

# Annual Mekong Flood Report 2015



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10-year lessons learnt of annual flood experiences

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## 1. SYNOPSIS

Since the introduction of the first Annual Mekong Flood Report, 10 reports were prepared of which 9 are linked with an annual theme. A theme elaborates on a topic which helps better understand floods and their impacts on the Mekong River Basin.

Flood hydrology of the Mekong mainstream was the first theme followed by the evaluation of the regional flood hydrology of the major tributary systems. Costs and benefits of floods were assessed in the AMFR 2008. The following two flood reports 2009 and 2010 took up a broader view and looked into climate change and its impact on floods and flooding in the Mekong Basin. With the exceptional flooding during the course of 2011, the 2011 report was the first one that took a retrospective view and summarised lessons learnt since the extreme events of 2000, given the exceptional flooding during the course of 2011. After the introduction of the flash flood guidance system at MRC in 2010, the report 2012 had the focus on flash floods. The regional impact of tropical storms was introduced in 2013. The AMFR of 2014 was again dedicated to scrutinise the impact of flash floods.

The AMFR 2015 was determined to look back and to summarise what lessons have been learnt from annual flood experience in the past 10 years. From the viewpoint of hydrology, a retrospective view of 10 years is short. As such, it is difficult to observe alternations in the hydrological regime with statistical evidence, unless anthropogenous effects emerge. In contrast, 10 years are long from the perspective of technical progress. Internet and computer technology, methods for data transmission and communication have changed drastically. What was cutting edge technology 10 years ago is nowadays almost a thing of the past.

With regard to the annual theme, this report cuts across different topics all of which played a role in the previous 10 years and will continue to do so in the future. This is why the AMFR 2015 has extended the view and includes drought, water infrastructure development, monitoring and flood forecasting, to mention some, in order to address the complex interplay between hydrological processes and human-induced effects.

As a result, one of the most important lessons learnt from the previous 10 years certainly is to strengthen the integrative approach to cope with future water resources related challenges in the Mekong River Basin.

## 2. 10-YEAR LESSONS LEARNT OF ANNUAL FLOOD EXPERIENCES

From the viewpoint of hydrology and flood analysis, a retrospective view of 10 years is short. Hydrological regimes normally develop over a longer period of time and thus, it is difficult to observe alternations with statistical evidence within 10 years. However, if we change the perspective and look at the technical progress that has emerged in terms of internet, computer technology, data transmission or methods of communication, the period seems to be rather long and what was cutting edge technology 10 years ago is nowadays almost a thing of the past.

In order to bridge these two very distinct worlds, we zoom out a bit from the 10-year period when it seems appropriate to reveal trends in hydrology and/or flood management and zoom in when it comes to advances in technology.

The whole range of hydrological extremes has occurred in the past 10 years. Thailand had to face the 2010 and 2011 floods, Viet Nam was hit by Typhoon Ketsana in 2009 and the 2008 flood was above average at least in the north. Prior to 2005, there was the exceptional flood event in 2000 and the flood season of 2001 with high flood volumes. Section 2.3 addresses the topic of major flood events. Apart from floods, droughts also occurred in recent years and were responsible for significant stress in the agricultural sector. This is briefly addressed in Section 2.4.

A major topic in the previous decade was and still is the development of hydropower and dams. It is difficult to say if dams along mainstream Mekong will turn out to be boon or bane, but it is easy to ascertain that dams cause an effect on the Mekong River in various ways. Sections 2.5 and 2.6 deal with this topic.

### 2.1 Overview of discharge along Mekong mainstream

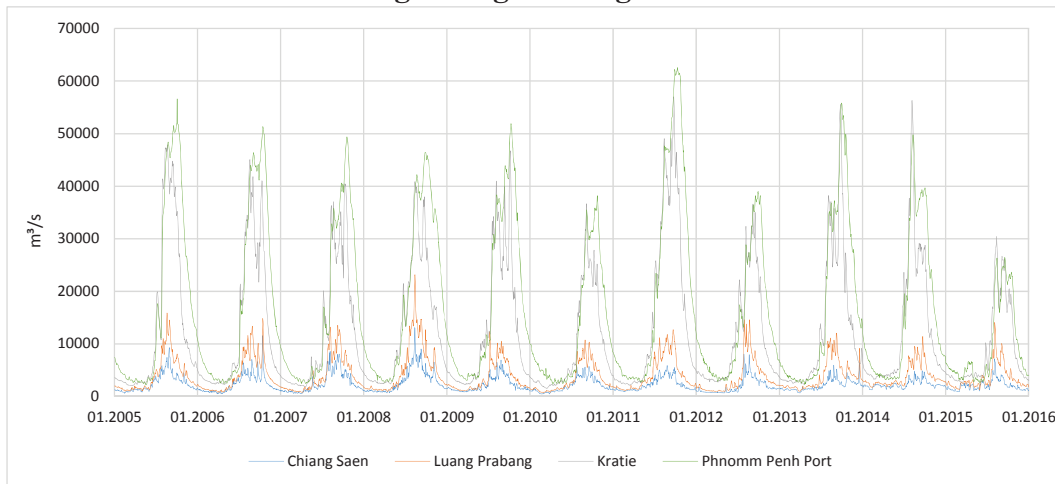


Figure 1: Flow time series from 2005 to 2016 for selected stations along Mekong River

The flood peaks for 10 discharge observation stations are listed below for the period 2005 to 2015. The colours indicate the magnitude with yellow as high and dark green as low. All data were extracted from the MRC HydMet database on the basis of 24h values (00:00 to 24:00).

Table 1: Flood peaks for 10 discharge stations from 2005 to 2015 in [m<sup>3</sup>/s]

Flood Peak [m <sup>3</sup> /s]	Chiang Saen	Luang Prabang	Chiang Khan	Nong Khai	Nakhon Phanom	Mukdahan	Kong Chiam	Pakse	Stung Treng	Kratie
2005	9228	15763	14911	15515	33290	36715	37258	39271	49012	47914
2006	11409	14757	13825	13870	24448	25609	29104	31284	44309	45069
2007	8474	13487	12101	13123	23943	24879	31418	33098	41452	40444
2008	12970	23116	22124	23564	32385	34125	33237	34875	41931	40842
2009	6895	12105	11448	11411	22461	24480	27303	29033	47411	46740
2010	5774	10652	11784	14432	25007	26767	30537	32539	36170	36637
2011	5838	12646	13005	16405	30744	35263	40753	43458	53330	57025
2012	7967	14525	13265	15578	23188	23819	24737	26936	35514	36589
2013	6282	12014	11835	13659	24894	25722	34464	39274	57612	55622
2014	4855	11399	11643	12329	23482	25686	33881	37228	55770	56323
2015	7159	14070	13549	14928	26130	27311	27126	28757	31802	30421

Return periods were assigned to the peak discharges based on the statistical analysis conducted in AMFR 2006 (MRC, 2007). The AMFR 2006 used time series of discharge dating back to 1913 for Luang Prabang (longest) and 1976 for Chiang Khan (shortest).

Table 2: Return periods for 10 discharge stations from 2005 to 2015 in [m<sup>3</sup>/s]

Return period [a]	Chiang Saen	Luang Prabang	Chiang Khan	Nong Khai	Nakhon Phanom	Mukdahan	Kong Chiam	Pakse	Stung Treng	Kratie
2005	1 a	2 a	1 a	1 a	20 a	25 a	2 a	2 a	1 a	1 a
2006	2 a	1 a	1 a	1 a	1 a	1 a	1 a	1 a	1 a	1 a
2007	1 a	1 a	1 a	1 a	1 a	1 a	1 a	1 a	1 a	1 a
2008	2 a	50 a	25 a	25 a	10 a	5 a	1 a	1 a	1 a	1 a
2009	1 a	1 a	1 a	< 1 a	< 1 a	1 a	1 a	1 a	1 a	1 a
2010	1 a	< 1 a	1 a	1 a	1 a	1 a	1 a	1 a	1 a	1 a
2011	1 a	1 a	1 a	1 a	5 a	10 a	5 a	5 a	2 a	2 a
2012	1 a	1 a	1 a	1 a	1 a	< 1 a	< 1 a	< 1 a	< 1 a	1 a
2013	1 a	1 a	1 a	1 a	1 a	1 a	2 a	2 a	5 a	2 a
2014	< 1 a	1 a	1 a	1 a	1 a	1 a	1 a	2 a	5 a	2 a
2015	1 a	1 a	1 a	1 a	1 a	1 a	< 1 a	< 1 a	< 1 a	< 1 a
2016	< 1 a	2 a	2 a	1 a	1 a	< 1 a	< 1 a	1 a	1 a	1 a

The flood years 2008 and 2011 are given in more detail in Section 2.3 where return periods are shown along the longitudinal section of the Mekong Mainstream.

El Niño/Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on inter-annual time scales. According to NOAA, the attempt is made to monitor ENSO by basing the Multivariate ENSO Index (MEI) on the six main observed variables over the tropical Pacific. These six variables are: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C). In order to keep the MEI comparable, it is standardized with respect to each season and to the 1950-93 reference period (Wolter et al., 2011).

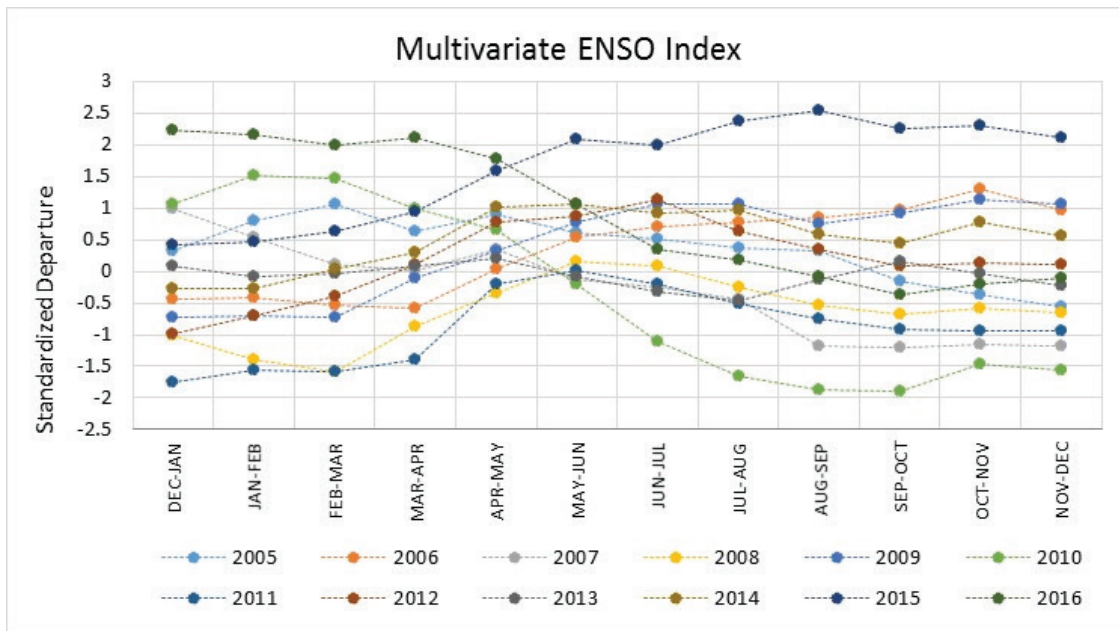


Figure 2: Multivariate ENSO Index (<https://www.esrl.noaa.gov/psd/enso/mei/#Home>)

Table 3: MEI ENSO Index ranked from 1 (strongest) to 68 (weakest) with data from 1950 to 2016

YEAR	DEC-JAN	JAN-FEB	FEB-MAR	MAR-APR	APR-MAY	MAY-JUN	JUN-JUL	JUL-AUG	AUG-SEP	SEP-OCT	OCT-NOV	NOV-DEC
2005	27	15	8	14	12	23	24	26	29	40	46	47.5
2006	42	43.5	48	52	40	24	18	17	13	15	7	14
2007	13	20	29	38	30	45	47	51	59	60	60	61
2008	57	64	66	56	50	34	37	44	51	53	50	52
2009	52	53	54	45	31	21	10	9	19	16	11	12
2010	12	5	6	7	20	49	60	66	68	67	65	65
2011	67	67	65	65	46	39	45	54	56	55	53	56
2012	56	51	47	35	16	17	9	22	27	33	30	31.5
2013	30	33	37	36	36	43	49	52	39	30	34.5	39
2014	38	39	34	30	10	10	14	13	20	25	18	21
2015	22	22	17	9	7	3	2	2	2	2	3	3
2016	3	3	4	4	6	9	32	32	38	45	41	35

## 2.2 ENSO – Hydrology relationship

### 2.2.1 From understanding principles to seasonal forecasts

Hydro-meteorological processes in the Mekong River Basin are influenced by global weather phenomenon such as ENSO. ENSO (El Niño–Southern Oscillation) is an irregularly periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting much of the tropics and subtropics. The warming phase is known as El Niño and the cooling phase as La Niña (definition from <https://en.wikipedia.org>).

In the previous 10 years the knowledge about the relationship between ENSO events and hydrological conditions in the Mekong River has advanced. At the beginning, the main interest was to understand governing principles of ENSO effects on hydrology in the Mekong River Basin, the focus has changed towards utilising ENSO-Hydrology relationships as precursor for more reliable seasonal forecasts regarding flood and droughts.

The variability of the rainfall-runoff relationships were investigated 2001 by Wooldridge et.al. In 2008, Li et.al. evaluated water level response to hydropower development in the upper Mekong River under consideration of ENSO effects. Climate variability, ENSO and sediment delivery in the Mekong Delta were further assessed by Xue et.al (2011) in light of dam development. This study further evolved in the report about sediment and coastline formation of the Mekong Delta and the impacts of dams by Li et.al. (2017). A summary regarding the evolution of knowledge in view of the ENSO – Hydrology relationship is given by (Räsänen, et.al., 2012) and (Hok Fum Kok, 2018).

Main findings are that ENSO events have a significant influence on precipitation, discharge, evaporation, water levels and snow accumulation and melting in the Mekong River Basin. (Räsänen et.al., 2012) shows that impacts were observed in the spatial distribution of rainfall as well as the temporal characteristics of the hydrological regime. Cumulative flow of a hydrological year (May–April) was statistically most related to ENSO index values from November–December from the previous year and January–February of the year when the hydrological year i.e. flood pulse started.

The spatial analysis of precipitation anomalies further revealed that ENSO related anomalies vary spatially within the basin. The positive precipitation anomalies related to La Niña (1 + 2 year) were experienced on average throughout the basin but more significantly in the southern parts of the basin, while negative anomalies related to El Niño (1 + 2 year) were observed more significantly in the eastern and central parts of the basin (Räsänen et.al., 2012).

With respect to discharge, flood volume and flood duration were below average during El Niño (1 + 2) years and above average with La Niña (1 + 2) years. The annual peak floods decreased with El Niño (increased with La Niña) and flood end dates advanced during El Niño (1 + 2) and delayed during La Niña (1 + 2) years.

The relationship between ENSO and Mekong hydrology is considered as a non-stationary process and subject to change over time. Still, there is a potential for

developing forecasts incorporating ENSO induced hydrological anomalies. ENSO index values from December–February months can explain approximately 50% of the inter-annual variation of the Mekong’s discharge. Results from (Räsänen, et.al., 2012) and (Hok Sum Fok et.al., 2018)) indicate that major floods and droughts in the Mekong were commonly associated with ENSO events.

