2011-2015 (this report).
- **The implementation of the PMFM in a learning-by-doing approach** will continue in 2015, including the further improvement of the PMFM webpage, the finalization of the PMFM Comprehensive Information Report, and the preparation of a PMFM brochure for wider stakeholders.
- **The 13th TRG meeting will be held** to discuss the PMFM implementation report for 2011-2015 and the updated Technical Guidelines for the PMFM, and to agree on a single minimum flow framework for Article 6A for planning purposes.

The four meetings with the National PMFM Experts (who were engaged in 2012) and MRCS staff focussed on the exchange of knowledge and experience, and joint learning. The meetings were also useful for the preparation of the national consultations and TRG Meetings. The national consultations focussed on awareness raising and capacity building on the PMFM, including possible solutions for the pending issues.

Since 2012, the PMFM expertise within MRCS has been strengthened with a PMFM staff for supporting and improving PMFM implementation, and maintaining PMFM knowledge base. The PMFM staff also functions as the liaison with the MRCS Modelling Team, Scenario Assessment Team, and the MRC Joint Platform for reviewing and improving the implementation of the MRC Procedures.

4.3 Engagement in the MRC Joint Platform

This section summarises the engagement of the PMFM in the ‘MRC Joint Platform to Review and Improve the Implementation of the MRC Procedures.’

4.3.1 Identification of PMFM issues for the MRC Joint Platform

The Basin Development Plan Programme has contributed in 2014 to a large review table that summarises the lessons learnt and the main pending and challenging issues for all five MRC Procedures, with a view to identifying issues that need to be addressed by the MRC Joint Platform. Because of its broader, cross-sectoral set-up, the MRC Joint Platform could help solve pending issues and implementation challenges. In particular, the MRC Joint Platform could capture potential synergies between the MRC Procedures to improve the implementation of individual Procedures.

The PMFM part of the overall review table is reproduced in Table 9. Its content is in line with the results and experiences described in Chapter 2 and Chapter 3 of this report. The table shows that the MRC Joint Platform could add value to some of the PMFM activities and issues.

Table 9. Identification of PMFM issues for consideration for the TRG and MRC Joint Platform.

Relevant PMFM experiences and lessons learnt	Action, also considering linkages with other MRC Procedures	Justification for role of the MRC Joint Platform
Implementation of the PMFM demonstrates that parts of the current draft Technical Guidelines for the PMFM for planning purposes are unclear. It is important that these are clarified so that there is no ambiguity over the manner, in which the PMFM Technical Guidelines are implemented.	The unclear wording related to the PMFM for planning purposes in the draft Technical Guidelines has been identified. The draft final PMFM Comprehensive Information Report and this report provide the options for addressing the unclear wording. The text of the draft Technical Guidelines will be updated considering those options.	This could continue to be discussed at the TRG for the PMFM.
Implementation of the PMFM demonstrates that if clarity is provided for the unclear wording in the draft Technical Guidelines, the PMFM for planning purposes can be implemented using any of the four minimum flow frameworks within the two considered ranges (ARI 1:4-1:5 and FDC 80-90%).	The difference between the four minimum flow frameworks within the two ranges considered (ARI 1:4-1:5 and FDC 80-90%) is small and insignificant for practical purposes. There seems little need to have the added complication of considering a range of values. A single flow framework for each month in the dry season would be more practical. Thus, a choice has to be made between ARI 1:4, ARI 1:5, FDC 80% and FDC 90%, or even more practical the mean.	This could continue to be discussed at the TRG for the PMFM.

Relevant PMFM experiences and lessons learnt	Action, also considering linkages with other MRC Procedures	Justification for role of the MRC Joint Platform
<p>The basin-wide cumulative assessment of the water resources plans of the Member Countries demonstrates that the redistribution of seasonal flows from the wet season to the dry season by hydropower developments in the Upper Mekong Basin and Lower Mekong Basin will provide potential dry season flow to meet planned consumptive water demands of the countries in the Lower Mekong Basin. The flow augmentation is of an order that the instances, where the currently considered flow frameworks are transgressed in the dry season will become rare, irrespective of which of the four flow frameworks is selected. The day-to-day monitoring of river flows confirmed the predicted flow augmentation for the Definite Future Scenario (2015).</p>	<p>Given the flow augmentation, and the very small difference between the four for minimum flow frameworks (ARI 1:4, ARI 1:5, FDC 80%, and FDC 90%), the Member Countries can selected any of these. The analysis in the PMFM Comprehensive Information Report and this report show that whatever of these flow frameworks is chosen, it will make no difference in practical PMFM implementation. The approach based on the monthly Flow Duration Curve (FDC) is the more robust of the two since it is only based on the observed data. The Annual Recurrence Interval (ARI) requires the fitting of a probability model, in this case a Log-normal distribution, which makes it less straightforward and appears to offer no advantage in terms of the results. The PMFM Comprehensive Information Report and this report also show that the Member Countries could consider another option for minimum flow frameworks: the ‘mean’ which is an average of the 15 monthly mean flows – one for each year during the 1985-2000, derived from the simulated daily flows in the DSF. The mean can be easier understood by relevant stakeholders while its application is more straightforward than the currently considered ARI and FDC.</p>	<p>This could continue to be discussed at the TRG for the PMFM.</p>
<p>Since 1995, many technical reports have been prepared in support of the preparation of the Procedures and Technical Guidelines for the PMFM. Most of these have been prepared by foreign experts (staff or consultants), mostly with a technological/hydrological background. Given the above lessons and the remaining pending issues, this situation is not conducive for the finalization of the draft Technical Guidelines and the optimal implementation of the PMFM.</p>	<p>Since 2012, the BDP Programme has engaged riparian BDP staff and National PMFM Experts in the PMFM process. Technical and negotiation workshops were conducted in 2014 for the (new) members of the TRG. The PMFM Comprehensive Information Report is addressing PMFM management issues within the broader context of Mekong Basin planning and management (including relationships with the other MRC Procedures). Such measures will in a few years result in a situation whereby the building blocks are in place from a PMFM process depending on external capacity (and funding) to a process that is carried forward by riparian experts and funded by the Member Countries.</p>	<p>This could continue to be discussed at the TRG for the PMFM.</p>
<p>The PMFM is being implemented since 2010 in a learning-by-doing approach for planning and monitoring purposes. The PMFM for planning purposes is used to predict whether development scenarios and large water use projects (as part of the PNPCA) would result in acceptable mainstream flow conditions. The PMFM for monitoring purposes is</p>	<p>The implementation of the PMFM in a learning-by-doing approach has not faced significant problems. The PMFM for planning purposes shows that the existing basin-wide development scenarios (and the projects submitted under the PNPCA) do not exceed the flow frameworks provided in the draft Technical Guidelines. The PMFM for monitoring purposes confirmed the predicted flow changes for the Definite Future Scenario (2015). The occasional</p>	<p>This could be information to the MRC Joint Platform.</p>

Relevant PMFM experiences and lessons learnt	Action, also considering linkages with other MRC Procedures	Justification for role of the MRC Joint Platform
being implemented to: (1) validate the predictions for PMFM for planning purposes, (2) enable early warning of the emergence of unusual flow conditions in any season, and (3) prompt analysis of unusual situations once certain flow frameworks are exceeded, and the subsequent consideration of mitigating measures.	changes in river flow along the Mekong mainstream (and caused public concern) have been observed and studied faster than before 2010. The results were communicated to relevant stakeholders.	
The actual implementation of mitigating measures to maintain daily flows, when certain flow frameworks are exceeded, cannot be implemented for 3 reasons: (1) there is no regional agreed legal and institutional framework that can be instigated to ensure that dam operators and irrigation managers maintain the mainstream flow regime within its natural range as specified by the PMFM, (2) the storage capacity in the Mekong Basin is still small compared to the annual flow, and (3) the nature of the flow regime in combination with the narrow ranges of flow frameworks can be transgressed within a day (thus there is no time for researching, alerting, and mitigation).	The legal and institutional issues are difficult to solve in the short to medium term. Actual maintenance of flows in the Lower Mekong Basin in real time requires high levels of regional integration (and regional legislation), which will probably take few decades. Moreover, in few decades the storage capacity in the Lower Mekong Basin may increase to higher levels than at present (as currently planned). Notwithstanding these limitations, the PMFM for monitoring purposes can be implemented to: (1) validate that the implementation of the PMFM for planning purposes has been correct over time, (2) enable early warning of the emergence of unusual flow conditions, and (3) to prompt analysis of unusual flow situations.	This could be discussed at the MRC Joint Platform.
The recent annual reports on the PMFM to the MRC Joint Committee demonstrate the importance of the adequate implementation of the PWUM, as well as the availability of reservoir operating data from the Upper Mekong River.	The PWUM needs to be based on a national water use database, which are part of a water use license (or permit) system, as is common practice elsewhere, e.g. the Murray-Darling Basin. All Member Countries are working towards the development/improvement of such a database. Whenever national water use data are needed to implement a regional task agreed by the Member Countries, the required water use data would be provided to the MRCS. As an interim measure, the irrigation area and abstractions can be periodically assessed by using the DSF with refreshed data of irrigated areas.	This could be discussed at the MRC Joint Platform.
The annual reporting on the PMFM to the MRC Joint Committee can be further improved by creating synergies with the Annual Hydrological Condition Report and the Annual Flood Report.	It is important that the Annual Hydrological Condition Report and Annual Flood Report will make use of the PMFM flow frameworks for monitoring purposes. Furthermore, these reports should move beyond reporting primarily on hydrological issues towards reporting on management issues.	This could be discussed at the MRC Joint Platform.
The implementation of the PMFM (in a learning-by-doing approach) demonstrates that most of the PMFM activities are core river basin	This lesson confirms the importance of embedding the PMFM process in a future core function unit of the MRCS that manages the implementation of the other MRC	This could be discussed at the MRC Joint Platform.

Relevant PMFM experiences and lessons learnt	Action, also considering linkages with other MRC Procedures	Justification for role of the MRC Joint Platform
management function activities that need to be implemented at the regional level, including the assessment of scenarios and large water projects (through the PNPCHA) against the PMFM flow frameworks for planning purposes and the web-based monitoring for raising awareness of the emergence of unusual flow situations and the associated studies.	Procedures (PWUM, PDIES, PWQ and PNPCHA) as well as the planning support function. This unit would also support the Member Countries in the gradual development of a legal and institutional framework that would make it possible in the longer term to maintain flows with the assistance of dam operators and irrigation managers.	
The insufficient continuity of key actors in the PMFM process at the MRCS and national level has hampered the finalization and the adoption of the PMFM Technical Guidelines.	The MRCS has created a staff function under the BDP Programme for the implementation of the PMFM. The BDP Programme also engaged National PMFM Experts, who assist (new) members of the TRG and other national stakeholders to become familiar with the PMFM and support consensus building on the pending issues.	This could be discussed at the MRC Joint Platform.
Finalization of the draft Technical Guidelines following its ongoing implementation through learning-by-doing approach. The main pending issue is a four-country agreement on minimum flow frameworks for Article 6A for planning purposes.	At the request of the TRG, the PMFM Comprehensive Information Report has been prepared to support the ongoing implementation of the PMFM in a learning-by-doing approach and to provide the information needed to address the main pending issue. The information in the report has been introduced in national consultation meetings and subsequently discussed in the TRG Meetings. Similarly, the report is used for consensus building on the pending issues and the finalization of the draft Technical Guidelines.	This could continue to be discussed at the TRG for the PMFM.
Technical solutions for the pending issues of how to obtain a comprehensive flow presentation for the tidally influenced stations at Tan Chau (on Mekong River) and Chau Doc (on Bassac River) in the Mekong Delta.	Further study is needed to achieve a comprehensive flow presentation consistent with the requirements of the draft Technical Guidelines. Such study may include the statistical filtering out of the tidal effects from the observed water level and discharge at these stations.	This could continue to be discussed at the TRG for the PMFM.
The TRG has adopted a 'working definition' of the wet and dry seasons for PMFM purposes: the wet season runs from June to November and the dry season from December to May. This definition is slightly different from the one used for the PNPCHA.	The working definition has served well the implementation in a learning-by-doing approach. The analysis in the PMFM Comprehensive Information Report demonstrates that the adopted working definition is likely in the future result in appropriate implementation of the PMFM and acceptable flow conditions year round. It is therefore recommended that, after the ongoing testing of the draft Technical Guidelines on a learning-by-doing approach, consideration should be given whether the definition requires any amendment in the light of experience gained.	This could be discussed at the MRC Joint Platform.

The full review table of all five Procedures resulted in a long-list of issues that could be addressed by the MRC Joint Platform. The MRC Joint Platform Meeting on 22-23 April 2015 discussed the long-list of proposed issues, which resulted in a short-list list of issues to be addressed by the MRC Joint Platform. The short-list of issues is dominated by the PNPCA and to a lesser extent by the PDIES and PWUM issues. One issue each was included for the PWQ and PMFM. For the PMFM, the opportunity to create synergies with the Annual Hydrological Condition Report and Annual Flood Report would be addressed by the MRC Joint Platform. The other PMFM issues can be addressed by the TRG.

At the request of the MRC Joint Platform, the following description of the **integration of the Annual PMFM Report, Annual Hydrological Condition Report and Annual Flood Report** has been provided to the M-IWRMP, which supports the MRC Joint Platform.

- **PMFM for planning purposes.** The aim of the PMFM for planning purposes is to evaluate with the DSF whether basin development scenarios and water infrastructure projects comply with the agreed PMFM flow frameworks. The results are reported in the Scenario Assessment Reports (in case of scenarios) and PNPCA Reports (in case of projects). The key findings are also presented in the integrated report on implementation of the five MRC Procedures to the MRC Joint Committee.
- **PMFM for monitoring purposes.** The aim of the PMFM for monitoring purposes is to: (1) monitor day-to-day flow conditions to validate the results of the PMFM for planning purposes and to enable early warning of unusual flow conditions, and (2) to analyse the causes of unusual flow conditions and the subsequent consideration of mitigating measures. The results of these activities can be reported through the conventional Annual Hydrological Condition Report to the MRC Joint Committee. The only change needed in the current Annual Hydrological Condition Report is to integrate the agreed PMFM flow frameworks into the hydrographs presenting the observed flow conditions and the future hydrological analyses.

In the short term, the Annual PMFM Report to the MRC Joint Committee can be merged with the conventional Hydrological Condition Report to the MRC Joint Committee. Hence, there would not need any more Annual PMFM Report to the MRC Joint Committee. In the medium term, the new Annual Hydrological Condition Report (with PMFM flow frameworks) may be merged with the Annual Flood Report, but this would require significant work and further consultations.

4.3.2 *Implications of new realities for the MRC Procedures*

For internal discussion within the MRCS, and as a possible input to the MRC Joint Platform, the BDP Programme prepared in December 2014 the note *'Implications of MRC reforms and national institutional development on the implementation of the MRC Procedures.'* The note describes that the current MRC Procedures and their Technical Guidelines are tuned to a centrally-organised MRC with an implementation-oriented and large MRCS that maintains large databases. It argues that this situation is increasingly less realistic given the ongoing decentralization and other reforms of the MRC, and the continuous strengthening of national water management agencies. This disconnection may have already hampered the effective implementation of the MRC Procedures.

The note explores the possible implications of ongoing reforms of the MRC and national institutional development for the implementation of the MRC Procedures. It suggests that the implementation of the MRC Procedures could become more country-driven, supported by national databases, and more closely linked to planning and management at the national and regional levels. For example, under decentralization, all data will be collected, assembled and stored in national databases, from which the regional MRCS databases may retrieve. The MRC Indicator Framework defines the scope and nature of the data that might be needed at some point during the 5-year planning cycle to support regional activities (which are agreed by the Member Countries in the MRC Strategic Plan for the planning period).

For each of the five MRC Procedures, the note identified measures to improve implementation, taking into account the potential linkages between the MRC Procedures. For example, regarding the PWUM, it is advised to assess the irrigation consumption and abstractions periodically by using the DSF with newly available data and information. For the PNPCA, it is suggested moving the notification process of water resources developments on mainstream and tributary of the Mekong River, from the current ad hoc process to one that is integral with the basin-wide planning cycle.

APPENDIX A – FLOW MONITORING FOR IMPLEMENTATION OF ARTICLE 6A

Article 6A of the 1995 Mekong Agreement concerns the maintenance of the flows on the mainstream of *not less than the acceptable minimum monthly natural flows during the dry season*. The flow framework for real time monitoring purposes during the dry season comprises of the **ARI 1:5, ARI 1:10** and **ARI 1:20** of the **historically daily flows (observed water level or rated discharge³⁰)**, usually the period of **1960-2009³¹**, at each of the selected hydrological stations along the mainstream, and using smoothed values³².

The daily observed water level and rated discharge from **1 December to 31 May** (the dry season) at the selected hydrological stations are compared with the flow frameworks for monitoring purposes. This flow framework is derived from available observed data in the DSF Knowledge Base, which usually covers a period of 1960-2009. The draft Technical Guidelines (October 2011) states that *“there are four zones in this flow framework of increasing drought severity, each involving specific actions.*

- **Zone 1 (green):** *If the daily updated flow lies **above the ARI 1:5**, it means ‘normal hydrological conditions’; there is **no need for action**.*
- **Zone 2 (yellow):** *If the daily updated flow lies **between the ARI 1:5 and ARI 1:10**, it means that hydrological conditions remain ‘stable’; there is a **need for caution**.*
- **Zone 3 (orange):** *If the daily updated flow lies **between the ARI 1:10 and ARI 1:20**, it means that hydrological conditions are ‘unstable’; investigation should be undertaken to **identify the possible cause(s) and possible mitigation measures**. There is a **need to be on alert**.*
- **Zone 4 (red):** *If the daily updated flow lies **below the ARI 1:20**, it means that hydrological conditions are ‘severe’; the **implementation of mitigating measures** should be considered.”*

³⁰ For the tidally influenced **Chrouy Changvar, Tan Chau** and **Chau Doc** stations, only the **daily observed water level** are used.

³¹ Including the historically daily observed maximum and minimum values.

³² All curves have been smoothed to produce more useful reference values for indicating the trends in the various thresholds through the dry season. The smoothing was done by taking the 30-day moving average of the daily values, i.e. the value of a given day is the average of the values of the previous 15 days and the next 15 days (including the given day).

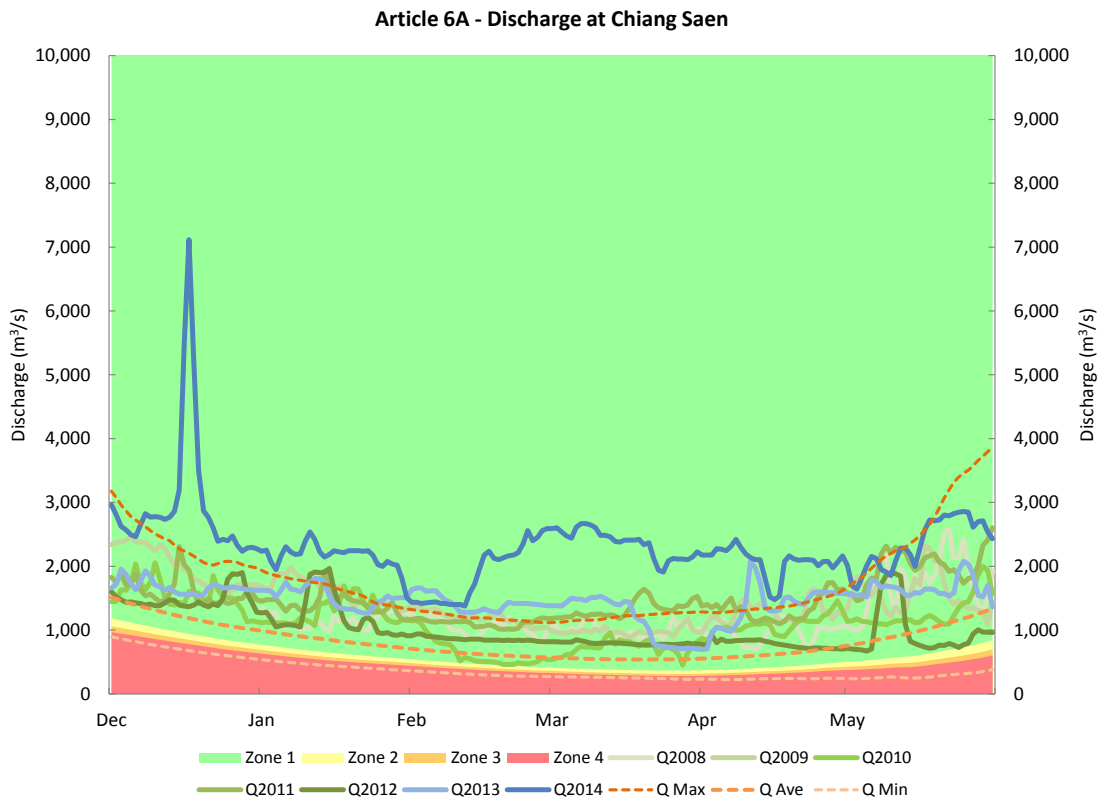
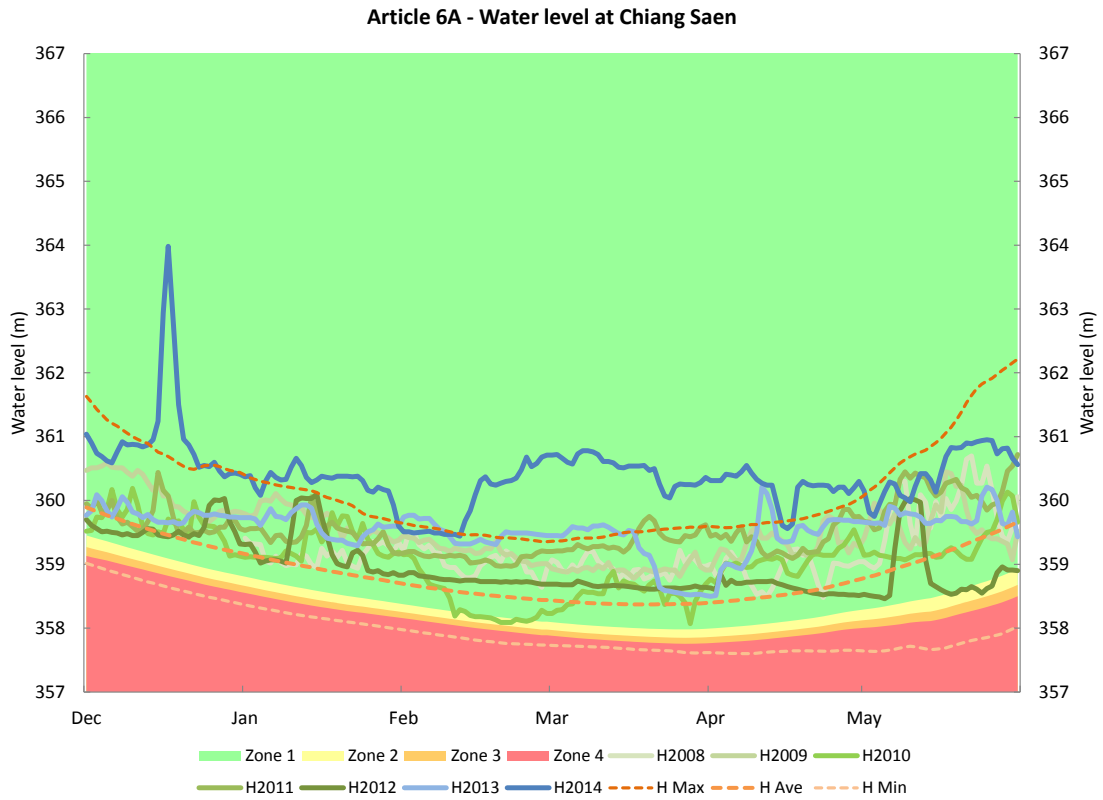


Figure A1. Daily flow monitoring for Article 6A at Chiang Saen for 2008-2014.