(Hok Sum Fok, 2018) presented an approach in which water levels in the Mekong Delta were reconstructed by means of hydro-meteorological indices and ENSO indices. The combination of upstream and downstream Palmer Drought Indices and ENSO information obtained the best-reconstructed water levels for Vam Kenh and Dinh An stations.

It is suggested by (Hok Sum Fok, 2018) that further improvement may lie in a better temporal resolution of the PDSI and ENSO indices with good accuracy. As PDSI uses soil water parameters, the application of spatially distributed hydrological models to derive these parameters could further enhance this methodology to develop it into a tool for predicting seasonal effects.

The evolution of forecasting water levels and discharge by means of ENTRO effects could also become an asset in addressing salinity intrusion in the Mekong Delta.

Historically, severe salinity intrusions have occurred in years with strong El Niño, such as in 1998 (after 1997 El Niño) and 2010 (after 2009 El Niño). Salinity intrusion is more serious during a drought with a large spatial distribution compared to freshwater shortage confined to the coastal provinces. On top of that, effects of climate change seem to take effect through sea level rise. The sea level around the Mekong River Delta has risen by 20 cm since 1901 and monitoring stations indicate an average sea level rise of 3 mm per year over the last 30 years (Ben Tre et.al, 2016).

In addition, the situation exacerbates by shoreline erosion. Investigations by (Li et.al., 2017) demonstrate that the total shoreline change rate has significantly decreased over the past four decades. In particular, there was a notable discontinuity in the delta area change in approximately 2005, when the Mekong Delta entered a destructive phase characterized by both shoreline and geomorphological changes. Coincidentally, the total accumulated installed capacity of the dams in the Mekong Basin abruptly rose after 2005. (Li et.al, 2017) concludes that the dam construction is an important but not sole factor of delta erosion.

### **2.2.2 Conclusion**

The knowledge about ENSO effects and its impact on the hydrology in the Mekong River Basin has evolved during the past 10 years. At the same time, global climate centres have developed sophisticated global weather models based on deterministic and statistical approaches. They capitalise on ENSO effects and provide the means to embark on long-range forecasts (MRC, 2016b).

Given the development in the previous 10 years, seasonal forecasts are on the verge of becoming trustworthy and powerful tools to support water management. As such, El Niño based forecasts in combination with hydro-meteorological indices can provide seasonal discharge forecasts, which can be used, among others, to predict risks of salinity intrusion. It is obvious that due to hydrological uncertainties in general and

climate change in particular, seasonal forecasts cannot deliver accurate information for flood and drought. However, long-range forecasts could be a valuable step towards a seasonal early warning system. Moreover, it would facilitate coordinate planning and water management, in particular, with all the dam development plans in the Mekong Basin in mind.

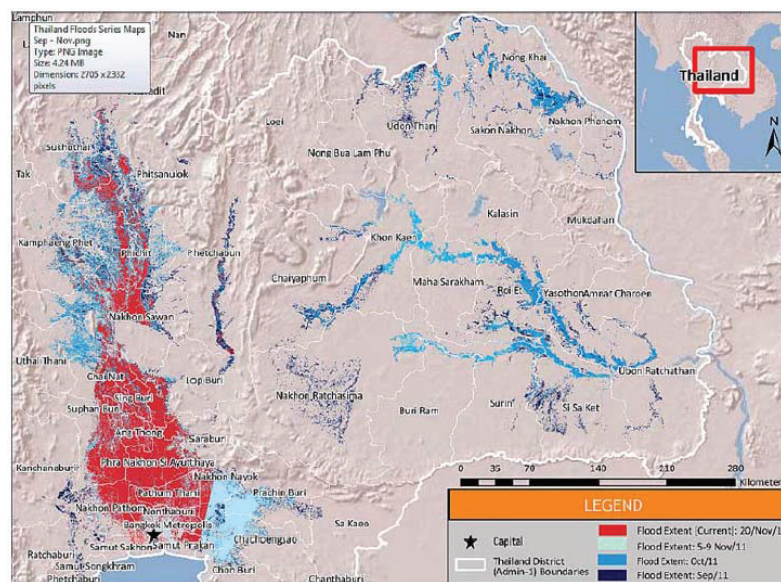
## 2.3 Flood

### 2.3.1 Flood season 2011

On October 21st, 2010, the New York Times reported “Thai Flooding Is Called Worst in Decades” and cited governmental officials that twenty-eight of the country’s 77 provinces had been affected, including provinces just north of the capital, Bangkok. With the surge of water moving toward the mouth of the country’s largest river system, the government had warned residents in some parts of the capital to prepare for flooding in the coming days. Ten of 33 major reservoirs in Thailand were over capacity and were being forced to dump water downstream, according to the government’s Department of Disaster Prevention and Mitigation.

At this point in time, it was truly difficult to imagine that one year later an even worse flood would hit Thailand again.

In 2011, Thailand witnessed its worst flooding in living memory, causing tremendous damage to the country’s economy, industrial sector and society. Floodwaters inundated 18,000 km<sup>2</sup> of farm land. The disaster ranks as the world’s eleventh costliest disaster with estimated costs of 45.7 billion USD (World Bank Statistic). The flood extent is illustrated in Figure 3.



Layer Sources: Admin. Boundaries (DIVA-GIS), Flood Extent Layers (GISDATA).  
Disclaimer: The borders and country names used are indicative and do not represent the views of The World Bank Group.

Figure 3: Flood extent of the 2011 flood in Thailand (World Bank, 2012)

The accumulated precipitation from January to October 2011 was 35% higher than average and was attributed to the La Niña phenomenon. In the wake of La Niña events, sea surface temperatures are lower than usual and have the potential to bring

increased precipitation to South East Asia (Guy Carpenter, 2012). In 2011, precipitation came earlier than usual and in unprecedented amounts. Bhumipol and Sirikit dams reached their overloading capacity and high tides and a storm surge in the Gulf of Thailand adversely affected the situation.

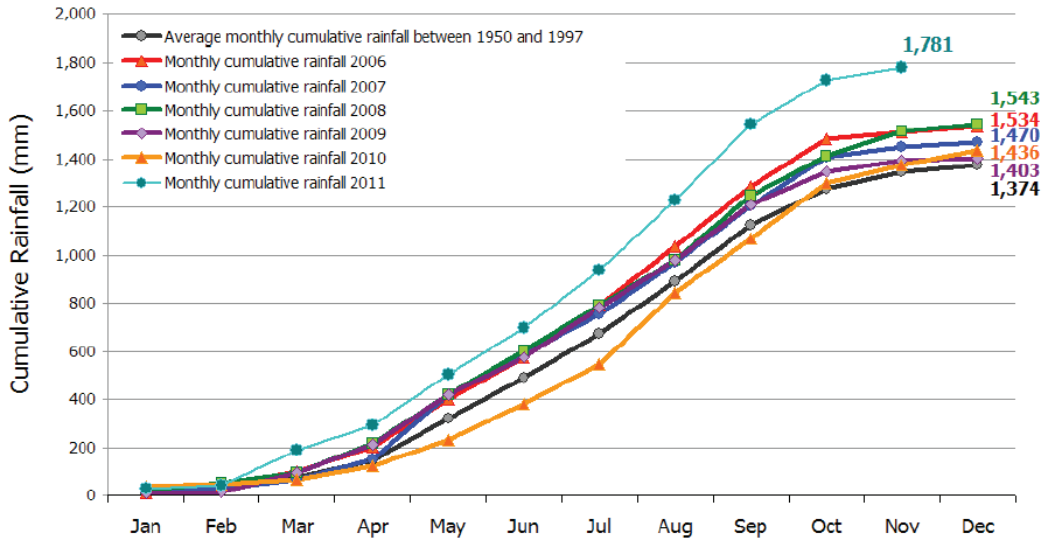
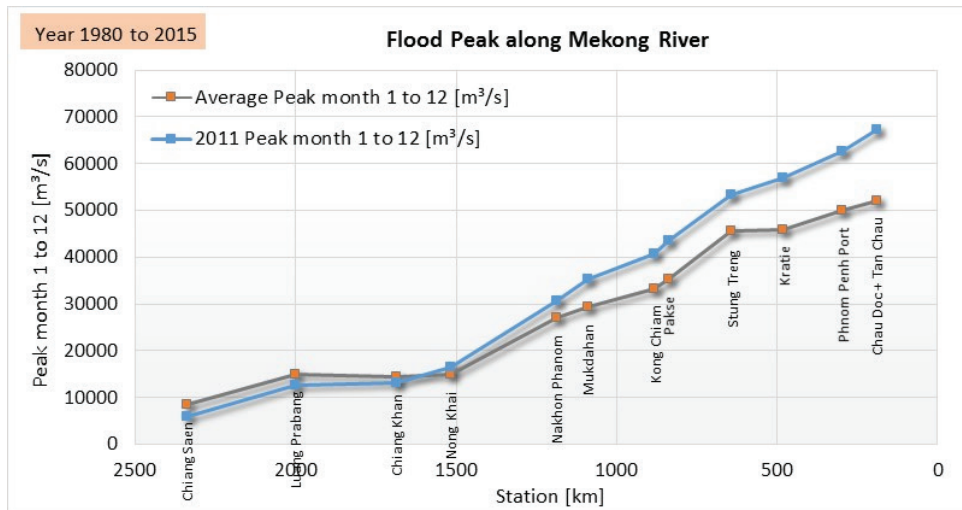


Figure 4: Cumulative rainfall in comparison to 2011 in Thailand (Thaiwater, 2012)

Extreme conditions like the Thailand flood 2011 do not necessarily affect the whole Lower Mekong Basin. The situation is diverse simply due to the extent of the basin. While the flood peak and flood volume at Chiang Saen was close to or below average, the gap between 2011 and long-term means for both peak and volume developed further south.



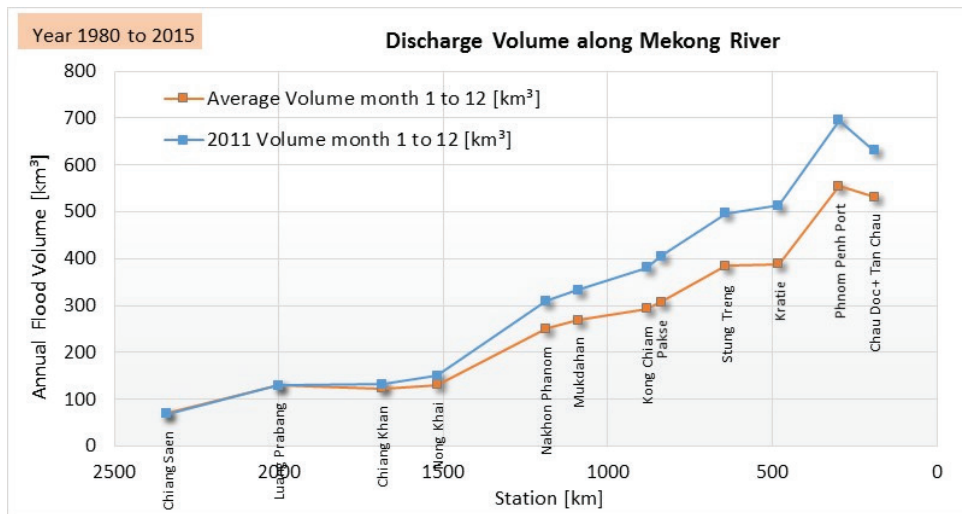


Figure 5: Peak and volume along mainstream Mekong, average 1980-2015 and 2011

Even though 2011 was the worst for Thailand, the Lower Mekong Basin (LMB) faced its worst floods not necessarily in 2011. By using records starting in 1980, the highest peaks with their respective year of occurrence are illustrated in Figure 6 and with the basis of 2005 to 2015 in Figure 7. When 1980 to 2015 is used for the analysis, 2011 does not show up at all. With the basis from 2005 to 2015, we obtain three flood seasons in terms of largest peak discharge: 2008 in the upper part up to Nong Khai, 2005 is indicated highest for Nakhon Phanom and Mukdahan and 2011 from Kong Chiam down to the Delta.

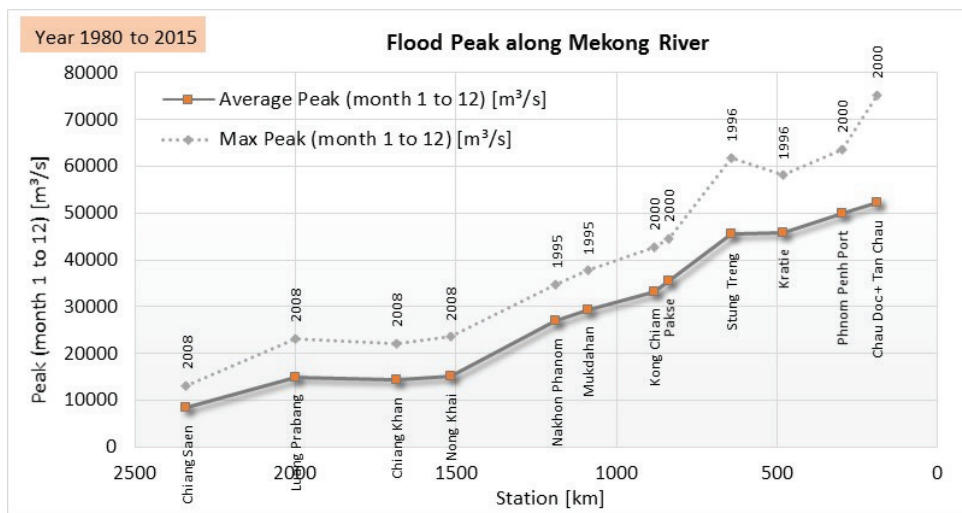


Figure 6: Average and max peaks (1980 to 2015) with respective year of occurrence

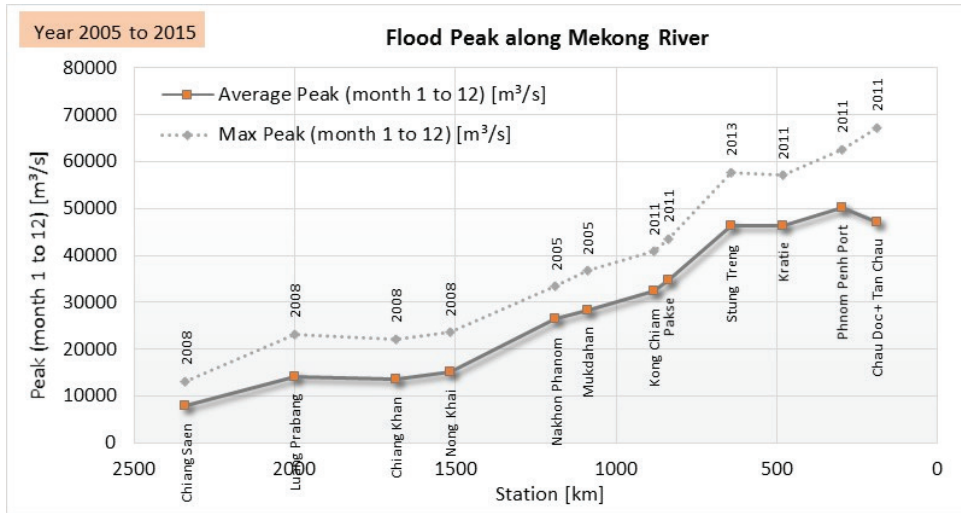


Figure 7: Average and max peaks (2005 to 2015) with respective year of occurrence

Interesting is how the maximum peak discharge of 2011 can be ranked along mainstream Mekong in terms of return periods. All years from 1980 to 2015 were used to derive distribution functions. Figure 9 shows how return periods differ along the Mekong. Chiang Saen reached an annual peak discharge, between Nakhom Phanom and Pakse a 5 to 10-year flood peak was observed, while almost annual conditions occurred further south.