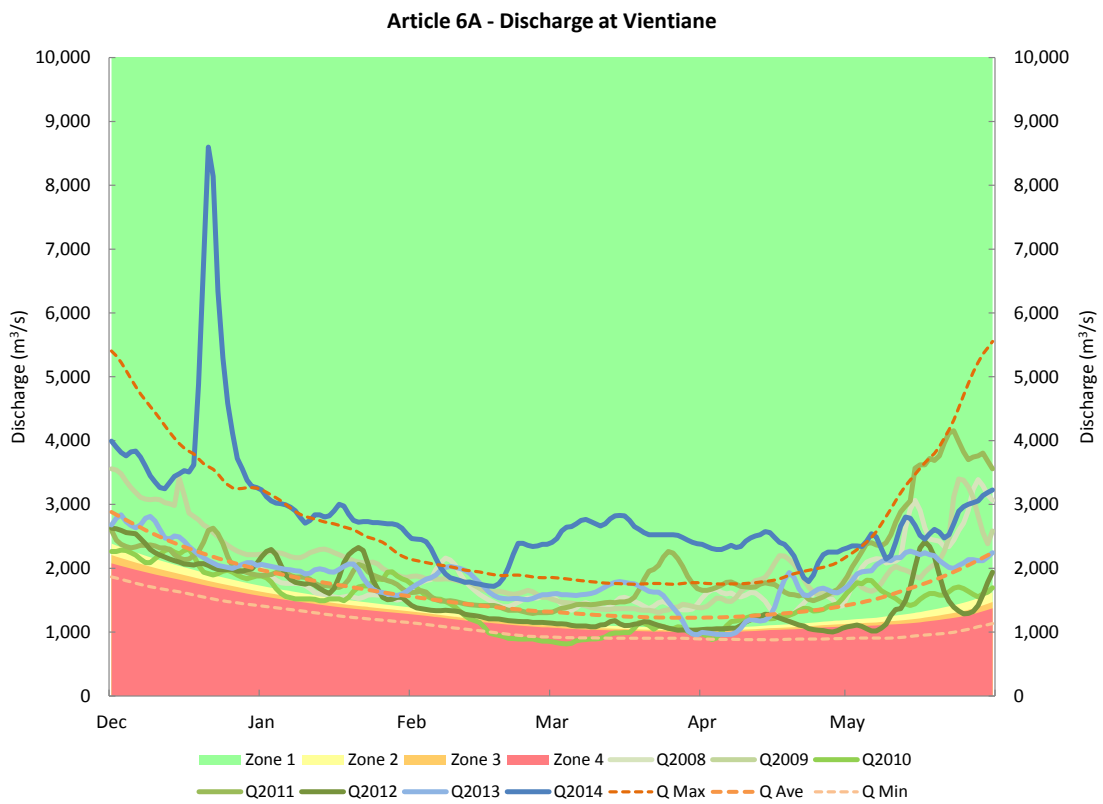
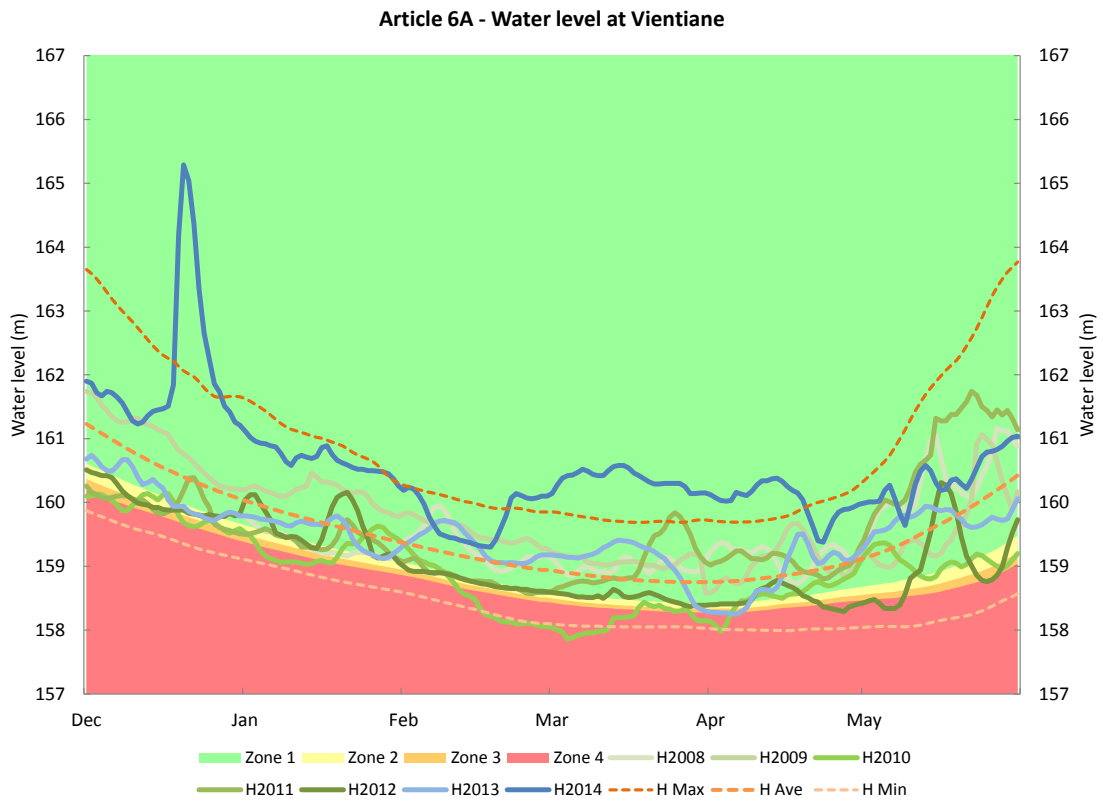


Figure A2. Daily flow monitoring for Article 6A at Vientiane for 2008-2014.

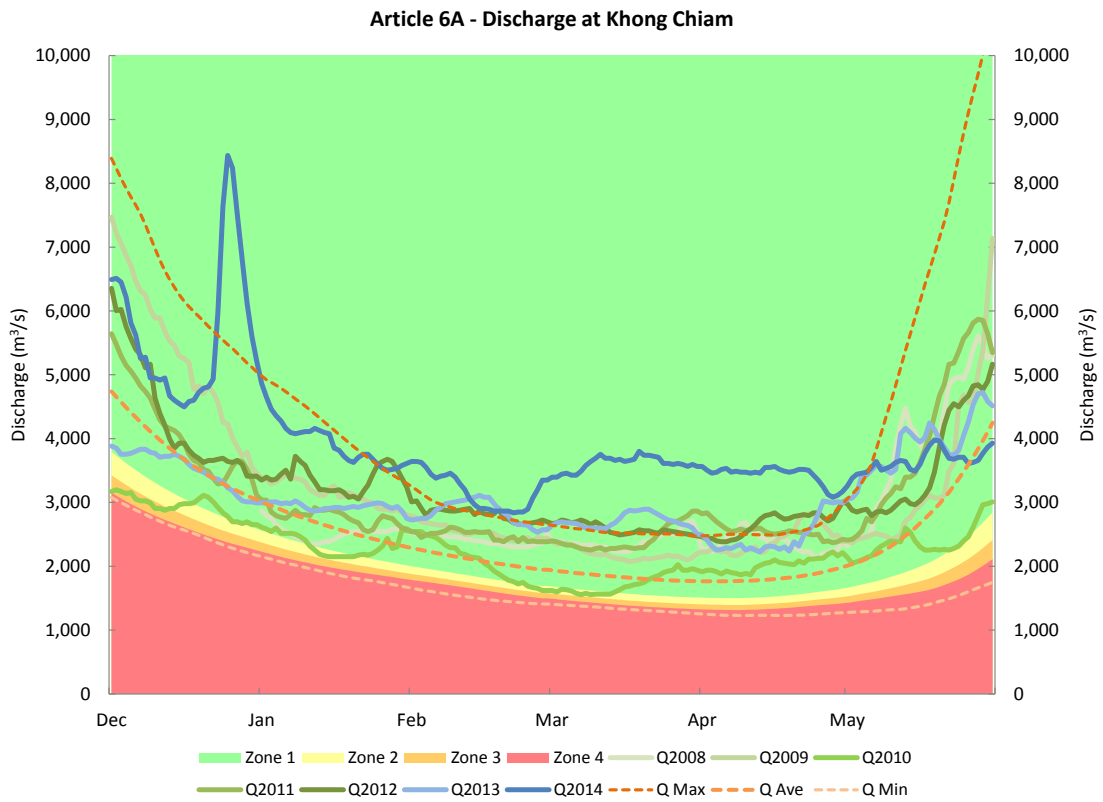
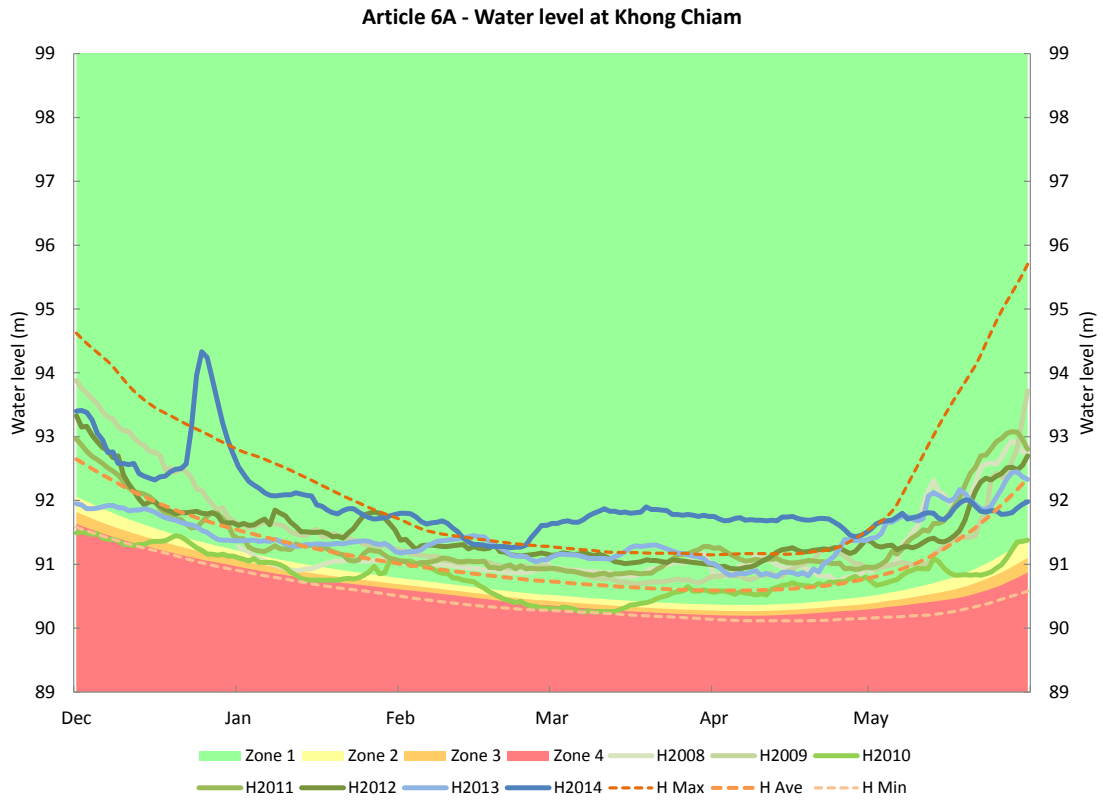


Figure A3. Daily flow monitoring for Article 6A at Khong Chiam for 2008-2014.

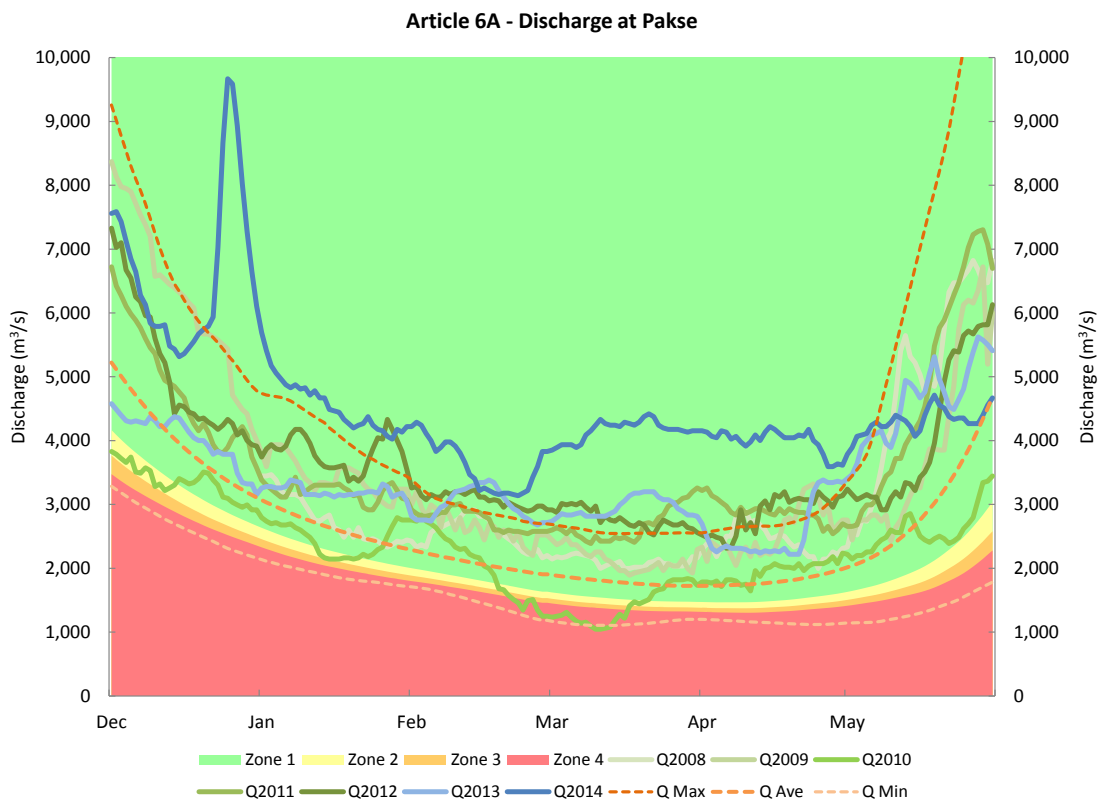
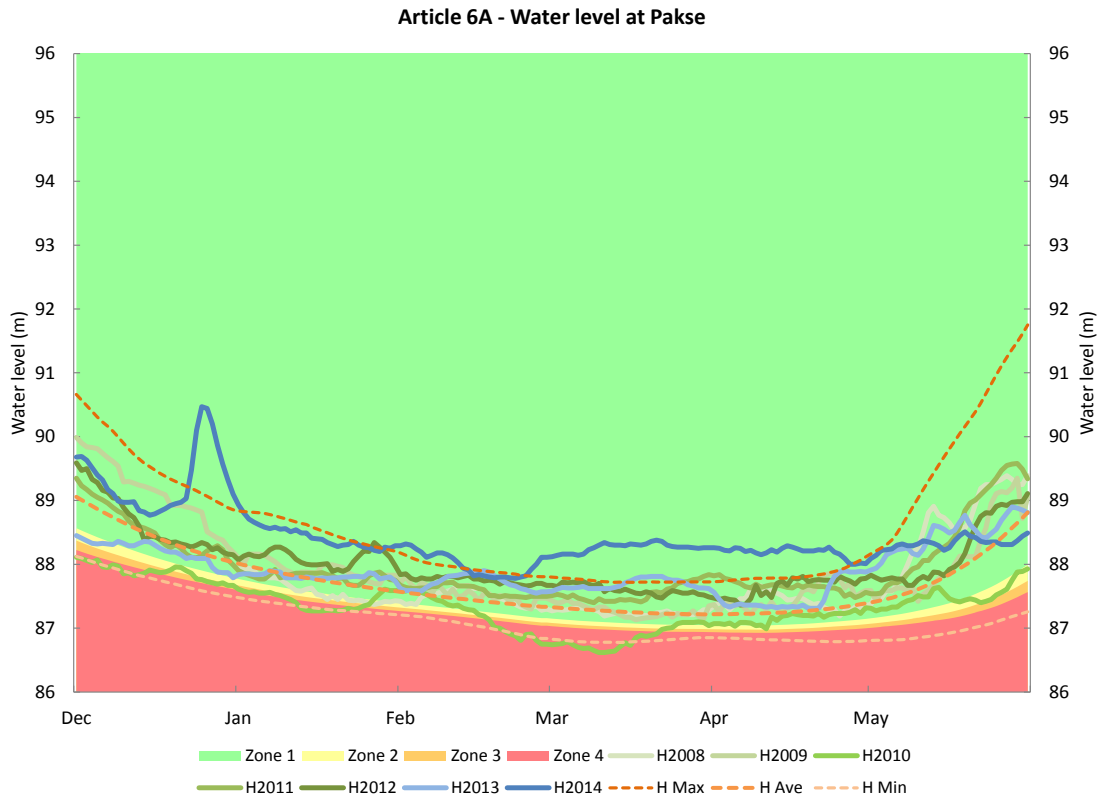


Figure A4. Daily flow monitoring for Article 6A at Pakse for 2008-2014.

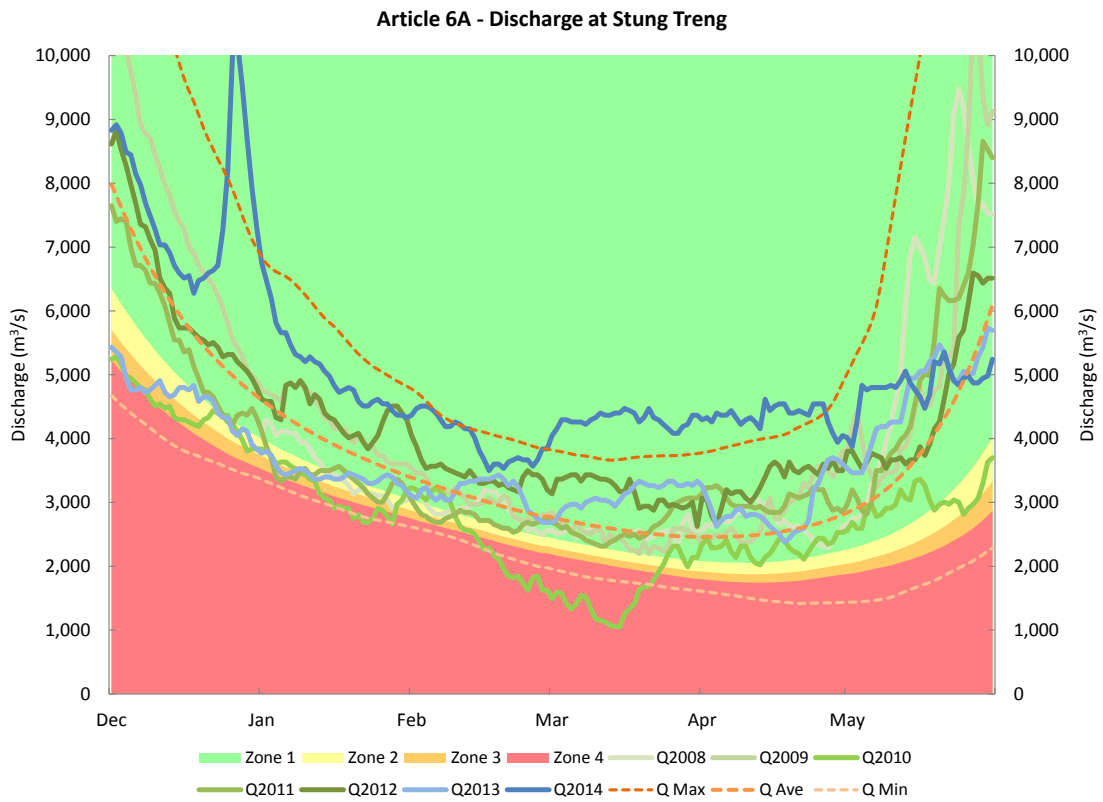
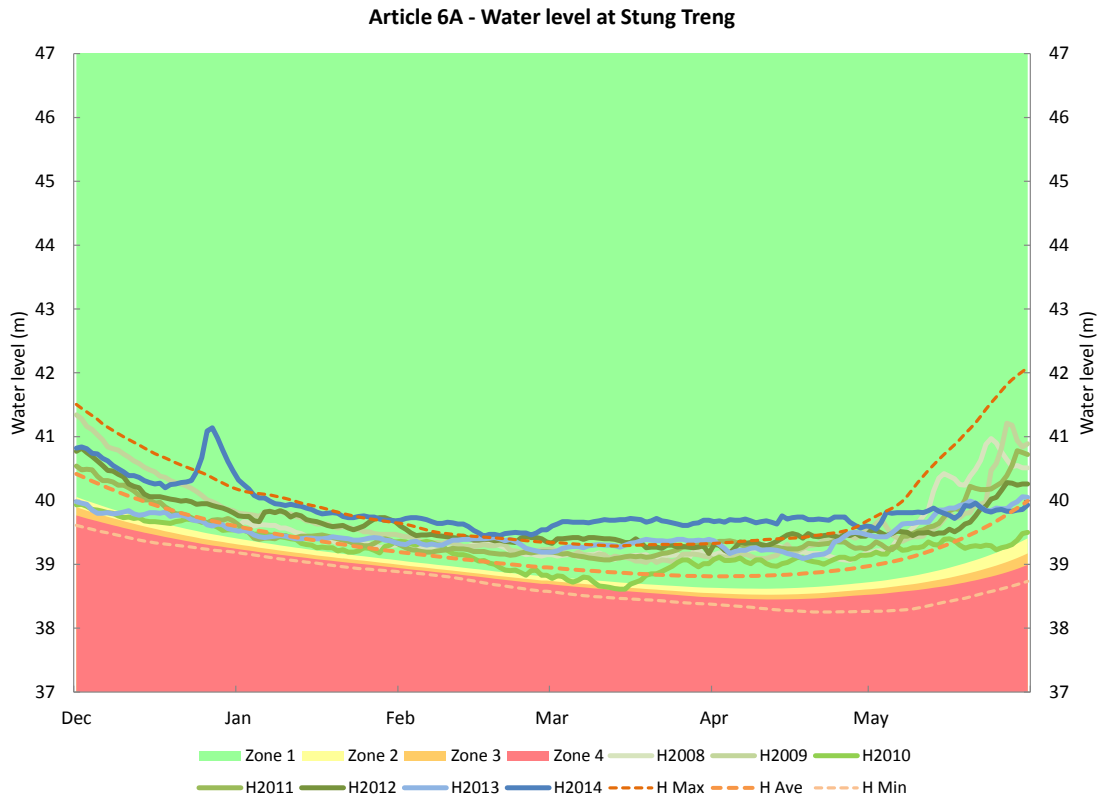


Figure A5. Daily flow monitoring for Article 6A at Stung Treng for 2008-2014.