This reveals that there is no homogeneous flood pattern and simple predictive transformation from one part of the LMB to another might fall short.

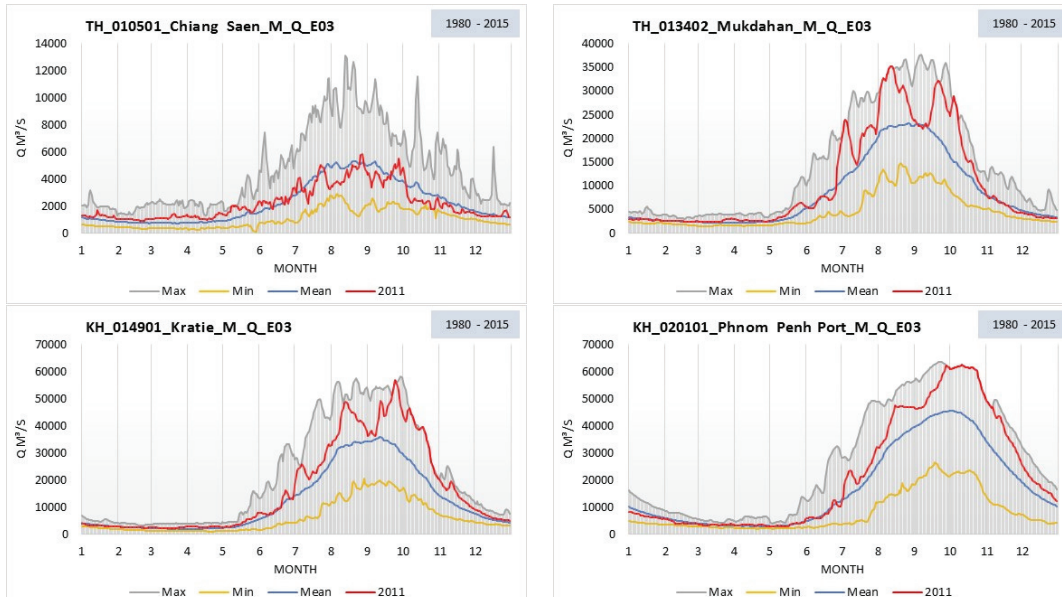


Figure 8: The year 2011 at different stations compared with mean, min and max 1980-2015

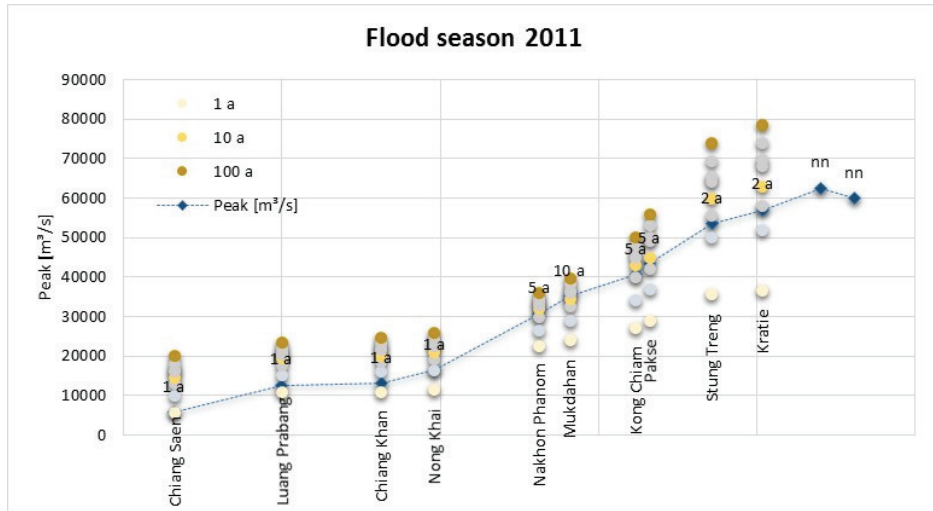


Figure 9: Return periods of peak flow compared with 2011 peak discharges (return periods from AMFR 2006, (MRC, 2007))

### 2.3.2 Flood season 2008

The flood season 2008 was characterised by extreme peak discharges in the north and below average flood peaks in the south. Along mainstream Mekong north of Pakse, flood peaks ranked close to 100-year return periods according to the frequency analysis conducted with values as of 1980.

The situation in 2008 is described in the AMFR 2008 as “flood conditions in the Lower Mekong Basin during 2008 were amongst the most extreme since records began and will be viewed along with those of 1966, 1971, 1978, 2000, 2001 and 2002 as defining the character and magnitude of severe flood conditions on the mainstream. Like the extreme events that have been observed in the past, conditions in 2008 were geographically confined to just a part of the Basin, in this case the areas upstream of Vientiane and Nong Khai. Only in 2001 were exceptional flood conditions basin-wide in any sense. The more typical pattern is for exceptionally high flows to be confined to either the reach upstream or that downstream of Vientiane, which represents a ‘hydrological discontinuity’ between the two. To the north the flood hydrology is determined by flows out of China and the contributions of the large tributaries systems such as the Nam Tha, Nam Ou and Nam Khan. The significance of these inflows then diminishes further downstream as the large left bank tributaries, specifically those in Lao PDR, begin to exert their dominant influence”.

Figure 10 represent the statement from the AMFR 2008 and return periods downstream of Nong Khai reveal only 10 year or smaller return periods.

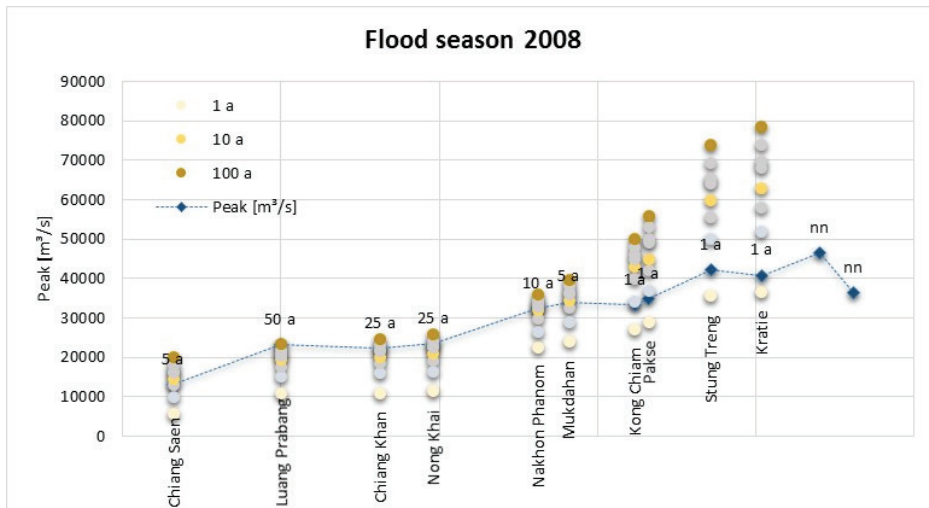


Figure 10: Flood peaks and return periods for the flood season 2008 (return periods from AMFR 2006)

The turning point where conditions were just on average is around Pakse. In Cambodia and in the Delta, the flood season 2008 is recognised as “normal”.

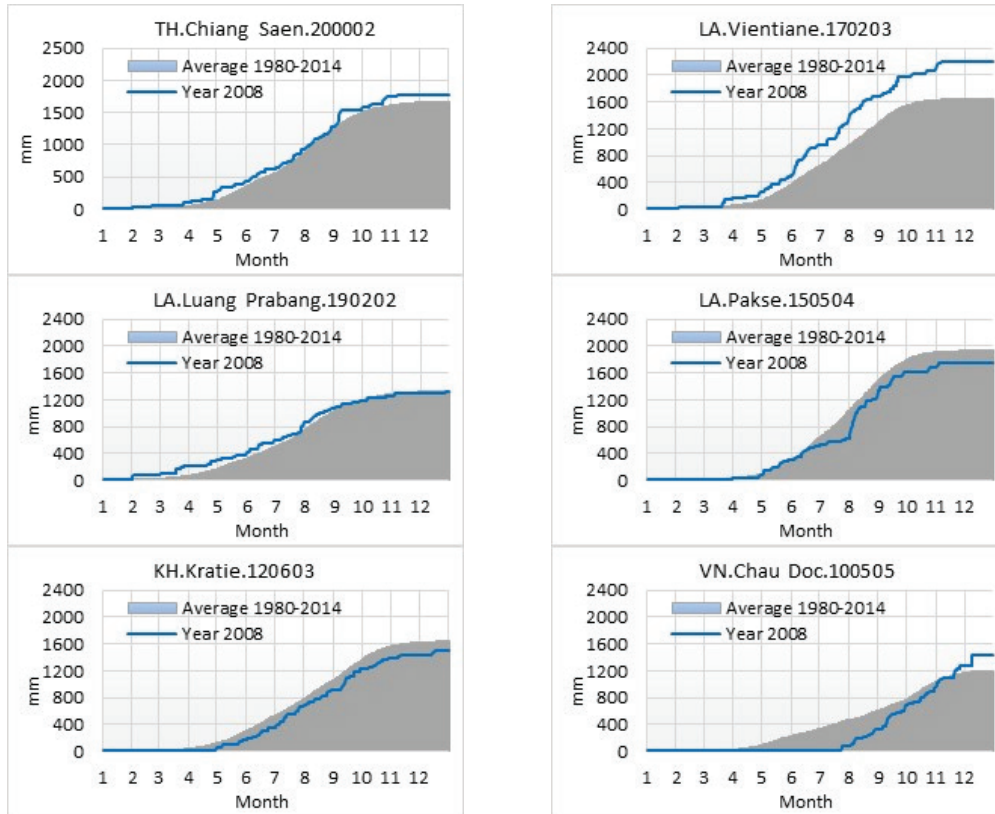
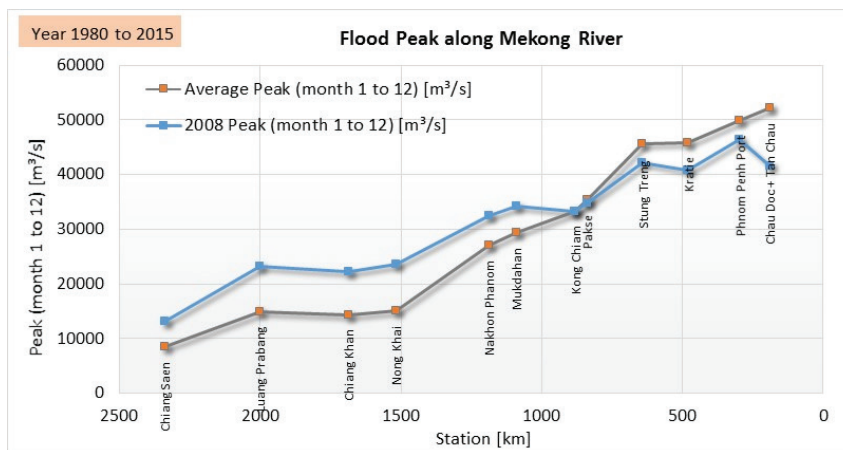


Figure 11: Cumulative rainfall in 2008 at selected stations

Cumulative rainfall outlines the discontinuity and is again a confirmation of the diversity in the basin's hydro-meteorological conditions.



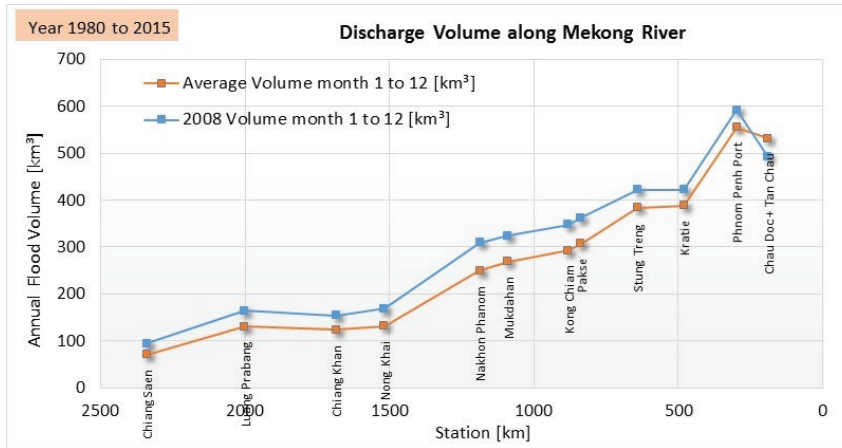


Figure 12: Peak and volume along mainstream Mekong, average 1980-2015 and 2008



Figure 13: Monthly statistics in comparison with 2008 at selected stations

### 2.3.3 Conclusion

What can be concluded from past flood events?

Observations are needed with a good spatial resolution. Each country should invest in a good hydro-meteorological observation network and in highly qualified staff to cope with the inhomogeneity of precipitation and runoff patterns. From the viewpoint of forecasting mainstream Mekong, a high spatial resolution in terms of precipitation is very important to cope with differences in the runoff characteristics within the basin.

This must be accounted for by a spatiotemporal high quality hydrological model. Modelling is already practised at MRC and in the member countries. To ensure high quality of hydrological modelling and to take advantage of activities at MRC and in each country, workshops for knowledge exchange, modelling and exchange of hands-on experience could be established.

Operation of dams is key for coping with floods. The risk of ill-operation and dam failures must be prevented. This can be achieved by coordinated and foresighted operation rules and a dam operation and dam safety framework in which skilled operators assume responsibility. Section 2.6 gives more details on this topic.

It is an illusion to believe that 100% flood protection is feasible. As a result, preparedness is a core element to alleviate impacts. Emergency preparedness plans (EPP) are required to identify hazard prone areas and to elaborate on countermeasures. The development of EPPs is necessary at all levels, from national level down to community level. The countries are already active in that regard. This topic is addressed in Section 2.7.3.

## 2.4 Drought

### 2.4.1 Annual flow volumes and 90-day low flow analysis

Significant low flow situations are attributable to below average precipitation occurring in several parts of the Mekong River Basin. Below average conditions occurred in 1992, 1993, 1998, 1999, 2003–2005 and in recent years, i.e. 2015. These hydrological extremes can be partly associated with ENSO effects (see Section 2.2). However, analysing low flow conditions along the mainstream Mekong will become more difficult due to anthropogenous impacts such as dam development.

Ever since the Chinese Lancang dam cascade upstream the LMB has been in effect, drought situations are obscured by dam operation. Knowledge of the releases from the Chinese dams is necessary to distinguish between natural conditions and man-made low flow augmentation further downstream.

Annual flow volumes are illustrated at selected stations in Figure 14. There is no homogeneous trend. Apparently, it seems as though Chiang Saen has an increasing trend while Tan Chau faces an ongoing reduction.



Figure 14: Annual flow volume at selected stations since 1980

The flood volume between June and October as compared with the average from 1980 to 2015 does not show uniform tendencies either.