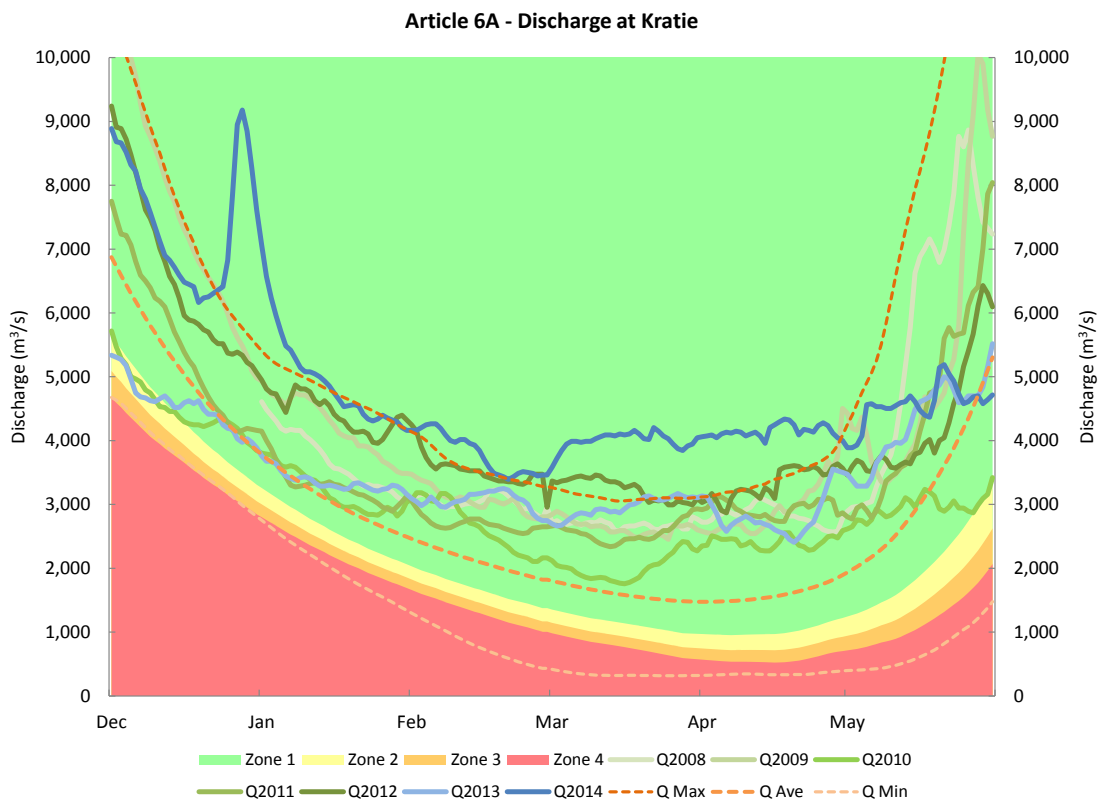
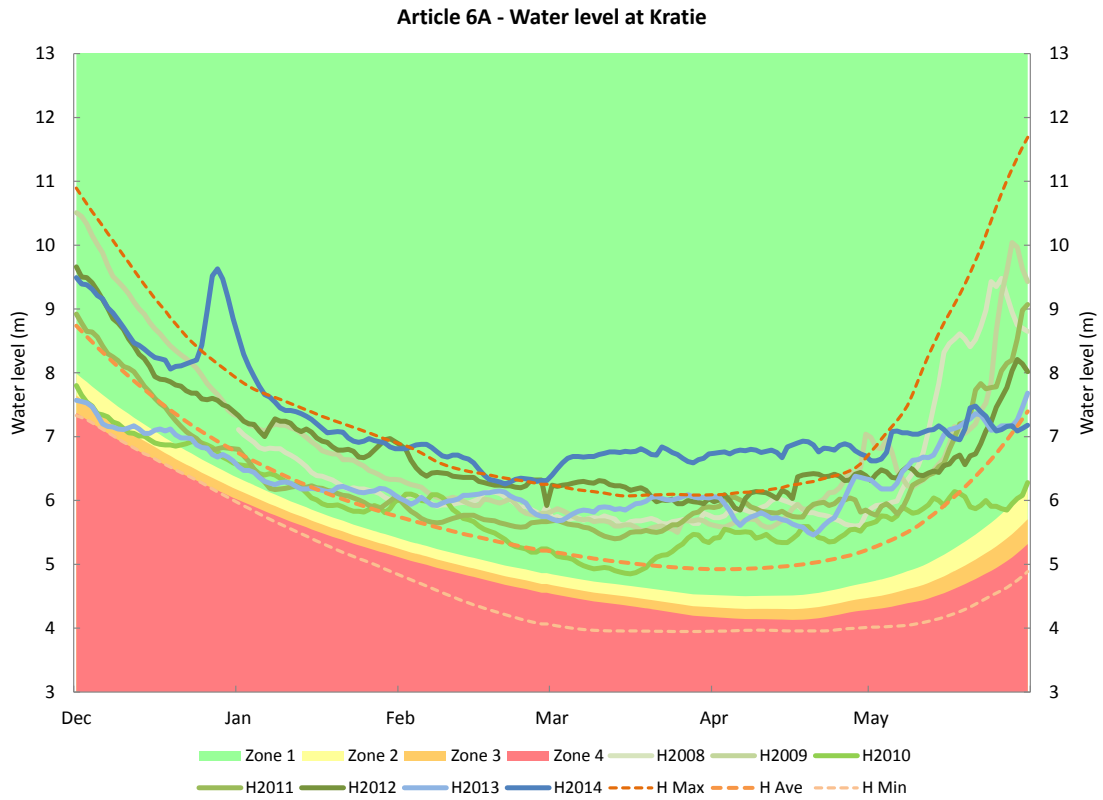


Figure A6. Daily flow monitoring for Article 6A at Kratie for 2008-2014.

APPENDIX B – REVERSE FLOW MONITORING FOR IMPLEMENTATION OF ARTICLE 6B

Article 6B of the 1995 Mekong Agreement is to *enable the acceptable natural reverse flows of the Tonle Sap River during the wet season*, which is defined in the 1995 Mekong Agreement as *“the wet season flows in the Mekong River at Kratie that allows the reverse flows of the Tonle Sap River to an agreed upon optimum level of the Tonle Sap Lake.”*

The flow framework for real time monitoring purposes during the wet season is the **historically observed accumulated reverse flows to the Tonle Sap Lake**. The draft Technical Guidelines (October 2011) states that *“the ‘**threshold band**’ provided by the **historically observed maximum and minimum accumulated reverse flow** at Prek Kdam will be used as the flow framework to evaluate the daily accumulated reverse flow to the Tonle Sap Lake for monitoring purposes. Furthermore, to determine the accumulated reverse flow volumes at Prek Kdam, the **available data at Kampong Luong, Phnom Penh Port and Prek Kdam stations between 1996 and 2005** were used. Although, this period is quite short (10 years) to analyse trend and probability in detail, it included a severe drought event of 1998 as well as a severe flood event of 2000 in Cambodia.”*

As the reserve flow to the Tonle Sap Lake usually occurs from mid-May to mid-October, the accumulated reverse flow is calculated from **1 May to 31 October**, which covers mainly the wet season from June to November, stipulated in the draft Technical Guidelines.

The draft Technical Guidelines of the PMFM stipulated that *“if the daily accumulated reverse flow volume at Prek Kdam lies **outside of the maximum and minimum threshold band**, it means that hydrological conditions are ‘**unstable**’, investigation should be undertaken to identify the possible cause(s) and possible mitigation measures. There is a need to be on alert.”*

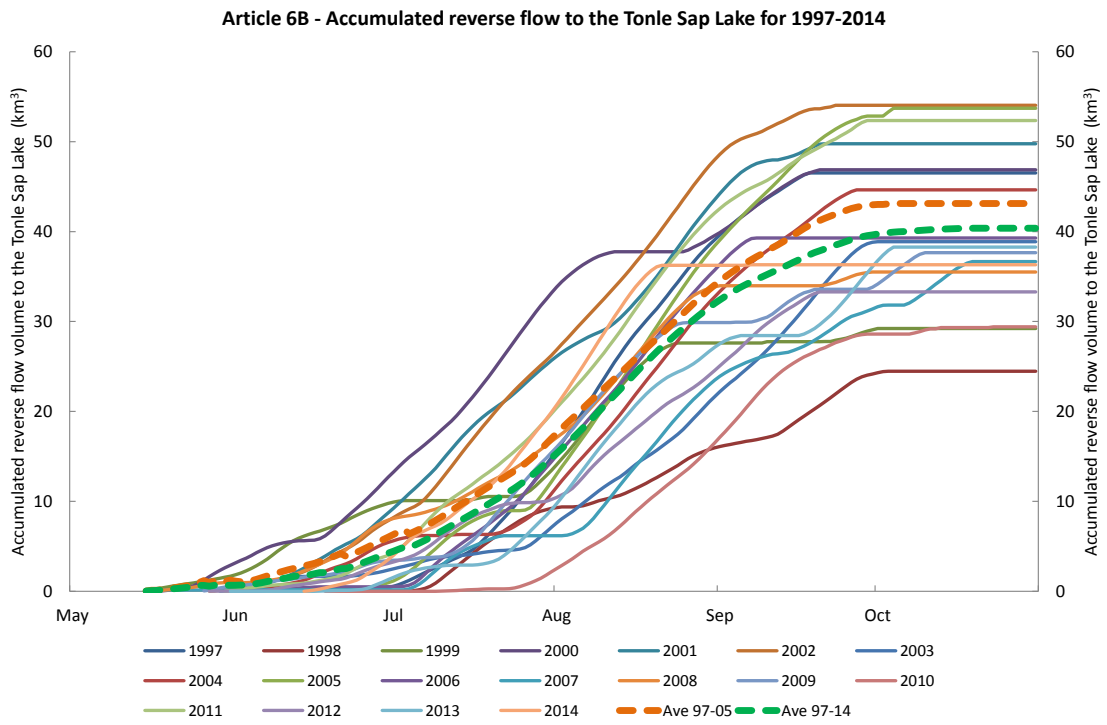


Figure B1. Daily accumulated reverse flows to the Tonle Sap Lake for 1997-2014.

APPENDIX C – FLOW MONITORING FOR IMPLEMENTATION OF ARTICLE 6C

Article 6C of the 1995 Mekong Agreement concerns the preservation of the natural flow regime of the Mekong mainstream and the need to “prevent average daily peak flows greater than what naturally occur on the average during the flood season.” This provision seeks to prevent water infrastructure operations that would amplify the natural peak flows and therefore could cause additional downstream damage.

The flow framework for real time monitoring purposes during the flood season is based on the **ARI 1:2, ARI 1:10 and ARI 1:20** of the historically annual daily peak flows (observed peak water level or rated peak discharge³³), usually the period of **1960-2009**, at the selected hydrological stations along the mainstream.

The daily observed water level and rated discharge from **1 July to 31 October** (the flood season) at the selected hydrological stations are compared with the flow framework below. The draft Technical Guidelines (October 2011) states that “there are four zones in this flow framework of increasing flood severity, each involving specific actions.

- **Zone 1 (green):** If the daily updated flow lies **below the ARI 1:2**, it means ‘normal hydrological conditions’; there is **no need for action**.
- **Zone 2 (yellow):** If the daily updated flow lies **between the ARI 1:2 and ARI 1:10**, it is greater than what naturally occur but it still means that hydrological conditions remain ‘stable’; there is a **need for caution**.
- **Zone 3 (orange):** If the daily updated flow lies **between the ARI 1:10 and ARI 1:20**, it means that hydrological conditions are ‘unstable’, investigation should be undertaken to **identify the possible cause(s) and possible mitigation measures**. There is a **need to be on alert**.
- **Zone 4 (red):** If the daily updated flow lies **above the ARI 1:20**, it means that hydrological conditions are ‘severe’ and the **implementation of mitigating measures** should be considered.”

³³ For the tidally influenced **Chrouy Changvar, Tan Chau and Chau Doc** stations, only the **daily observed water level** are used.

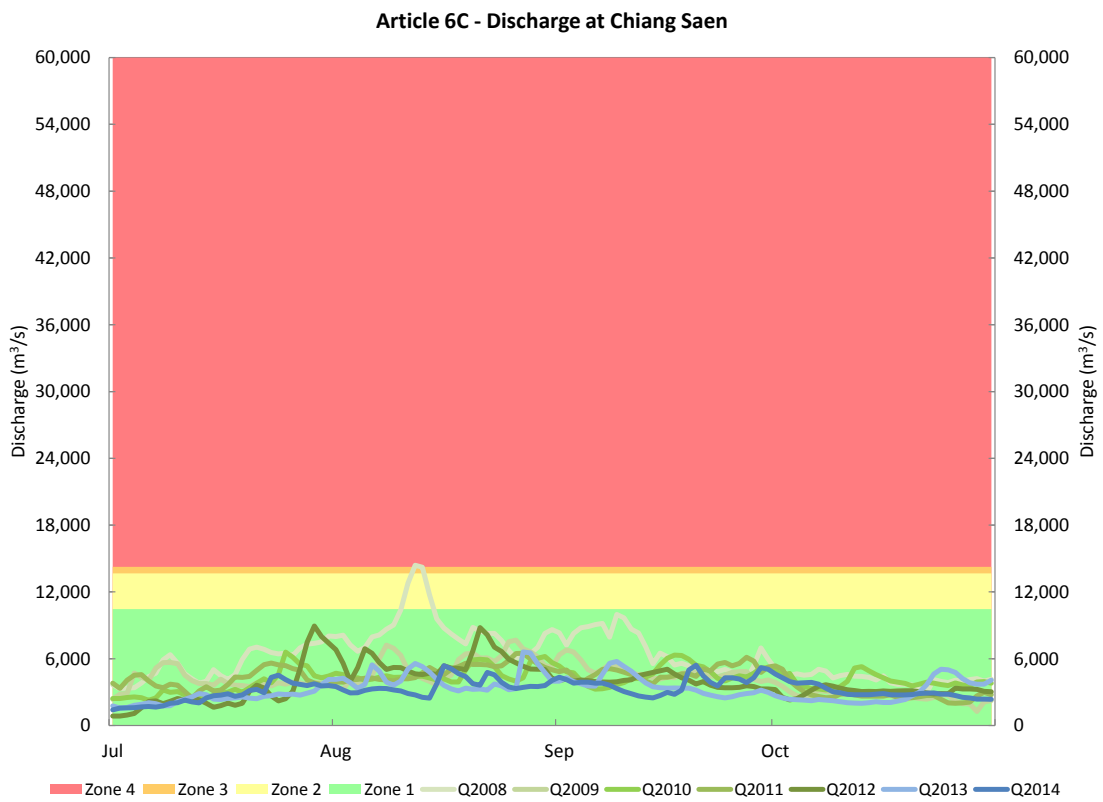
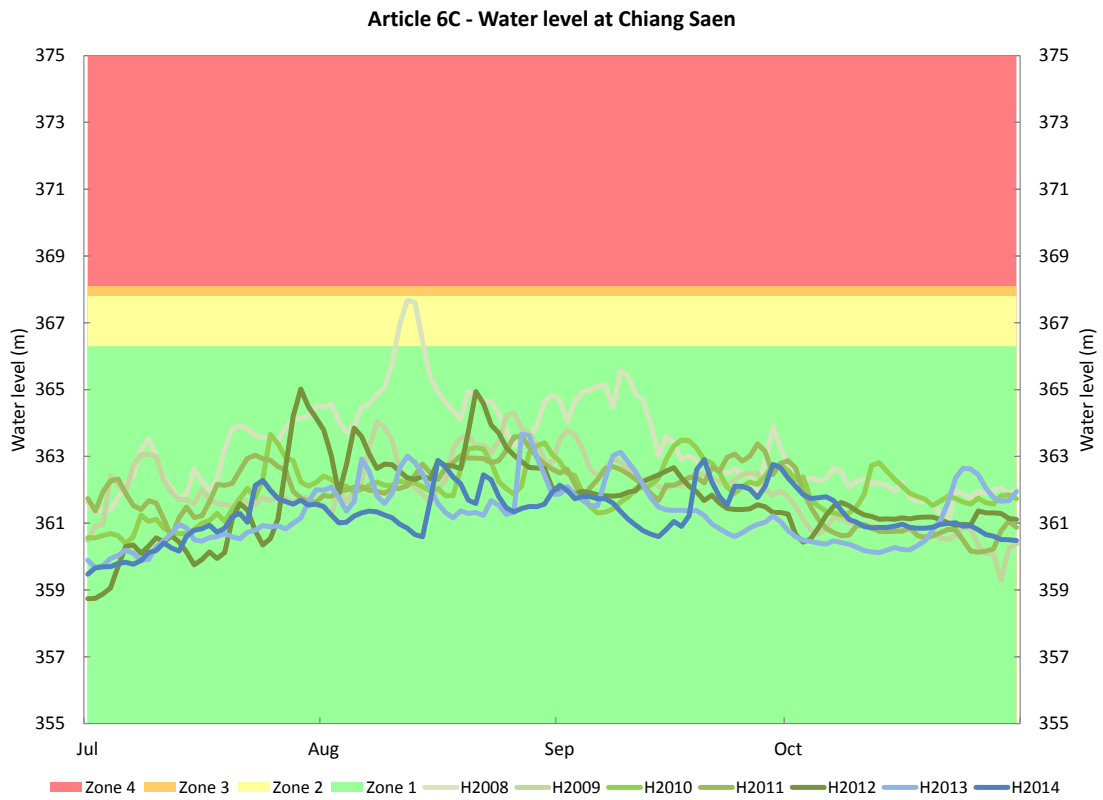


Figure C1. Flow monitoring for Article 6C at Chiang Saen for 2008-2014.

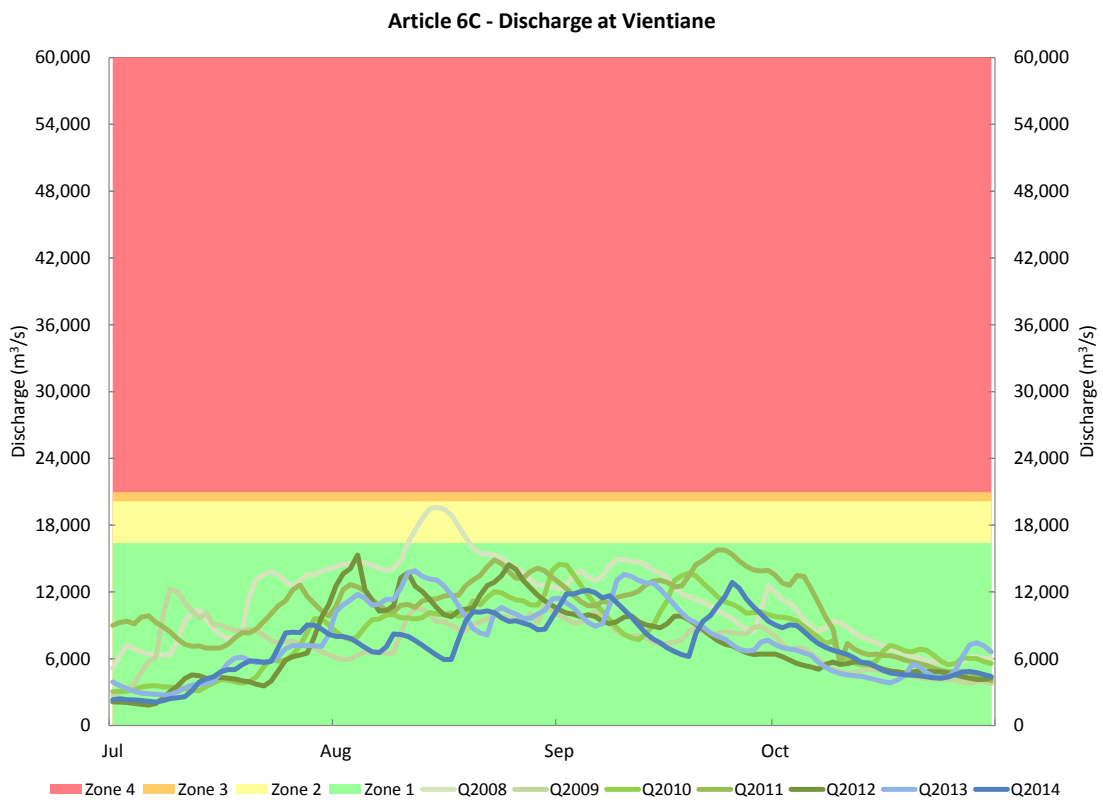
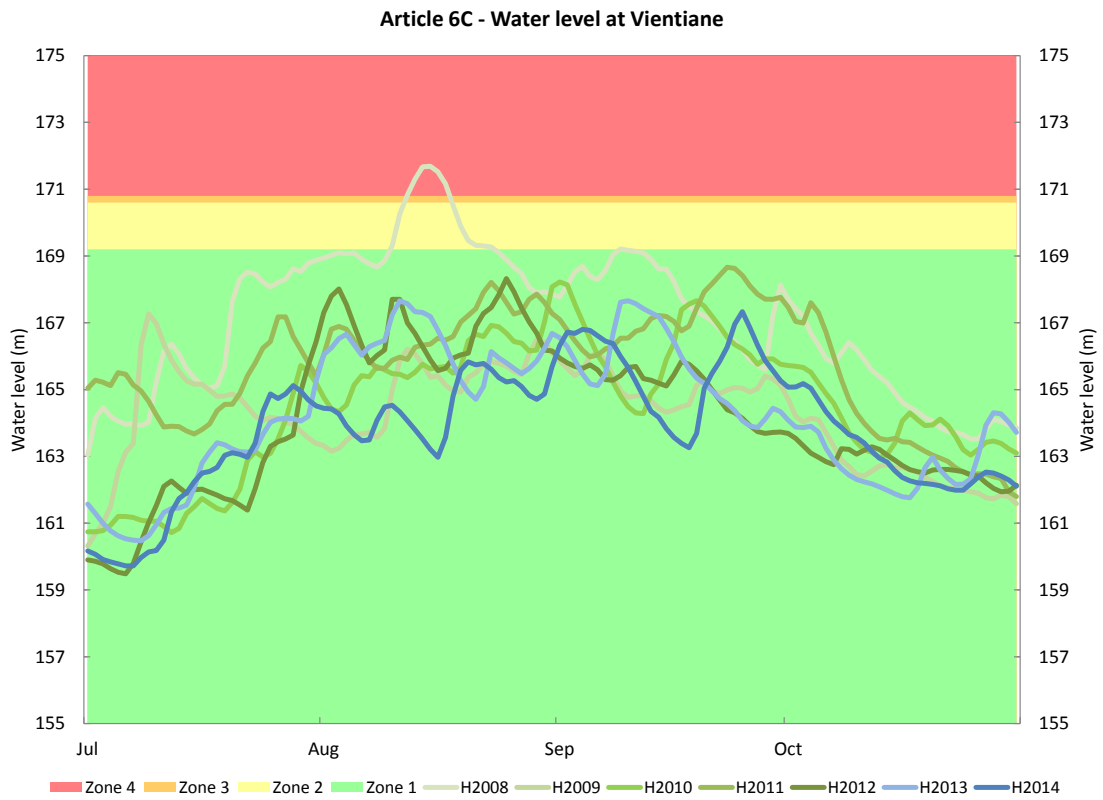


Figure C2. Flow monitoring for Article 6C at Vientiane for 2008-2014.