Figure 15: Gain and loss of flow volume against long-term averages at selected stations since 1980 (June-October)

The picture changes if the driest 90 days periods in every year are determined and plotted against time. The year starts at 01. Nov. A homogeneous trend becomes visible except for at the Delta. The tendency is very distinct at Chiang Saen. This is the location where effects of dam operation are strongest. All other locations show a trend that starts between 2010 and 2012. Kratie seems to show three stages indicated with green lines. Stage 1 goes up to 2000 where values remain at the same level. Later than 2000, the average flow of the 90-day periods steps up and remains constant again until 2010 from where values are gradually rising. The opposite is true for Tan Chau where the tendency reverses indicating a decrease.

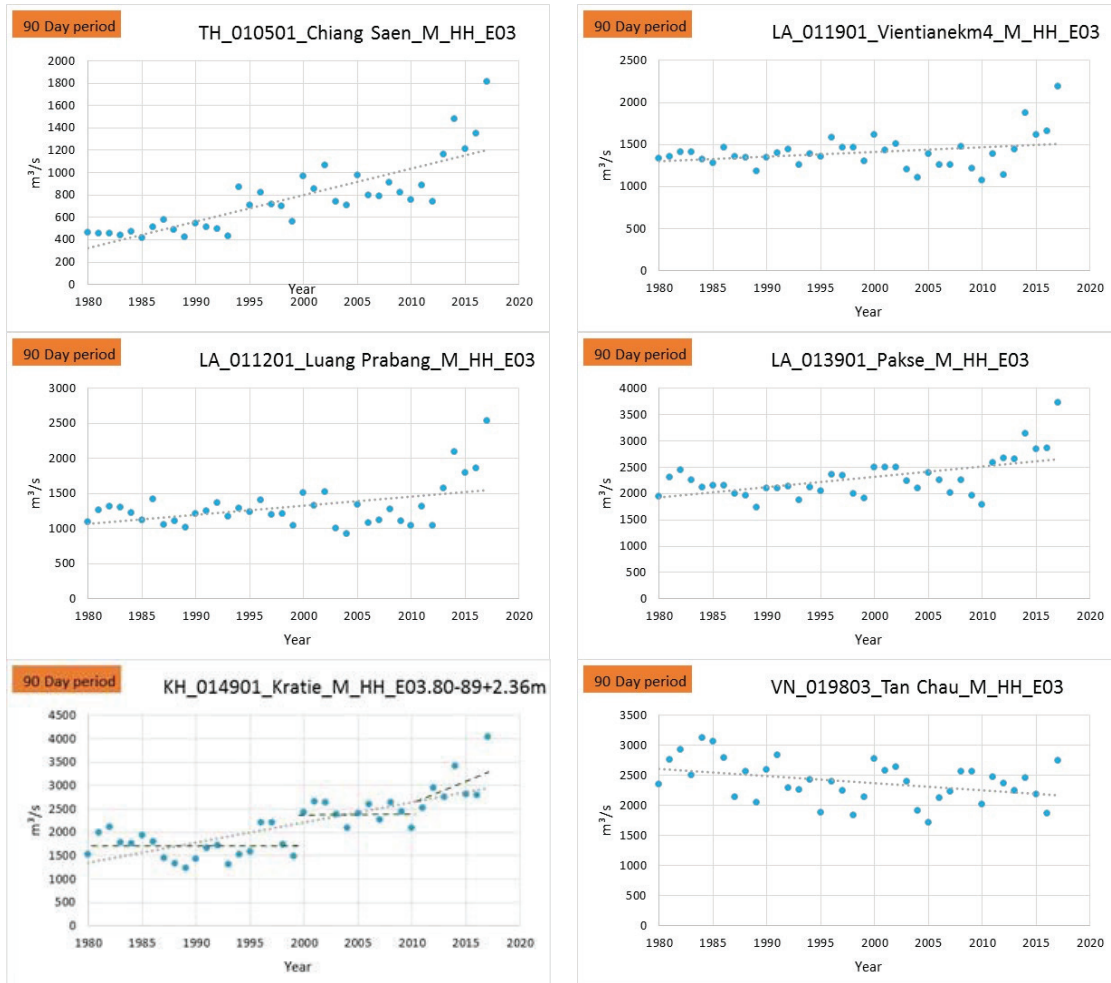


Figure 16: Low flow analysis with 90 day period at selected stations since 1980

The illustration of the relationship between the ENSO Index and precipitation and flow volumes anomalies seem to indicate a link.

Hydrological anomalies in the Mekong basin during the period 1981–2005 are shown with (A) Annual precipitation and (B) discharge anomalies (left y-axis) and the monthly ENSO index according to (Meyers et al., 2007) (right y-axis). The figure was taken from (Räsänen et.al., 2012).

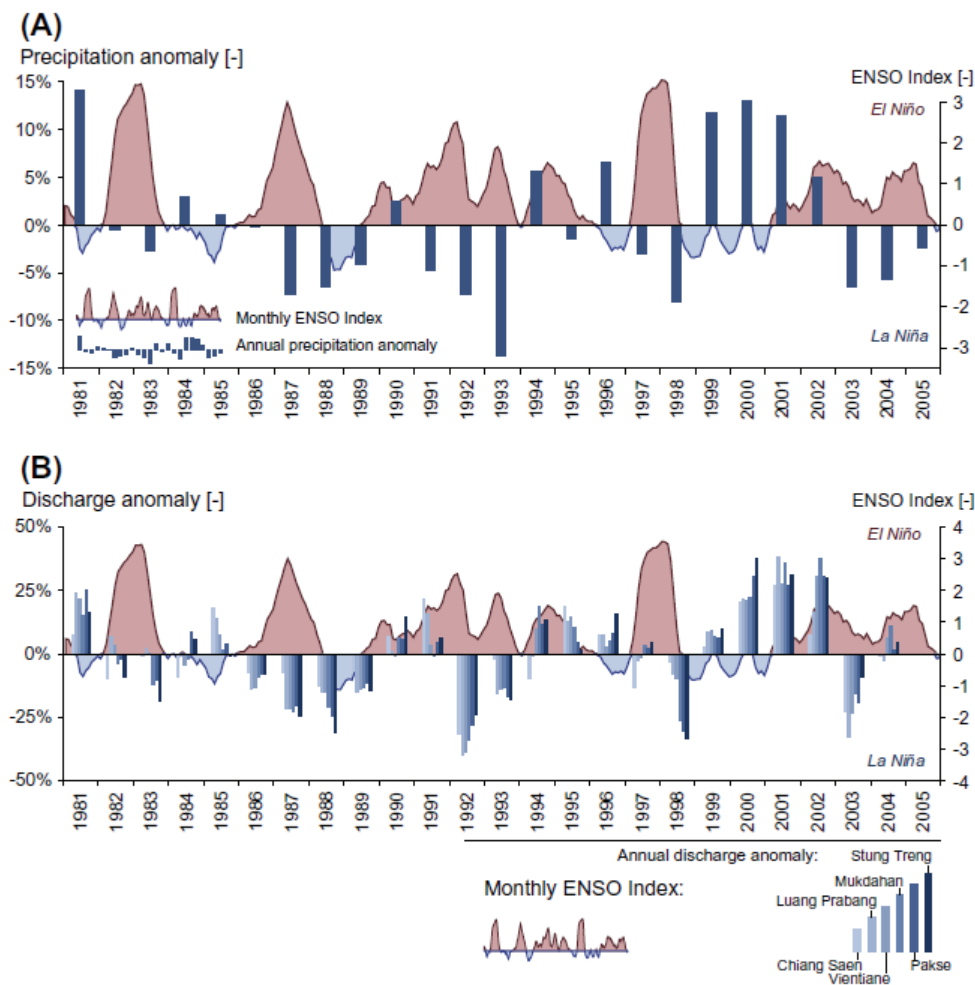


Figure 17: Hydrological anomalies in the Mekong basin during the period 1981–2005: (A) Annual precipitation and (B) discharge anomalies (left y-axis) (Räsänen et.al. 2012)

### 2.4.2 Conclusion

Records of releases from the Lancang cascade are needed to conduct a reliable drought analysis of the LMB. The increasing trend of 90-day periods confirms what has been determined: dry season flow is augmented. The next section will show whether or not flood periods are decreasing.

The opposite trend at Tan Chau could have different reasons:

- Increase of losses due to irrigation, abstraction
- Change in operation of diversions
- Change in the cross-section that is not reflected in the stage-discharge curve

According to (Ben Tre et.al. 2016), levels of salinity intrusion are very sensitive to upstream conditions. Increased salinity intrusion in El Niño years was due to decrease in upstream flows. This emphasizes the importance of upstream flow management and calls for transboundary water management. Ben Tre further suggests that there is a need to strengthen regional integration and coordination in implementing water-

saving technologies throughout the Mekong River Delta, particularly in upstream provinces (e.g. An Giang, Can Tho, Dong Thap) to reduce water withdrawal and allow higher water flow to coastal provinces.

## 2.5 Flood patterns

The term flood pattern is understood as the characteristics of the hydrograph expressed as statistics of monthly values, peaks, flood volumes, etc. and their changes over time.

The northern reach of the Mekong is used to identify if changes have occurred in the upstream part of the Mekong.

Starting at Chiang Saen, the overview of the discharge for 36 years from 1980 to 2015 reveals that a change starting around 2011 seems obvious. Apparently, there is a rise in the dry season flow accompanied by high and rapid fluctuations while the peak flows are reduced. The hydrograph is smoothed and the difference between min and max reduced.

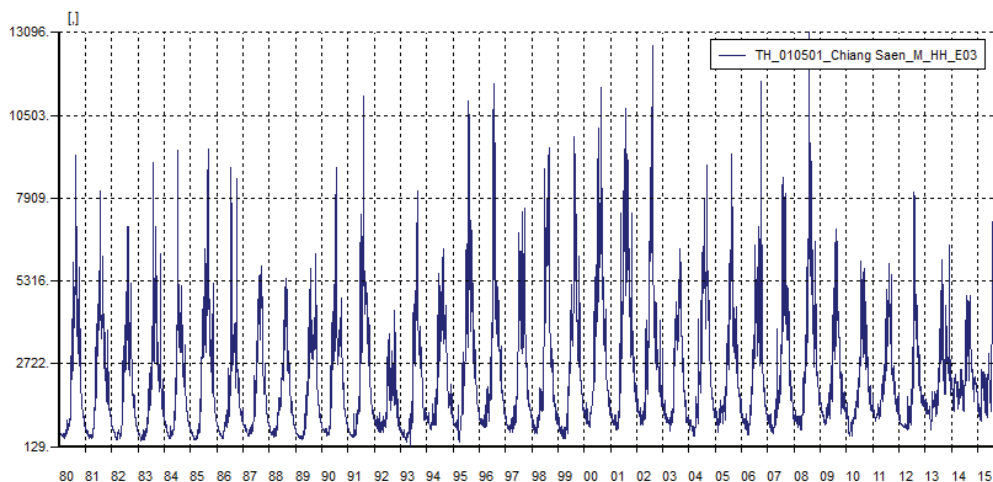
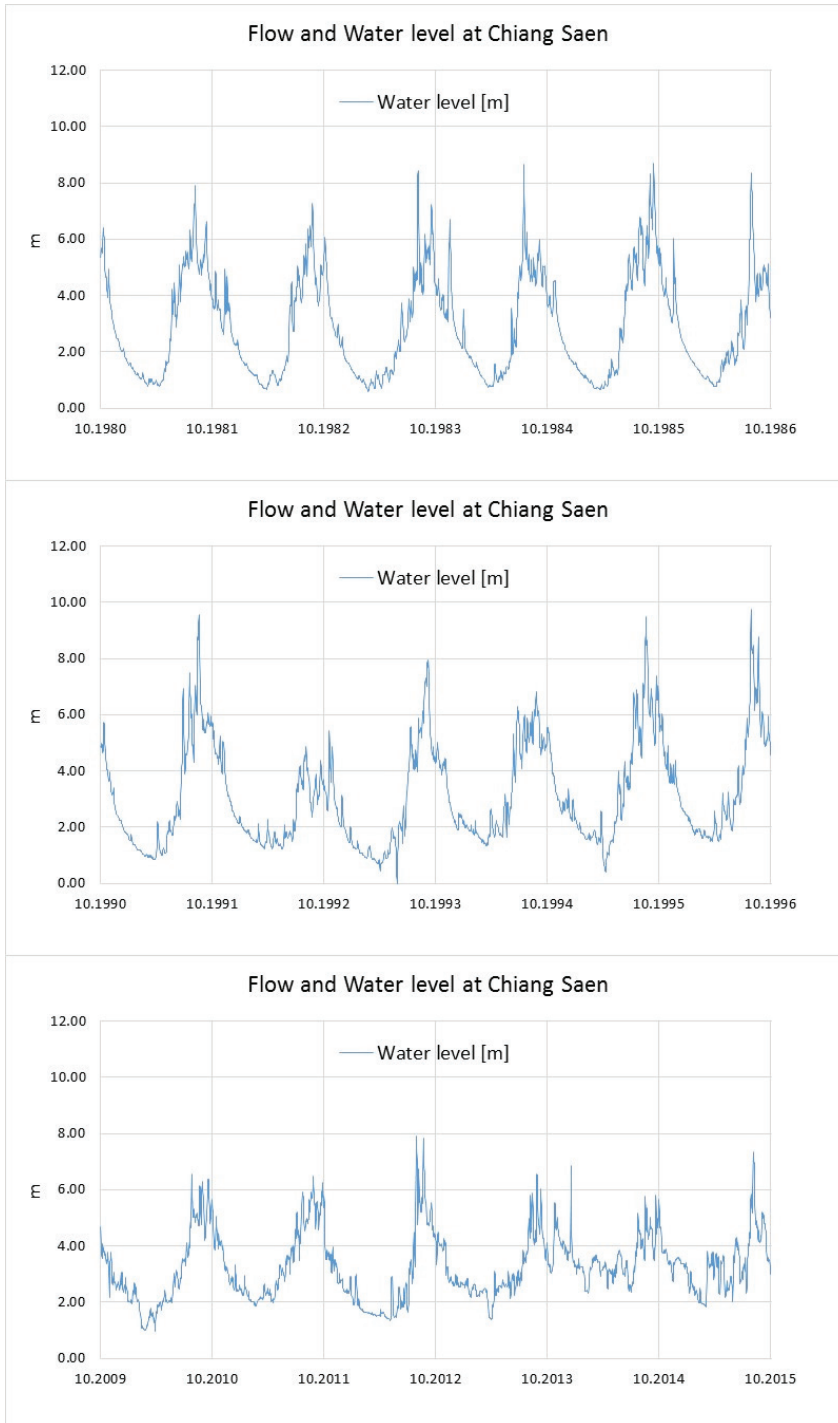


Figure 18: Hydrograph of Chiang Saen since 1980

By comparing the hydrographs from three decades (80s, 90s and as of 2010), the tendency of a more unnatural hydrograph with higher low flows and lower peaks becomes visually obvious. The records may contain uncertainties but not to the extent visible.



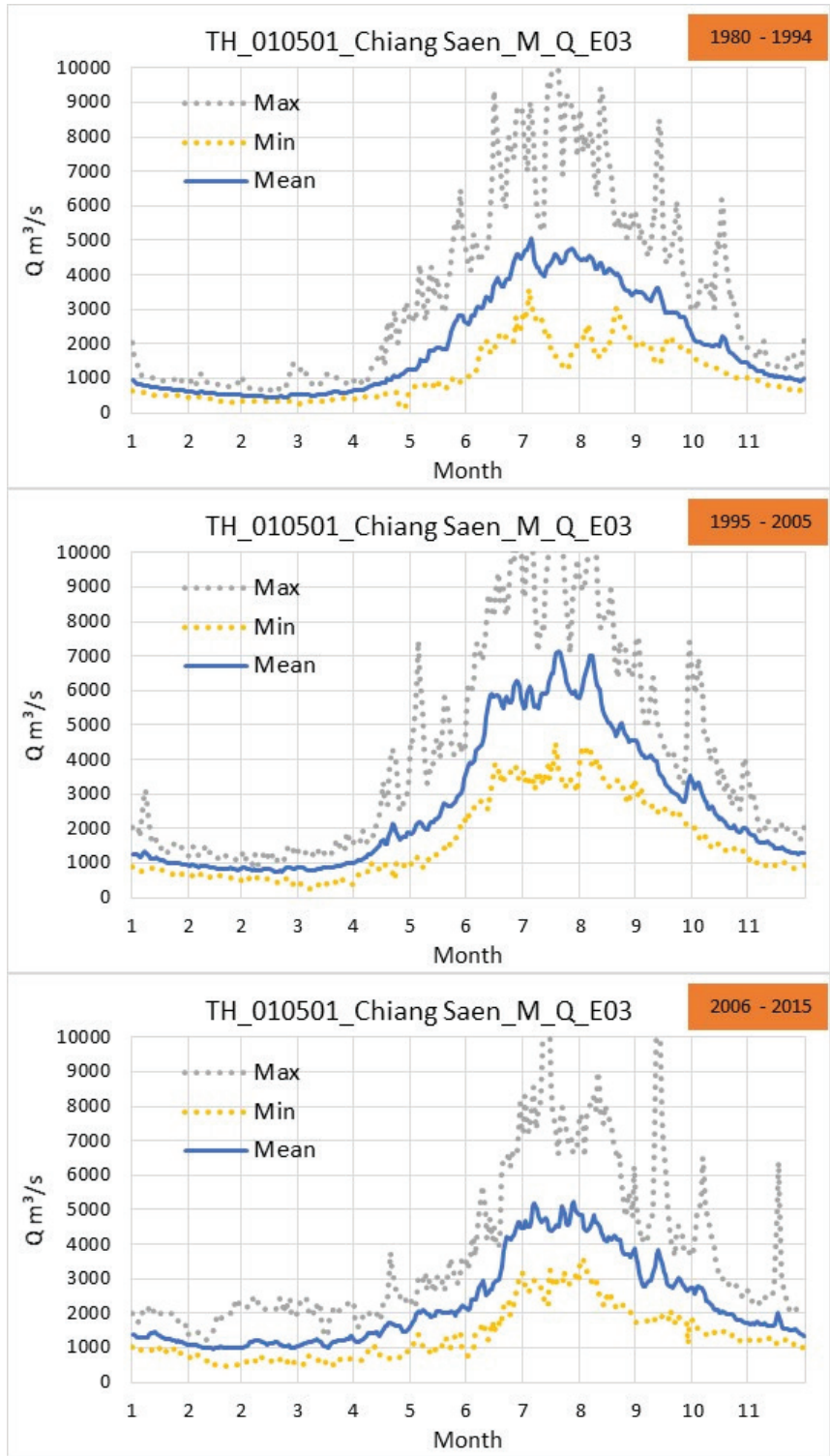
Hydrograph  
in the 80s of  
the last  
century

Hydrograph  
in the 90s of  
the last  
century

Hydrograph  
in the 2<sup>nd</sup>  
decade of  
the current  
century

Figure 19: Hydrographs in comparison at Chiang Saen

In contrast to the fact that the years as of 2013 tended to be dry, the minimum flow during January to April between 2006 and 2015 was higher than the mean values from 1980 to 1994 and 1994 to 2005. In addition, the flow during the dry months does not seem to follow a natural pattern dominated by a steadily flowing baseflow.



1980 - 1994

1995 - 2005

2006 - 2015

Figure 20: Mean/min/max hydrographs in comparison at Chiang Saen

What can be hypothesised by visually analysing the hydrograph, can be confirmed by statistics. There is clear evidence that conditions have changed over years. Each of the graphs below show the monthly means, minimum and maximum values and standard deviation of 10 years. The year 2015 is illustrated in all three charts. The means of the

dry months January to April have almost doubled with the minimum value still above the max in the 80s.

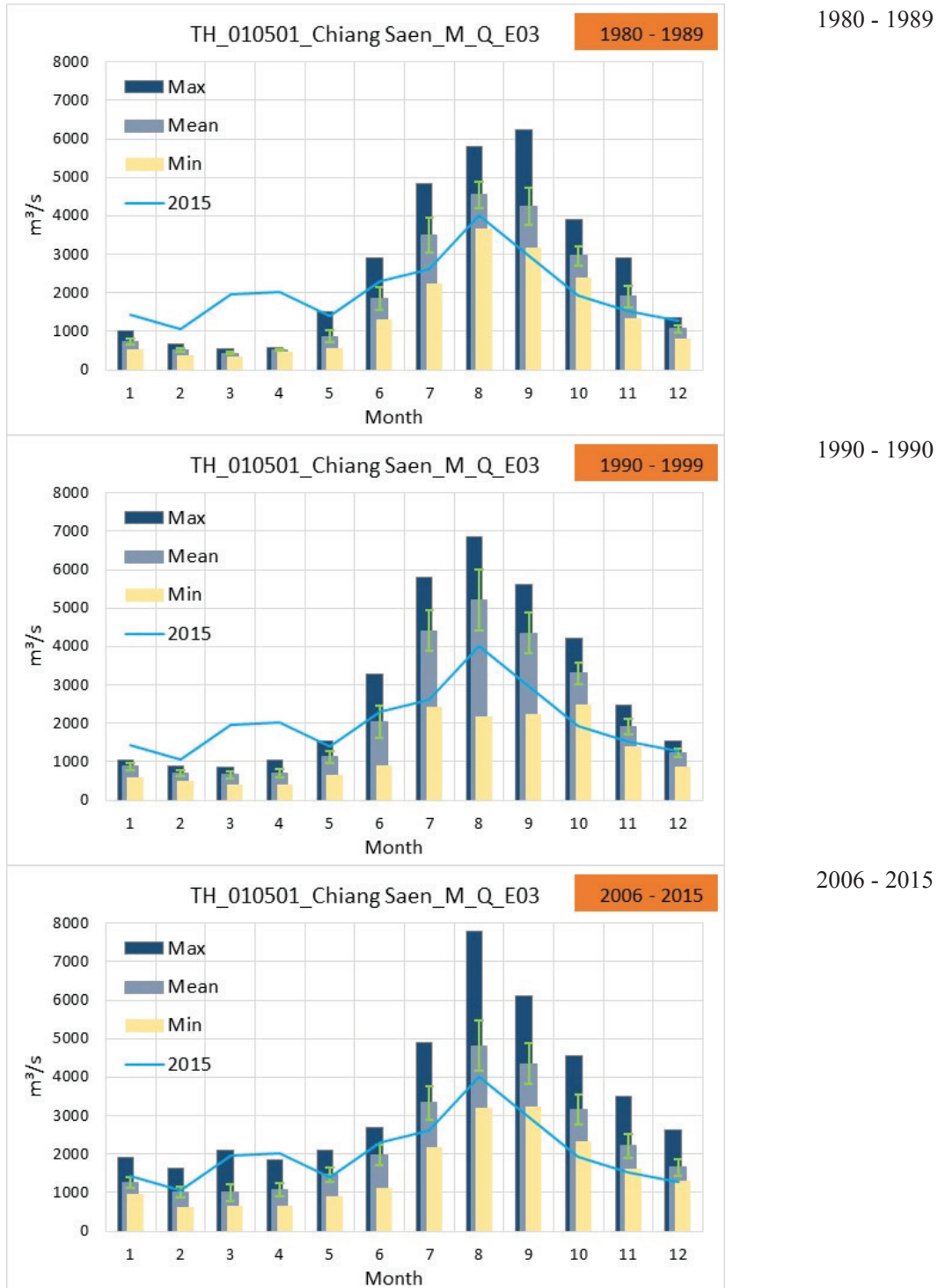


Figure 21: Monthly statistics of flow in comparison at Chiang Saen

Section 2.4 showed that average flow in consecutive driest 90 days each year tend to increase. The consecutive 30 days with highest flows each year as expected show the opposite, even though the tendency is low.

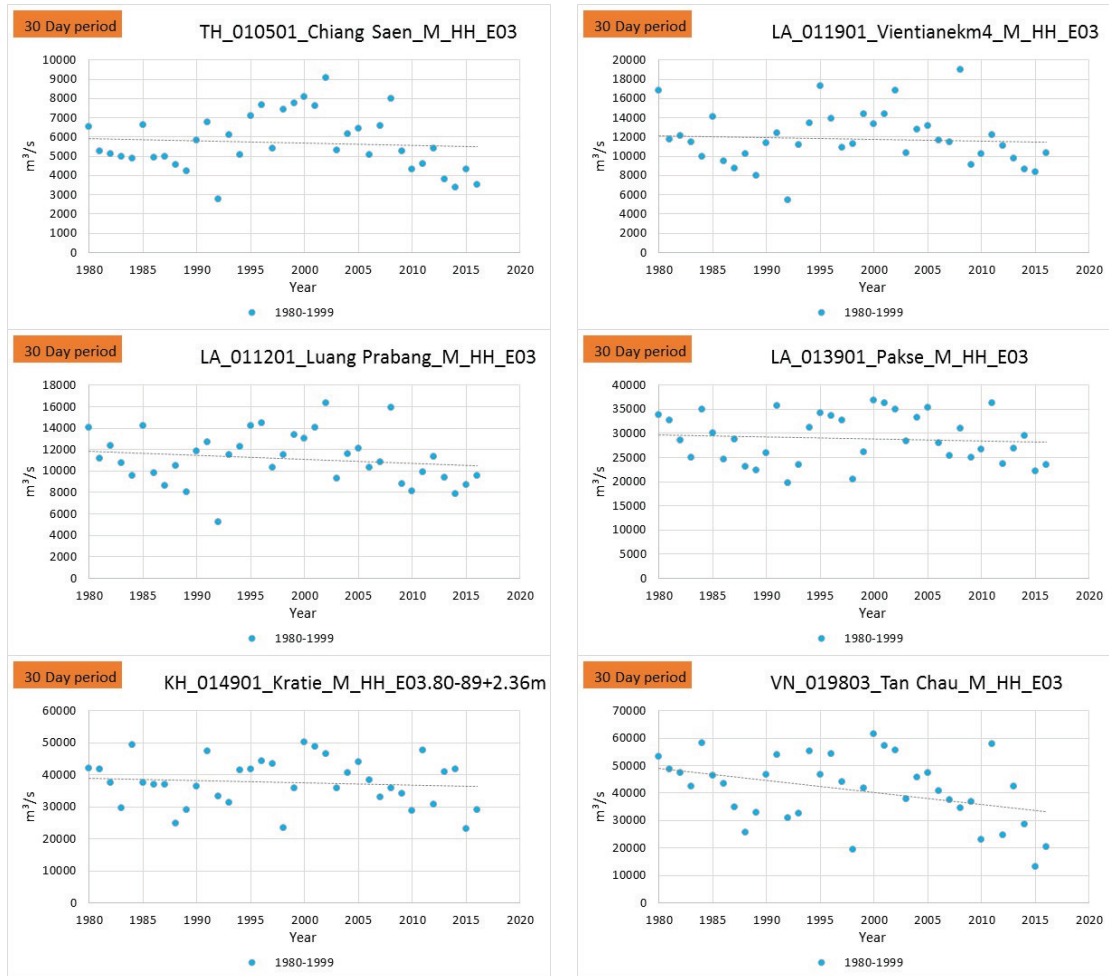


Figure 22: Analysis of 30 day period with highest flows within a year at selected stations since 1980

The impact of dam operation also generates new patterns in terms of quickly rising and falling discharges that differ from natural conditions. Assuming natural conditions, a hydrograph recedes according to its basin characteristics. A three-day window was used to evaluate decreasing discharges. The number of events that show high and rapid drops of discharge have increased to an extent that forecasts are more and more impaired.

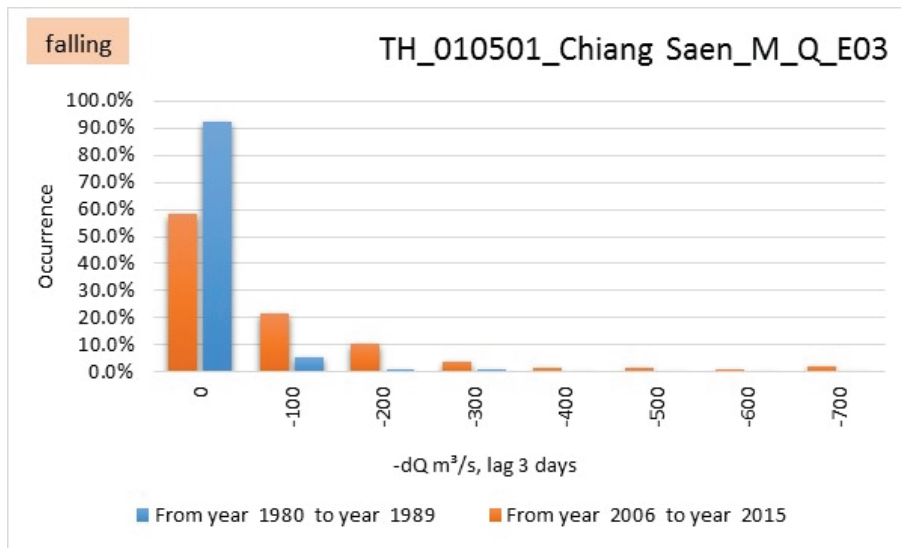


Figure 23: Analysis of 30 day period with highest flows within a year at selected stations since 1980

The rather erratic behaviour during the dry season is not only a burden for forecasters but also induces stress for the ecosystem.