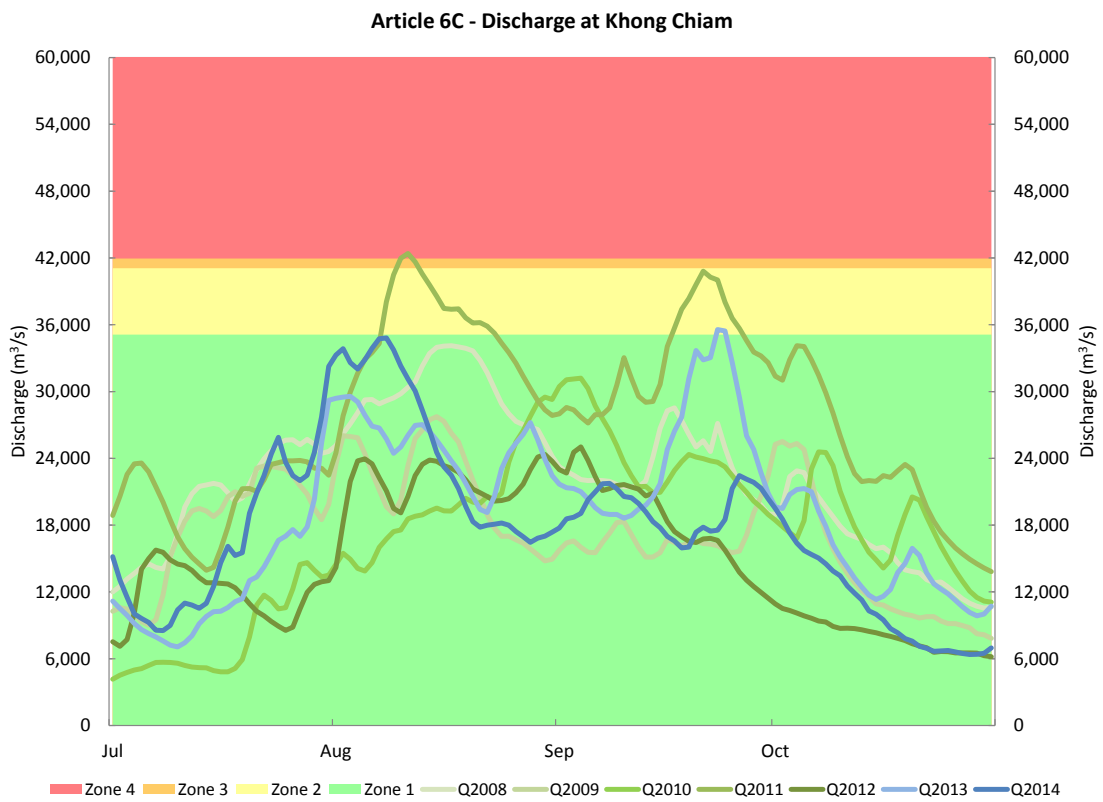
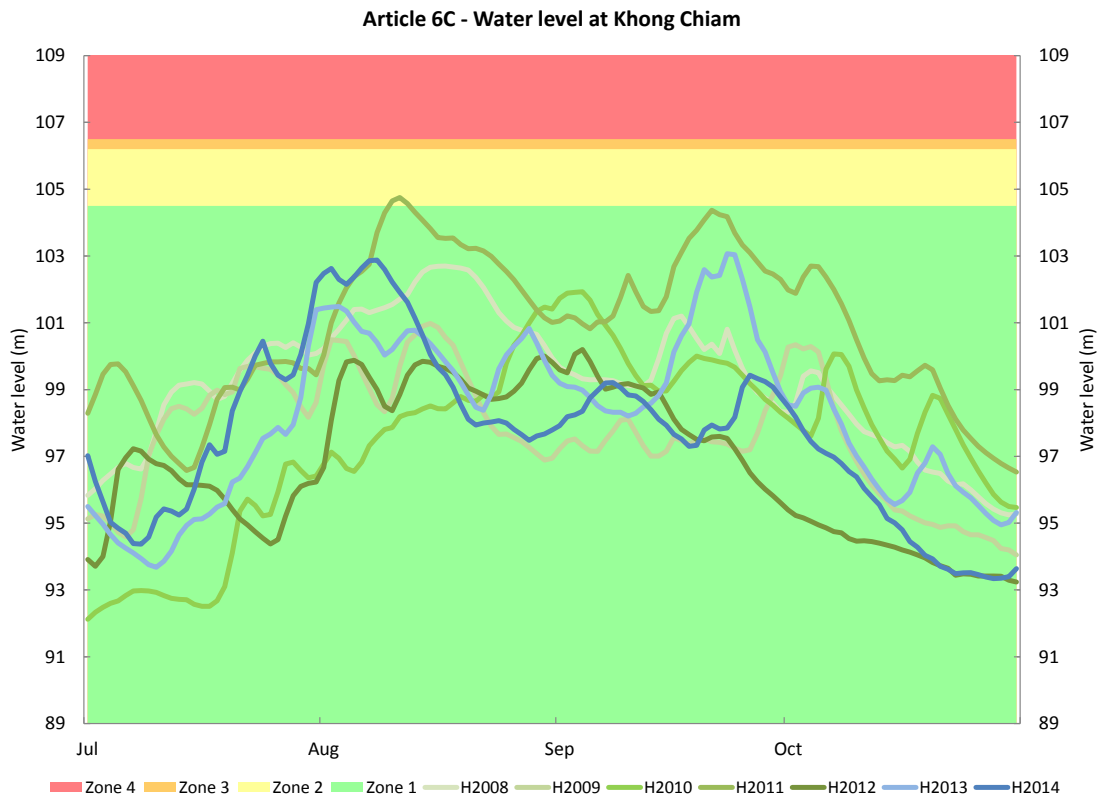


Figure C3. Flow monitoring for Article 6C at Khong Chiam for 2008-2014.

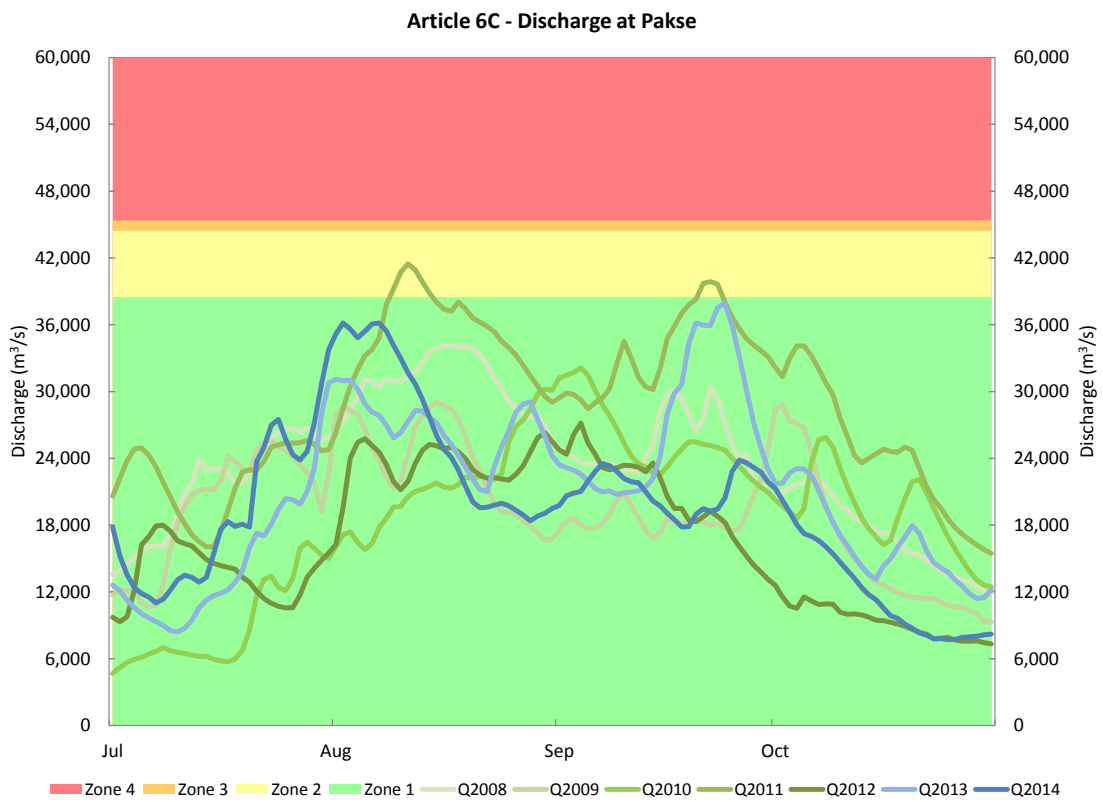
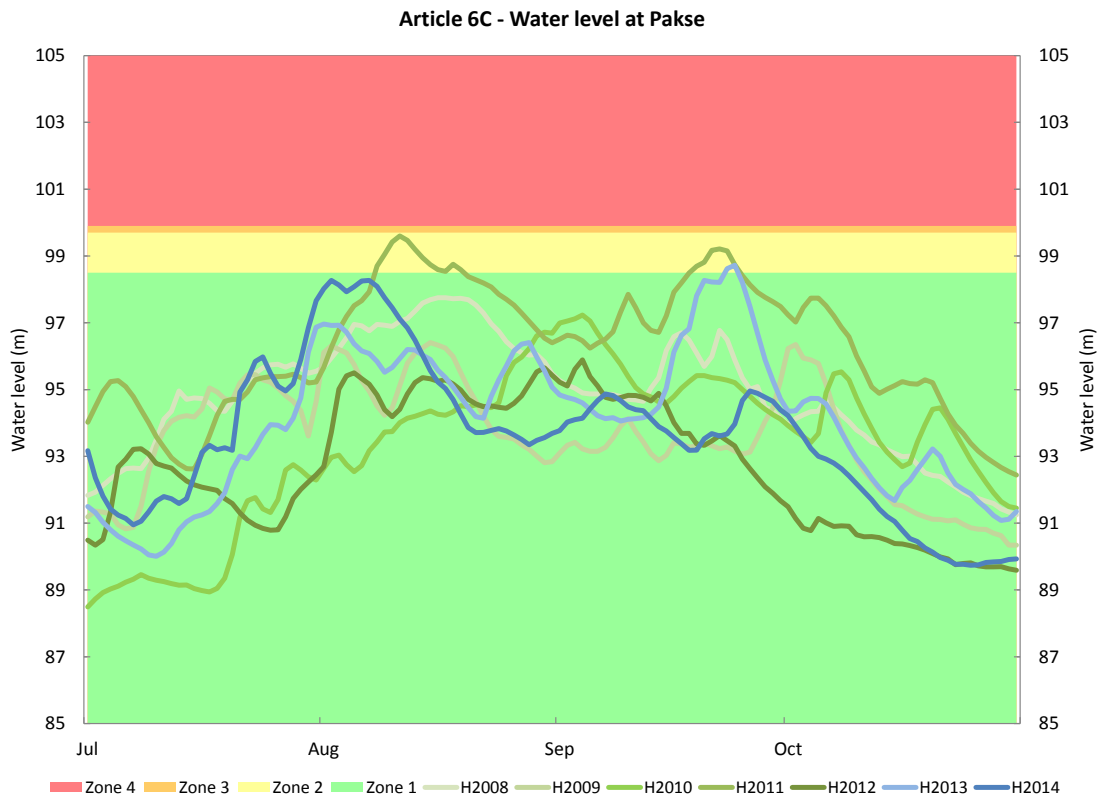


Figure C4. Flow monitoring for Article 6C at Pakse for 2008-2014.

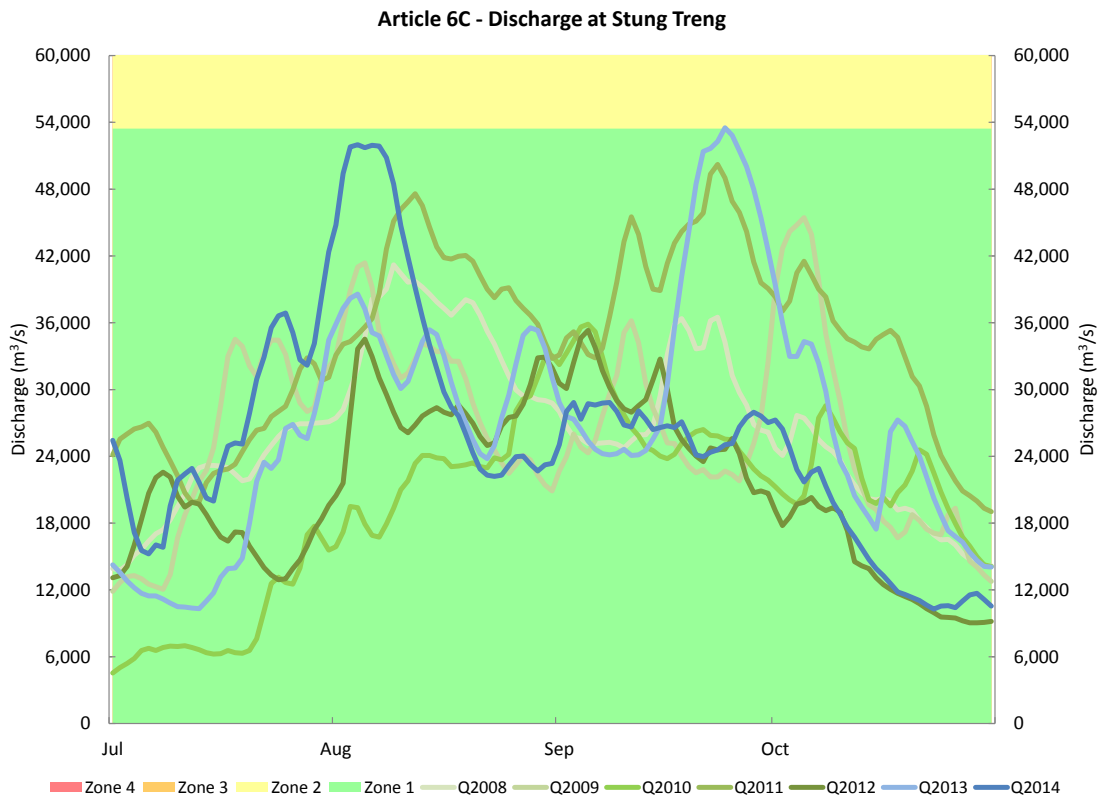
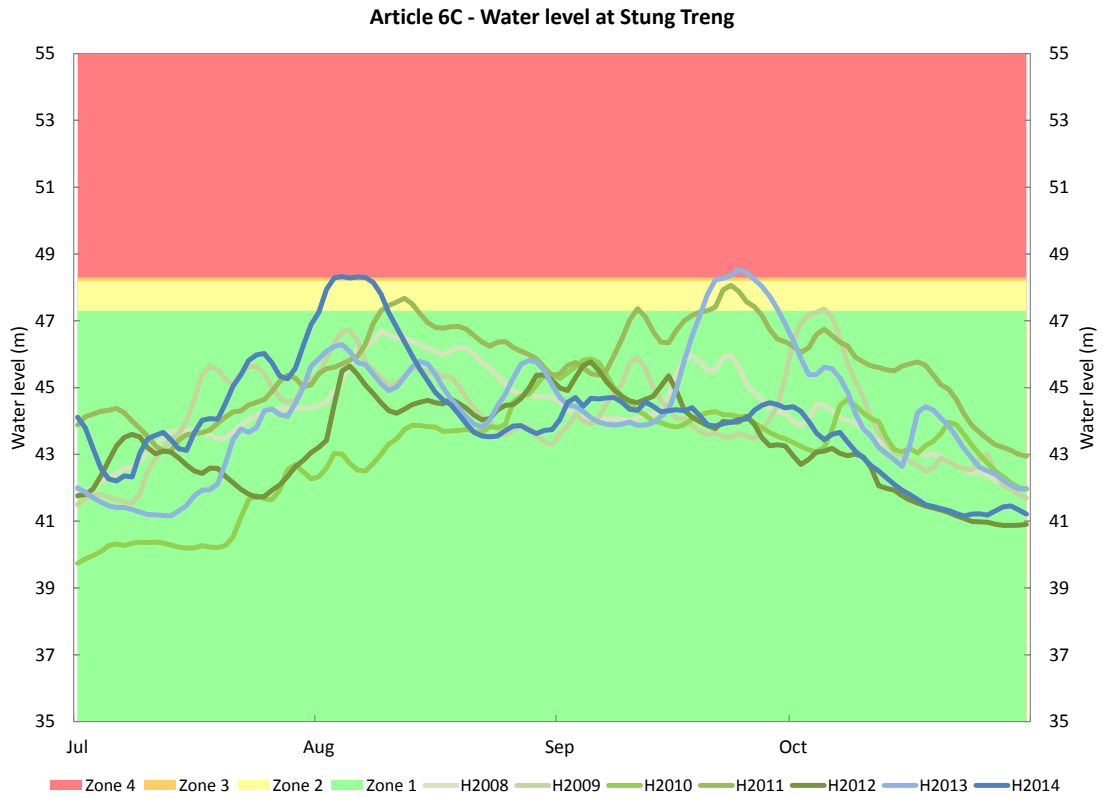


Figure C5. Flow monitoring for Article 6C at Stung Treng for 2008-2014.

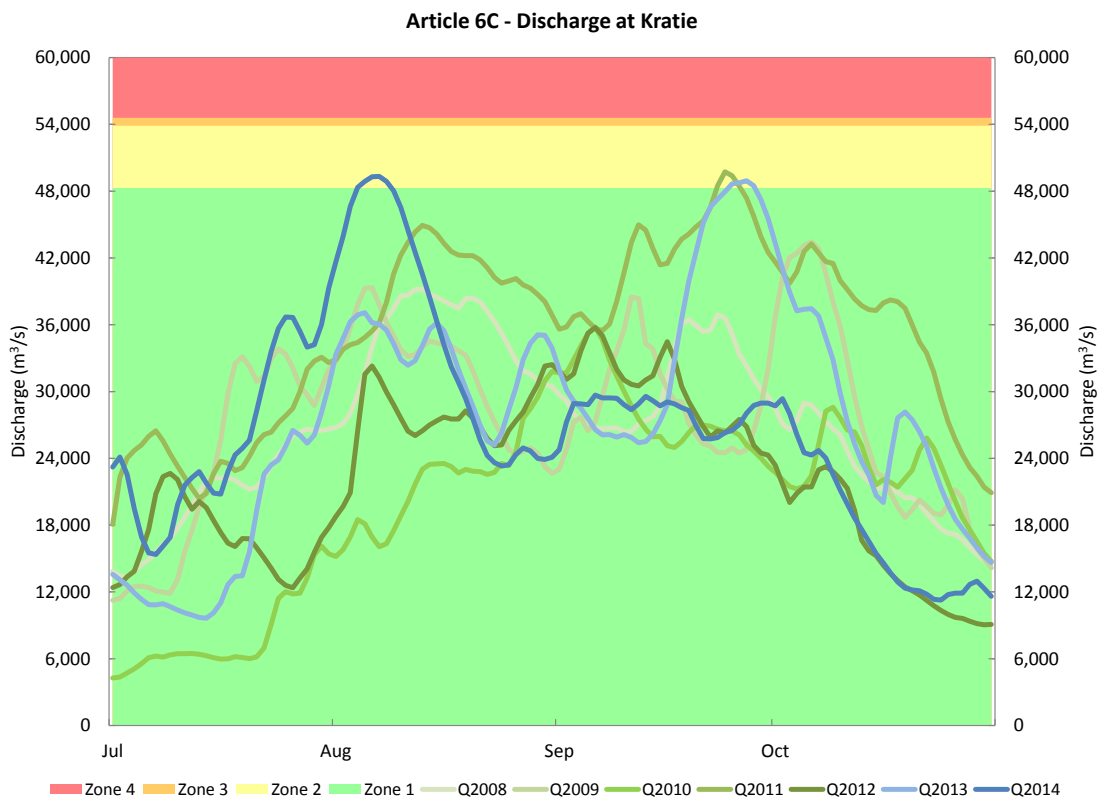
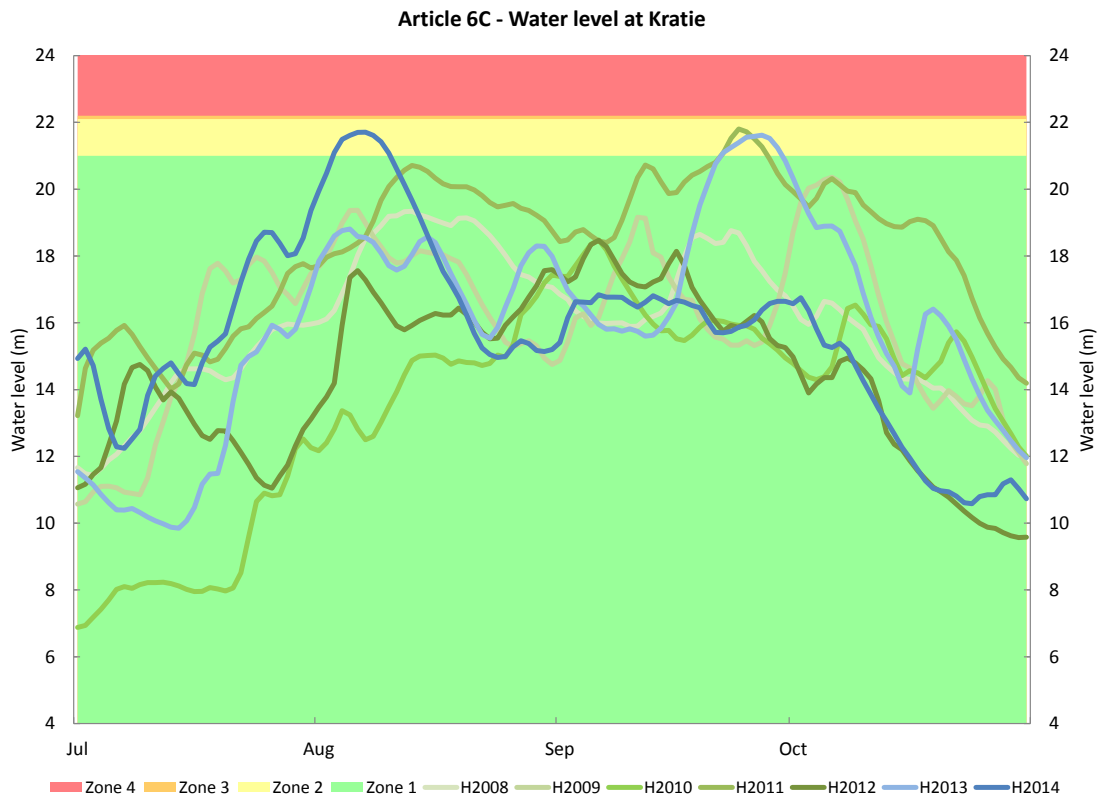


Figure C6. Flow monitoring for Article 6C at Kratie for 2008-2014.



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