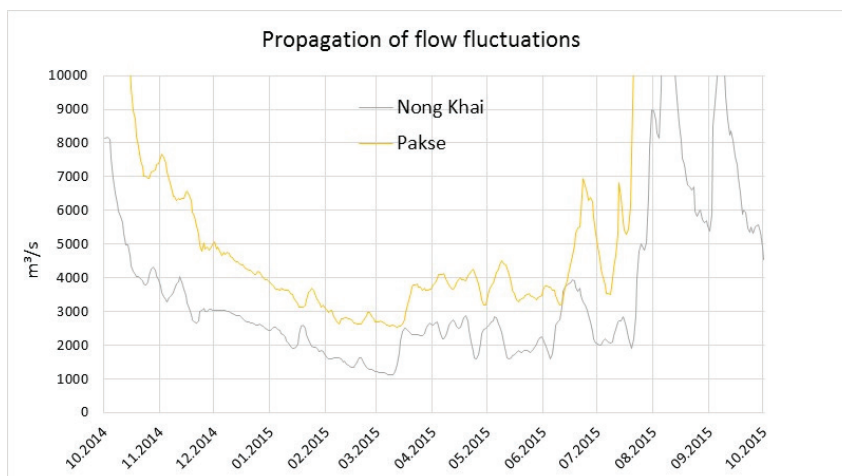
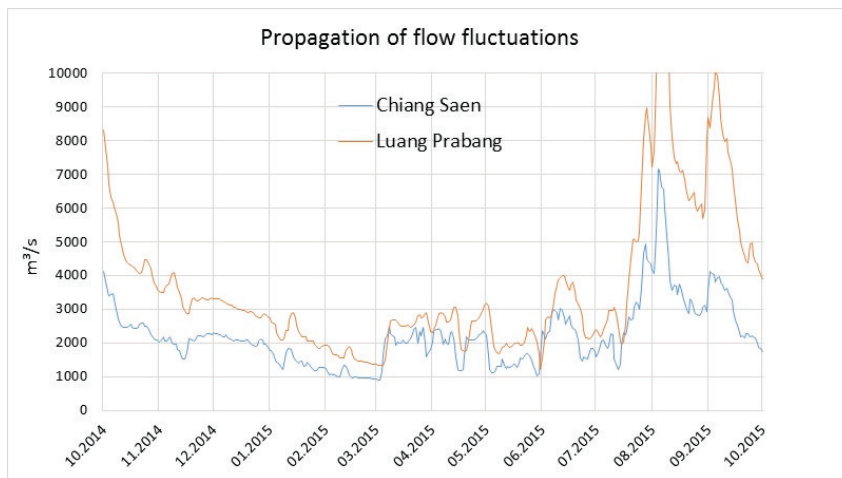


Figure 24: Hydrograph affected by dam operation

### **2.5.1 Conclusion**

The dams upstream the LMB cause higher flow in the dry season and a tendency of reduced peaks in the wet season in the Mekong River. The impact of dam releases on the water level or flow respectively at Chiang Saen is so strong that forecasting water levels requires knowledge about the releases. The behaviour with rapid rises and drops during the dry season propagates further downstream and is still visible at Pakse.

The information sharing about dam operation is therefore paramount for keeping the forecast of water levels along mainstream Mekong at a high quality.

Moreover, the fluctuations will also affect dams which are being built or will be constructed in the near future in Lao. If a water level rise comes unexpectedly for dam operators downstream, an optimal operation is hardly possible and even mal-operation leading to increased flow peaks is possible. For this reason, a major challenge in the near future will be to reach coordinated cascade operation of dams. The operation must happen in a transparent way with a strong component of information sharing to enable other stakeholders to adapt themselves accordingly. The next section deals with this topic.

In addition, other changes in the hydrograph are possibly obscured by dam operation. Deforestation and land use alterations, which are an issue in the basin, affect runoff behaviour. This topic is at danger to being ignored due to the overwhelming impact of dam operation.

## **2.6 Water infrastructure development**

### **2.6.1 Retrospective view and current situation**

Water resources development in the LMB mainly concerns dams and hydropower. Since 2010, approximately 20 tributary hydropower projects and the Xayaburi mainstream hydropower project have moved from the planning stage to the implementation stage (MRC, 2016).

The Lancang hydropower cascade, consisting of five dams, has already been completed in China. In Lao PDR, seven dam projects are under consideration and two, Xayaburi and Don Sahong, are under construction. Cambodia has two projects in the pipeline, one upstream and one downstream of Kratie. Vietnam has no dam projects along the Mekong River.

The discussion about developing dam projects along Mekong mainstream is diverse and a lot of uncertainties are associated with this topic. There are benefits and drawbacks and to find an overall win-win solution encompassing all sectors and stakeholders seems impossible (ICEM, 2010). However, and that is for sure, developing dams will lead to a change in the flow regime and the possible impact increases with the number of dams and active storage respectively.

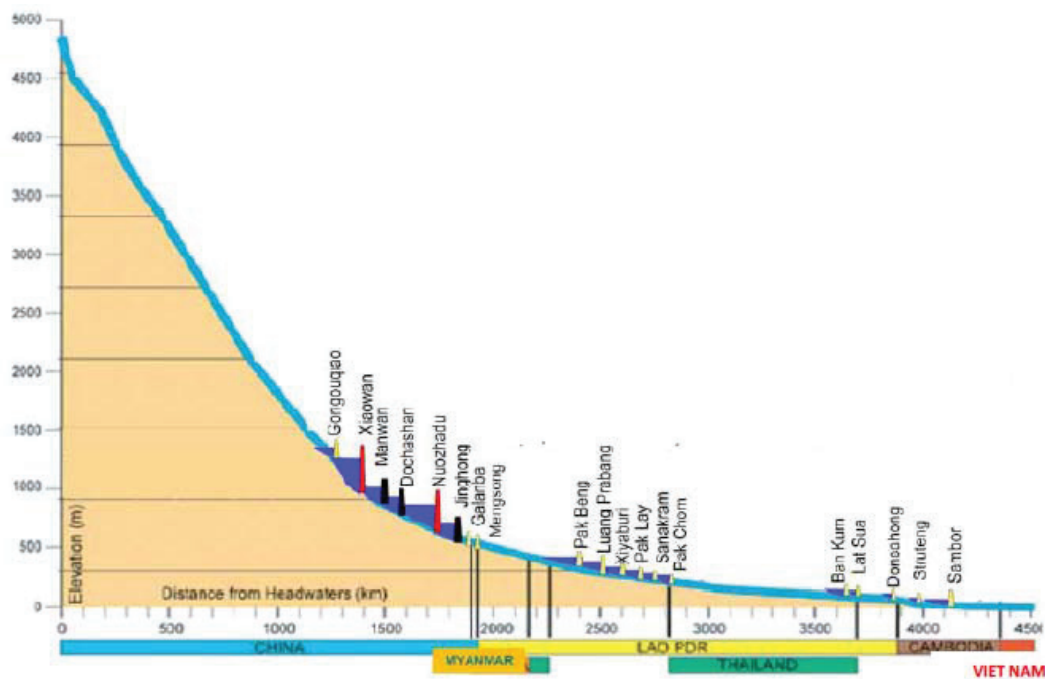


Figure 25: Planned, under construction, completed dams along Mekong River (source: ICEM 2010)

The monitoring of river flows and of the longitudinal sections of discharge volumes (Figure 26) show that in recent years, dry season flows upstream of the Mekong delta have been close to or above the historically observed maximum levels. Another already observable impact is that flows are significantly lower than average at the beginning of the wet season. These observations are in line with MRC's prediction in 2009 for the Definite Future Scenario. The main reason is the redistribution of water from the wet to the dry season caused by the filling pattern of the storage dams on the recently completed Lancang hydropower cascade in China.

Since the dams have been built, the trend in the flow regime is significant and will certainly increase the more dams come into operation. Apart from the effect of mainstream dams, dam projects in the tributaries bring forth changes as well depending on their size and location. It is obvious that filling and release patterns will follow the rules of retaining water at the beginning of the rainy season and releasing water at the end. As a result, release patterns running synchronously will yield accumulated effects in the Mekong mainstream and change the natural flow regime even more towards a regulated river.

Water infrastructure development at a scale which is evolving along the Mekong River calls for coordinated transboundary reservoir operation. This holds especially true for the cascade dams along Mekong mainstream.

It must be noted, that effects like acceleration of rising limbs of floods and increase of flood peaks are likely to happen once all the dams are in operation. The dams along mainstream Mekong will maintain high water levels, at some locations above the current 1 in 1000 year water level. This results in a permanent inundation of wetlands and floodplains (ICEM, 2010). In other words, there is a loss of storage volume to

retain floods. The loss, however, could be compensated by means of coordinated release policies, so that flood peak reduction would be possible to a certain extent. Similar effects were observed at River Rhine (IKHR, 2007) where a smaller number of dams is in place compared to the Mekong.



Figure 26: Discharge volume during January to March along Mekong River (2012-2015)

Coordinated operation of the cascade dams, however, will be one of the major challenges in the future. Coordination does not come naturally but requires prerequisites.

The question is now, what is the lesson learnt of the past 10 years that might help tackle the challenge of cross-border operation of large water infrastructure. The answer is given in the history of the dam development process. Looking back 10 years, hydropower was highest on the agenda of the MRC and a profound scientific knowledge base has been generated. Built on these findings, a goal-driven dialogue took place. Tools and guidelines have been developed setting clear frameworks that enable stakeholders to continue in their effort to obtain sustainable solutions (MRC, 2015a), (MRC, 2015b). Consequently, three pillars arose and have proven to be important components to be successful which are:

- an impartial mediator and coordinator is needed to facilitate the scientific background and dialogue
- a profound scientific knowledge base is required
- the willingness at different levels of decision making to respect scientific results and to act on them is a must



Figure 27: Dam development along Mekong Mainstream (ICEM, 2010)

### 2.6.2 Lessons learnt

In retrospective, the focus was on assessments regarding cross-sectoral impacts and trade-offs, development options and consequences, scenario development, environmental and socio-economic concerns. This was and still is necessary to avoid a site-specific perspective that overlooks basin-wide impacts. In fact, a bird's-eye view must be maintained when it comes to the next stage that is the concrete operation of dams.

The lesson learnt is that a mediator and coordinator is required more than ever to prepare the ground for dialogue and informed decision-making. The focus, however, will change to scenario development aiming at short-, mid- and long-term operation rules.

A way forward could be the development of a road map that guides through the process and addresses the topics each of which are closely linked to transboundary operation. The establishment of an Interim Coordination Unit (ICU) hosted by MRC could constitute the beginning of the process towards coordinated operation of dams. The ICU could oversee and accompany the whole process and in parallel could try to prepare procedures concerning:

- Qualification and training of staff
- Involvement of research institutions
- Mechanisms of formalising operation rules

Ideally, the ICU creates documents and manuals in preparation for an agreement between the countries to embark on coordinated operation. The unit works at transnational level and liaises with national boards. Figure 28 follows a structure that has been taken from the road map for coordinated operation of cascade dams at the Nile River (ENTRO, 2016). The situation in the Eastern Nile Region is comparable to the Mekong except for the fact that active storage of the reservoirs along the Blue Nile is much higher.

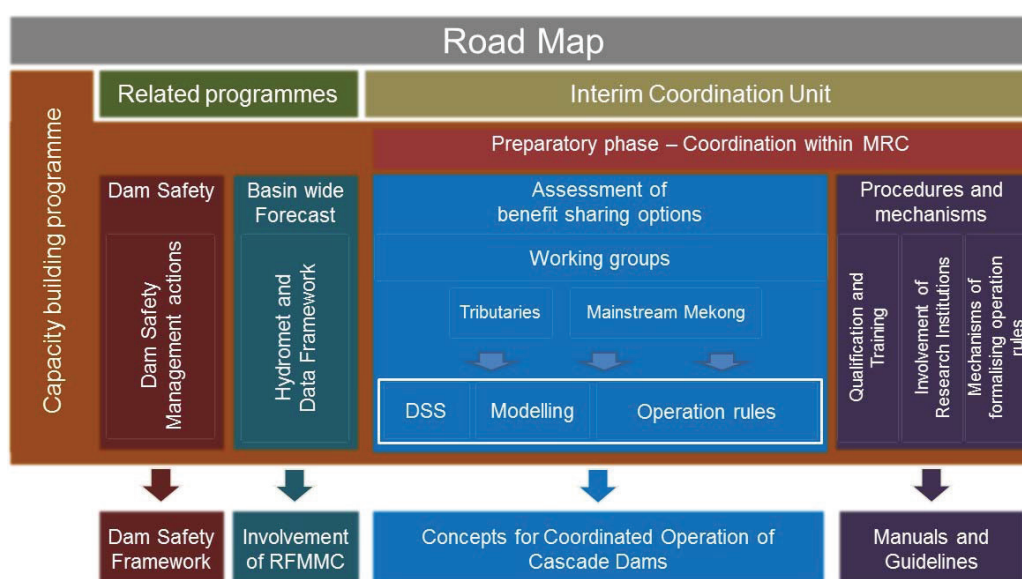


Figure 28: Possible structure to develop coordinated operation of cascade dams (adopted from ENTRO, 2016))

The development of common procedures and mechanisms for qualification, training and operation of dams are seen as essential with the following topics:

- Harmonisation of procedures for qualification and training
- Harmonisation of mechanisms concerning operation rules including
  - validation of rules and level of validation
  - involvement of public authorities
  - public consultation mechanisms

To facilitate measures for qualification and training, two aspects should be considered:

- Development of a manual on training courses for coordinated reservoir operation

A harmonised manual on training courses for coordinated reservoir operation seems mandatory with the rapid development of dams in mind. A manual should serve as a reference for all countries with aligned contents and the needs of all members considered.

- Development of regulations defining the course of action for training

At the same time, regulations are needed to establish training as part of the professional conduct of staff. Thus, regulations should be established which define the course of action for training and the financing mechanism.

A step-by-step approach is recommended to develop regulations for formalising and approving operation rules. International good practice is to separate responsibilities of approval and operation. Hence, approving authorities and operators should be separated and independent from each other. The Interim Coordination Unit could prepare the process of formalising operation rules. Steps are needed when operation of reservoirs is concerned as the following:

- What kinds of assessments are required?

In order to identify the performance of operation rules, assessments are required. These assessments can be long-term continuous simulation, evaluation of supply safety for all purposes, evaluation of safety against overtopping, etc.

- What a level of validation is needed depending on the expected impact of operation rules?

It is not necessary to conduct all assessments every time operation rules are changed. In fact, it depends on the expected impact a change of the rules might induce. Rules could be classified according to expected implications and associated with a level of validation. The level of validation decides on the extent of the evaluation and the approval process.

- Who needs to be consulted?

The involvement of stakeholders depends on the level of validation. The group of stakeholders should be identified for each country.

- Review periods for operation rules

Operation of reservoirs must be reviewed periodically even without any changes in the rules. This needs to be discussed and coordinated between the countries.

The outcome should be adopted at national level ensuring that different operators obtain equal treatment. Finally, a guideline and template for operation manuals could be prepared to establish a common standard.

The assessment of benefit sharing options is at the heart of the process towards coordinated cascade operation of dams. Scenario development and best practice rules adapted to the specific situation along the Mekong could be established, such as:

- Assessment of flood protection benefits downstream with forecasts from upstream
  - Scenarios with coordinated upstream/downstream releases
  - Scenarios with coordinated upstream/downstream releases and short-range forecasts
- Assessment of benefits from drought early warning with long-range forecasts
  - Scenarios with coordinated upstream/downstream releases

- Scenarios with coordinated upstream/downstream releases and long-range forecasts
- Assessment of benefits from upstream dams to adjust filling and emptying phases for downstream dams
- Assessment of a prolonged life time of reservoirs due to reduced sediments trapped by dams upstream

Accompanying processes are basin-wide forecasting and dam safety procedures. Basin-wide streamflow forecasting is already in place. However, as dam operation impacts streamflow significantly, it is absolutely necessary to involve the forecast unit into the process.

Another topic is dam safety. It is considered as very useful to establish a harmonised dam safety framework. A dam safety framework could address dam break studies, notification procedures, transnational inundation maps and joint preventive actions in case of emergencies. Especially clear and concise communication is a crucial element of coordination.

Dam break studies analyse different failure modes from which flood hydrographs will be derived to develop inundation maps. Failure modes can arise from

- Internal erosion / sheer stress / abutment failure
- Earthquakes
- Floods
- Landslides
- Driftwood jam and spillway blockage
- Operation failure

The list of failure modes shows that addressing dam safety also requires expertise with regard to geotechnics and structural engineering.

Inundation mapping includes flood routing of a dam break flood, calculation of water levels and mapping the levels to the area. It should be continued to a point downstream where the dam break flood no longer poses a risk to life and there is limited potential for further damage of property. In a cascade of reservoirs, the downstream point is the next dam. In any case, the impact of a dam break must be assessed to see if the dam downstream is able to resist the incoming flood wave.

Clear and fast notification in case of an emergency is a core component. A notification flowchart shows who is to be notified, by whom and in what priority. A working group could be established in order to compile information needed to launch a call-down tree. This could be accompanied by awareness raising measures for stakeholders who are not directly involved in the dam safety business.

Early warning makes or breaks preventive measures in case of an emergency. Part of preventive measures are regular drills. The countries could embark on designing common drill procedures to train staff on-site and dam managers in dam safety and emergency preparedness activities.

Reservoirs are perfect structures to enhance emergency preparedness if they are monitored, well-staffed and procedures for identifying hazards, notification and preventive measures are unambiguously organised.

In particular, cascade dams are beneficial in disseminating information of upcoming emergency situations from upstream to downstream. The Mekong System is large enough to provide sufficient lead time on the condition that notification works across country borders.

## **2.7 Flood mitigation and flood management**

### **2.7.1 Retrospective and current situation**

Flood mitigation, flood management and risk reduction is based on four pillars:

#### **Design standards**

- Appropriate rules, regulations and standards
- Qualified assessment of design floods
- Identification of all design criteria (geotechnical, geology, hazards, operation)
- Identification of local conditions

#### **Monitoring**

- Good network of ground stations
- Observations in the catchment (Early Warning System)
- Maintenance of the monitoring network

#### **Operation of water infrastructure**

- Capacity of staff, capacity building and training
- Coordinated operation rules
- Interplay between operation and emergency preparedness

#### **Preparedness**

- Awareness of risks
- Emergency Preparedness Plans (EPP)
- Established mechanisms for response actions

Good governance is a prerequisite to establish each of the aforementioned pillars and clear assignments of roles and responsibilities are needed. Each country has established their institutional framework to cope with flood risks.

#### **Cambodia**

In Cambodia, the National Committee for Disaster Management (NCDM), which was established in 1995, is responsible for providing emergency relief with respect to all hazards. NCDM's core subjects are strengthening coordination in preparation for and during disasters, capacity building and establishing disaster policy mechanisms. NCDM works closely with different line agencies and ministries at different levels. The NCDM has currently evolved from national level to community level. The process of development is ongoing and the capacity is being increased.

Under the umbrella of the Ministry for Public Works and Transport, departments at district and community level are in place taking care of design and maintenance of critical infrastructure relevant to floods like drainage systems and roads.

### **Lao PDR**

The Government of Lao PDR coordinates disaster preparedness and response activities through two key entities: the National Disaster Management Committee (NDMC) chaired by the Vice Prime Minister and the Department of Disaster Management and Climate Change (DDMCC) within the Ministry of Natural Resources and Environment (MoNRE), which also acts as secretariat to the NDMC. Disaster management committees are established at the provincial and district levels and Village Disaster Management Committees (VDMCs) at the village level, to inform and implement preparedness, assessment and response efforts of the Government.

### **Thailand**

In response to the 2011 flood, the Royal Thai Government drafted a Master Plan on flood management from which the National Water Resources and Flood Policy Committee (NWFPC) and the Water and Flood Management Commission (WFMC) have emerged.

These bodies formulate policies, approve investment projects and monitor the implementation and impact of these projects. Besides these national committees, there are three major ministerial departments involved in flood management. The Royal Irrigation Department (RID), under the Ministry of Agriculture and Cooperatives, plays a significant role in constructing and maintaining waterways and flood protection systems. The Department of Disaster Prevention and Mitigation, Ministry of Interior, is responsible for the coordination during disasters and recovery management. The Department of Water Resources (DWR), Ministry of Environment and Natural Resources, monitors flood mitigation in the 25 river basins. Other departments come into play in terms of preventing and managing floods.

### **Vietnam**

In Vietnam, responsibilities for flood management and flood response are shared among different departments and committees. The Central Steering Committee for Flood and Storm Control (CSCFSC) is responsible for emergency response in Vietnam. Its organization spans from central to local levels and is set up by various ministries and governmental institutions.

The National Committee for Search and Rescue (NCSAR) is responsible for coordinating, controlling and implementing a national warning system and equipment for providing the technical assistance/expertise to search and rescue victims caused by natural disasters. Originally focused on flood hazards, its role was enhanced and now also covers other sectors including marine areas.

The Department for Dyke Management, Flood Control and Storm Preparedness (DDMFCSP) is another entity that deals with flood hazards. DDMFCSP approves

Disaster Management Plans and acts on the ground. It takes necessary steps to prepare for floods and typhoons and participates in emergency repairs and protective works.

Hydro-meteorological forecasting agencies, that form an important part for preparedness and non-structural measures, include 3 levels:

- Central level is performed by the National Centre for Hydro-meteorological Forecasting;
- Regional level is implemented by 9 Regional Hydro-meteorological Centres;
- Provincial level is executed by 54 Provincial Hydro-meteorological Centres.

## **Conclusion**

In general, the member countries have structures in place which follow the principles of design/monitoring/operation/preparedness in one way or another. The underlying scheme of roles and responsibilities are rather complex and difficult to survey. This is understandable as flood prevention, preparedness and response actions affect and cut across different sectors and make coordination difficult. Flood management is basically considered as a sovereign function of the government partly supported by additional non-governmental actors on site in case of emergencies.

The lessons each country has drawn from the past depend on the flood events that they have experienced and the most urgent problems that each country faces due to its topography and location. However, some common ground can be found regarding lessons learnt.

- Enhancing the capacity of early warning systems by means of satellite data and radar technology
- Taking advantage of social media to disseminate warnings
- Establishing committees at the local level to accomplish fast response on site
- Establishing notification chains between stakeholders at different levels

Even though institutional structures are in place and steps to combat flood hazards have already been taken, the way forward is ongoing and most likely subject to change. The following topics could serve as follow-ups and supplementary actions in the process of enhancing flood mitigation, preparedness and flood response capacities:

### **2.7.2 Ecosystem-based Disaster Risk Reduction (Eco-DRR)**

Conventional engineered flood mitigation measures are probably neither feasible nor affordable in order to provide sufficient flood protection for the vast majority of rural areas. This is even more relevant taking the adverse effects of climate change into account. However, rural areas seem to be most affected by floods, predominantly flash floods.

As a consequence, ecosystem-based disaster risk reduction (Eco-DRR) and nature-based adaption to climate change can help solve the gap. What is ecosystem-based disaster risk reduction?

Ecosystem-based disaster risk reduction (Eco-DRR) is the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim of

achieving sustainable and resilient development. People derive indispensable benefits from nature, also known as ecosystems services, which can be harnessed for hazard mitigation. In contrast to conventional engineered solutions such as floodwalls or dykes, Eco-DRR provides benefits even in the absence of a disaster event and provides cost-effective, no-regret investments (Sudmeier-Rieux, et.al. 2013).

Acceptance and implementation of Eco-DRR has risen since it was identified and acknowledged by the international community on disaster risk reduction. The Hyogo Framework for Action, for example, has five priorities for action, from which one entitled “Reduce the underlying risk factors” recommends two key activities that have a direct link to ecosystems and ecosystems management (UNISDR, 2005):

- Environmental and natural resource management
- Land-use planning

Examples of Eco-DRR, also called “Green Infrastructure”, are given here <http://nwrp.eu/>, here <http://envirodm.org/flood-management> or here <https://www.iucn.org/theme/ecosystem-management/our-work/ecosystem-based-adaptation-and-climate-change>.

Projects with Eco-DRR have already arrived in the member countries and are promoted at different places (see <http://www.ecoswat-thailand.com/>, <http://www.asiapacificadapt.net/resource/ecosystem-based-adaptation-greater-mekong-sub-region-review-current-challenges-best>).

### **2.7.3 Preparedness**

Neither flash floods nor riverine floods can be fully prevented. In fact, 100% flood protection is not feasible. Thus, flood management should also strengthen awareness and preparedness.

While riverine floods are mostly associated with a lead time that gives some time for preparation, flash floods occur locally and very quickly leaving hardly any time left to take adequate actions. Weather forecasts are not yet accurate and fine-grained enough to localise flash floods with sufficient lead time and certainty. Thus, countermeasures should begin with assessing disaster risk accompanied by mapping hazards and risk prone areas, training on how to read risk maps and what implications emerge from them. Additionally, introducing low-cost ecosystem-based measures, as mentioned above, is certainly a feasible way of increasing resilience. A manual on this topic is presented in (ADPC, 2017) and was established for Lao PDR. This is a good example showing that flood management in the country scales up with support of key entities.

Riverine floods cannot be solved at the local level because of their larger geographical extent. This calls for coordinated intervention from authorities. As described above, foresighted land-use planning is one of the most important elements. Any effort that is geared towards strengthening and enforcing land-use planning by linking the urban and rural development sector, the agriculture sector and the water sector will pay off.

### **2.7.4 Root causes**

The priority in terms of flood management must be prevention as it prevails all other flood mitigation measures. Prevention, however, requires identifying and tackling root

causes. Climate change is often used as a major driver for natural hazards, but at the same time human-made drivers do exist as well. Neglecting human-made root causes and solely claiming climate change instead is like passing the buck. Tackling the predominantly socio-economic root causes entails a long process of behaviour change and sometimes uncovers weaknesses in laws and regulations, lack of enforcement, lack of coordination between sectors, unsustainable agricultural policies, population growth, urbanization trends or simply inadequate lifestyle. However, if underlying root causes are not addressed, combatting flood hazards will partly remain at the level of fighting against symptoms.

### 2.7.5 Flood forecasting

Flood forecasting is at the heart of the MRC's tasks, reflected in the core goals of MRC:

- i) To promote and support coordinated, sustainable, and pro-poor development
- ii) To enhance effective regional cooperation
- iii) To strengthen basin-wide environmental monitoring and impact assessment
- iv) To strengthen the Integrated Water Resources Management capacity and knowledge base of the MRC bodies, National Mekong Committees, Line Agencies, and other stakeholders

The previous 10 years have brought far-reaching developments with respect to flood forecasts. The flood forecasting process can be subdivided into 6 steps:

1. Data collection
2. Data processing and validation
3. Forecasting
4. Evaluation of the forecast
5. Authorization
6. Dissemination of results

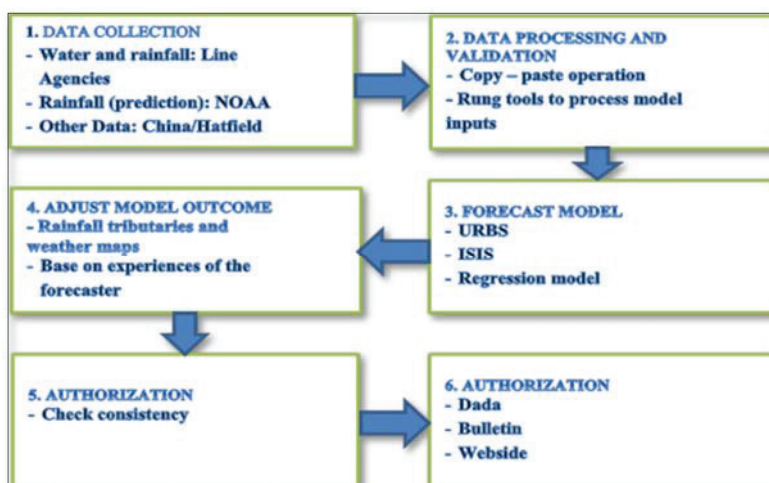


Figure 29: Workflow of flood forecast by RFMMC (MRC, 2014c)

The RFMMC runs a complex toolbox in order to facilitate forecasts of discharges and water levels along the Mekong Mainstream. The toolbox consists of a sophisticated data acquisition and transmission system (HydMet), a hydrological rainfall-runoff

model called URBS (Unified River Basin Simulator), a hydrodynamic model for modelling flows and water levels in open channels and estuaries called ISIS and a regression model which relates water levels from upstream to downstream locations. All components evolved over the years and underwent several development steps.

The URBS flood forecasting model is a distributed rainfall-runoff(hydrological) model. The development of the URBS flood forecasting model was started in the 2007 with model setup and calibration. Recalibration of the URBS model using with Satellite Rainfall Estimates data from 2008-2014 was conducted in 2015. Currently, the URBS model has a set of 52 URBS sub-models, covering over 740,000 km<sup>2</sup> and represented by over 2,217 sub areas. 49 sub-models are linked by three channel routing models from Chiang Saen to Kratie, the Tonle Sap system and from Kratie to Tan Chau/Chau Doc.

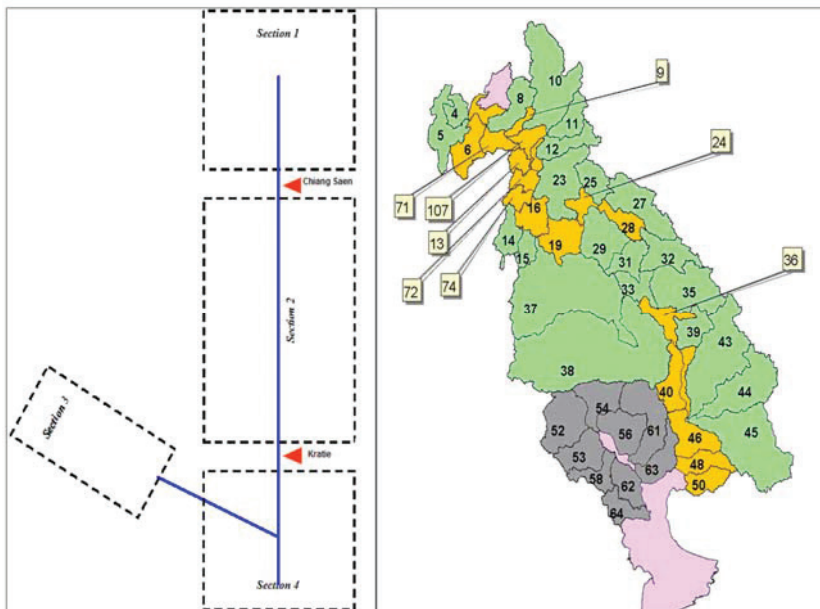


Figure 30: Rainfall-runoff sub-models (MRC, 2014c)

The hydrodynamic model ISIS covers the Mekong Basin from Stung Treng to the Delta, including the Tonle Sap and floodplain, the Cambodia floodplain and the Vietnam Mekong Delta.

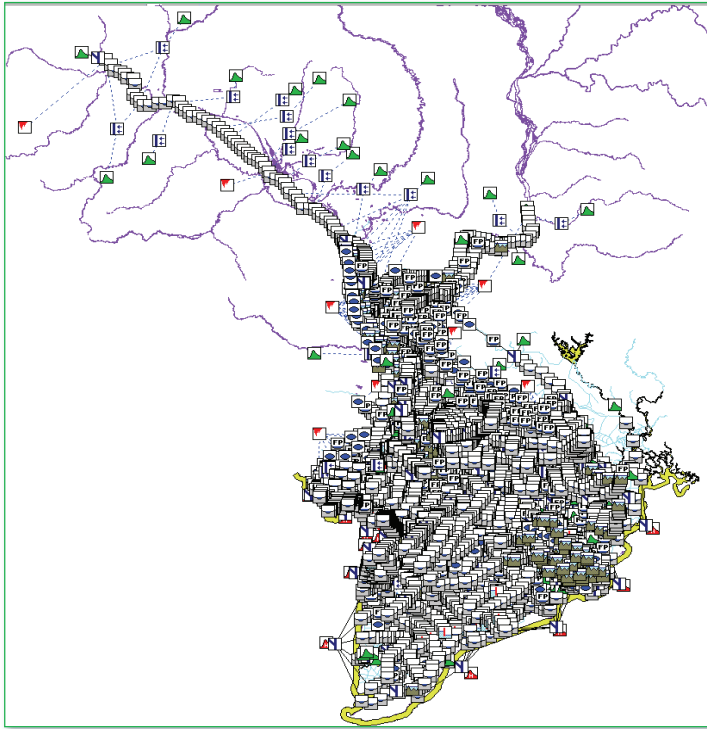


Figure 31: The ISIS model schematization (MRC, 2014c)

The Regression model is used for the forecasts in the lower part of the basin from Strung Treng in Cambodia to the delta in Vietnam (Tan Chau and Chau Doc). The Regression model is based on a Fast Fourier Transformation (FFT).

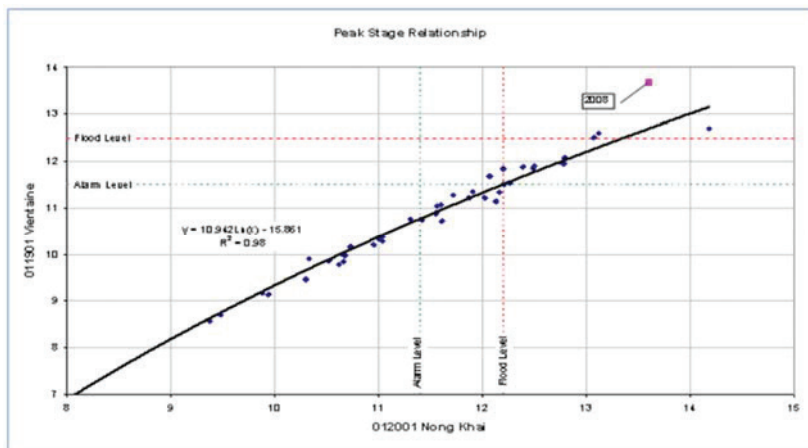


Figure 32: Peak Stage Relationship - Vientiane to Nong Khai (MRC, 2014c)

### 2.7.6 Early warning and communication

Early warning systems are in place or are being implemented in the member countries. The countries are stepping up efforts and investing in new technology. The MRC with its Regional Flood Management and Mitigation Centre (RFMMC) runs a sophisticated streamflow forecast system and disseminates results daily during the rainy season and weekly during the dry season. Additionally, a flash flood warning system has been established recently. Concerning achievements of the countries and

MRC, it can be stated that there is not necessarily a lack of information. The problem, however, is that not everybody makes use of these sources for various reasons:

- The sources itself are not known
- The information about the sources is vague and thus not used
- Lack of an adequate internet connection
- Lack of capacity to deal with the information

Each of aforementioned problem was encountered during a disaster risk assessment in the Tonle Sap region (ADB, 2017) and it is very likely that these problems are not unique in the LMB (see next Section).

It would be possible to counter the problems by launching an information campaign initiated by MRC with follow-ups in each member country.

### **2.7.7 Coordination of early warning procedures**

MRC's Regional Flood Management and Mitigation Centre (RFMMC) disseminates streamflow forecasts for mainstream Mekong. According to the review of activities in the member countries, these also have early warning mechanisms in place. Details are given in Section 2.8. The more these activities evolve and result in a reliable spatiotemporal coverage of parts of the LMB, the more interesting this data will become for the RFMMC to enhance its forecasts.

A process aiming at identifying benefit sharing options by data exchange mechanisms could be launched. This would be to the mutual advantage of both the RFMMC and the corresponding entity in the member country. Better data helps RFMMC in their effort to generate good forecasts and good forecasts help the country in their effort to be prepared for floods events.

### **2.7.8 Lessons learnt**

The advance in computer technology and internet facilitates the use of more complex computer models, a higher rate and amount of data transmission and the utilisation of globally available data sources like satellite data. Above all, the immense improvement with respect to computer performance and internet offers many opportunities. However, a complex system, like the flood forecasting toolbox of RFMMC, must evolve in a homogeneous way, that is, all components need development and improvement. A system is as strong as its weakest link and thus, missing data due to problems with mobile networks may not be overlooked while at the same time cutting-edge technology in terms of modelling advances. Modelling requires a good observation network and a course of action which remains feasible. The quality of the output of models are directly related to the quality of the input.

Another lesson learnt is that all systems need maintenance. Once a system is established, e.g. the forecasting tool box, flood hazard and risk maps, emergency preparedness plans, the performance and quality can only be kept if the systems are regularly checked and updated. From the viewpoint of the forecasting tool, recalibration was carried out, new stage-discharge curves have been tested and data processing and data quality checks were improved. This is necessary for mastering

future problems when forecasts and water management will gain even more importance with increasing variability of the climate.

## **2.8 Monitoring in the Lower Mekong Basin**

### **2.8.1 Data collection and transmission to RFMMC**

The Regional Flood Management and Mitigation Centre (RFMMC) of the Mekong River Commission (MRC) receives during the flood season the hydro-meteorological data of the Lower Mekong Basin (LMB) from the National Line Agencies (NLAs) of the MRC Member Countries through the telemetry system and SMS (manual) data using the HydMet database software. The HydMet database was developed and updated under the MRC information system to support sustainable water resources development and management in the LMB according to the 1995 Mekong Agreement (MRC, 2014b).

The National Line Agencies are:

Cambodia:	Department of Meteorology (DOM) and Department of Hydrology & River Works (DHRW), Ministry of Water Resources and Meteorology
Lao PDR:	Department of Meteorology and Hydrology (DMH), Ministry of Natural Resources and Environment
Thailand:	Thai Metrological Department (TMD), Ministry of Information and Communication Technology  Department of Water Resources (DWR), Ministry of Natural Resources and  Environment
Viet Nam:	Highland Regional Hydro-Meteorological Centre (HRHMC) and Southern  Regional Hydro-Meteorological Centre (SRHMC), Hydro-Meteorological Service

The number of meteorological stations was 118 in 2001 (MRC, 2014b) and has risen to 146 stations in 2012 (MRC, 2012). Data transmission follows the illustration given in Figure 34 and is rather stable and reliable. 80% to 95% of data was sent from the National Line Agencies before 9:00 AM to RFMMC. Problem occur mainly due internet communication. Data collection at some remote stations is difficult, because of a limited coverage regarding the mobile phone network.

Another type of problem that occurred in the previous 10 years are computer virus requiring re-installation of the HydMet software.

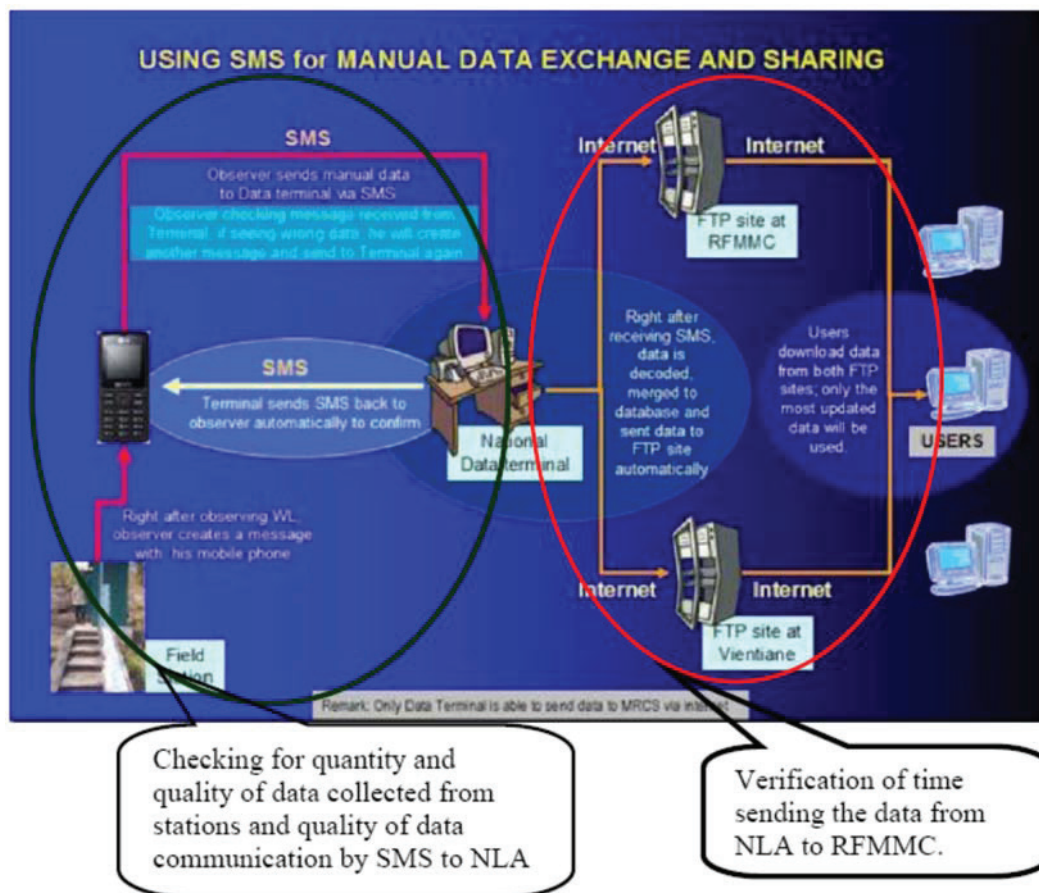


Figure 33: Data transmission and steps for analyzing and evaluating the availability of data provided to the RFMMC (MRC, 2012)

### 2.8.2 Retrospective view and current situation in the Member Countries

Each country runs its monitoring system with ground stations. Climate stations, precipitation and flow measurements constitute the base for all hydrological assessments.

#### Cambodia

The Ministry of Water Resources and Meteorology (MOWRAM) is responsible for hydrological observations.

MOWRAM, supported by ADB, is currently modernising the infrastructure of Automatic Hydrological Stations (AHS) and Automatic Weather Stations (AWS) in order to get real time data aiming at improving timeliness and accuracy of weather and flood forecasts. Currently, there are 42 AHS stations (25 stations from ADB, 5 stations by MOWRAM and 12 stations by MRCS). 35 AWS stations and Doppler Radar covers the weather observation.

The Department of Hydrology and River Works (DHRW), embedded in MOWRAM, monitors water levels in the dry season on a weekly basis and issues daily forecasts with three days lead time in the flood season on the Mekong, Bassac and Tonle Sap rivers. The Flash Flood Guidance System (FFGS), implemented by MRC, is not fully

used by DHRW staff due to a lack of capacity and limitations regarding the interpretation of results.

A step forward has been achieved at the Department of Meteorology under MOWRAM regarding the technology used. To improve the accuracy of forecasts, MOWRAM has upgraded its equipment and tools and has invested in capacity development of its staff to gain more knowledge of the new technology such as Doppler Radar S-band with real time detecting, MTSAT (Satellite images), GTS (Data transmit and receiving).

(source: Yin Savuth, et.al., 2017a and 2017b)

### **Lao PDR**

The Department of Meteorology and Hydrology (DMH) monitors and issues weather forecasts for the whole country by using the facilities and sources from different forecasting centres as a member of the World Meteorology Organization (WMO).

The hydrological division of the DMH receives real time data from six major stations along the Mekong River (Luangprabang, Vientiane, Paksane, Thakek, Savanakhet, and Pakse) and in main tributaries by high frequency / single slide band (HF/SSB) and telephone. The most important features are:

- The near real time data collection from more than 40 stations.
- Flood forecasting for 6 major stations along the Mekong River for two days in advance.
- Using MRC FFG for flash flood watch and flash flood warning for 1, 3, 6, 12 and 24 hrs.
- Forecasting inflow to Nam Ngum reservoir for dam operation (daily, weekly, and monthly).
- Using MRC URBS model to forecast the water level in Sebangfai river basin for 7 days in advance and issuing flood bulletins and warning information.
- Disseminating flood bulletins and warning information to the organisations concerned via mass-media (TV, radio and newspaper).

(source: Somzay Champathangkham, et.al., 2017a and 2017b)

### **Thailand**

The Thai Meteorological Department issues weather forecasts for seven days separated for seven regions. According to the WMO, Thailand runs 123 surface and upper-air stations (Volume A/ OSCAR/Surface) and operates a radar system.

### **Viet Nam**

The National Centre for Hydro-Meteorological Forecasting (NCHMF) is the core entity for meteorological and hydrological forecasts and warnings. A system has been established that integrates data collection, communication, data management and hydrological modelling. This system consists of real-time rainfall and water level data to be collected at the selected stations in the basins. The collected data is transferred to the master computer at the control station by radio links, landlines and satellite. All

collected data arriving at the computer in the control centre is used as input into a modelling software system to simulate flood events including peak water levels, flood areas and duration of inundation as well as flood extent. 25 hydrological stations are visible via the homepage of NCHMF.

(source: Pham The Vinh, et.al., 2017a and 2017b)

### **2.8.3 Lessons learnt**

Summarising the information from the national reports and the countries reveals that a new level of accessing data has been accomplished. All countries possess real-time or near real-time monitoring systems and have established data transmission and collecting systems. The advances in internet technology and enhanced rates of transmission have overcome the obstacles of the past and provide affordable solutions for data collection from ground stations. The advances in technology have the potential to transform the observation networks into a new generation. At the same time, hacker attacks from the internet are more likely nowadays than before and protection of data and security of computers is an issue more than ever.

The lesson learnt from the viewpoint of monitoring is, that a high-quality observation network is indispensable for high quality early warnings. Budget and staff should be scaled up rather than cut down. Maintenance of the network is mandatory to keep systems going reliably. Investment in monitoring saves more money than it costs. This is obvious, as ill-designed water infrastructure or weak forecasts have the potential to cause damages that outstrip the costs for monitoring by far. The spirit of investing in observation networks has obviously arrived at relevant ministries and development banks as projects concerning the enhancement of meteorological and hydrological observation networks are on the way.

With the progress in technology, a progress in staff capacity should run in parallel to best take advantage of the investment.

The issue of inadequate temporal resolution of records could be tackled as well.

The issue of inadequate temporal resolution of records could be tackled as well. Time series of precipitation with a temporal resolution of less than one day are still exceptions. The technological progress should be used to make the next step towards higher temporal resolutions of records. The reasons to do so goes without saying as early warning systems and design of water infrastructure could be improved with rainfall intensities and storm profiles with better temporal resolutions. Drainage systems in urban areas, frequency analysis of flood peaks, the design of spillways, culverts and pipes, to mention some, depend on high quality data with temporal resolutions significantly less than one day. Furthermore, accuracy of flow forecasts would be enhanced with bias corrected data and full spatial coverage of the area of concern.

Higher temporal resolution than one day allows for making better use of remotely sensed precipitation from radar or satellite data that also come with higher temporal resolutions. Both have the distinct advantage of providing 100% spatial coverage that cannot be achieved with ground stations. However, radar or satellite data require calibration and bias correction.

## 2.9 Exposure, vulnerability and consequences

Risk is the result of the occurrence of a hazard and exposure to the hazard. The degree of vulnerability of those exposed to hazards determines the consequences and the ability to recover.

It is quite evident that population growth, urbanisation and migration from rural areas to urban centres increases exposure. The pressure on land increases and it becomes more and more likely that areas traditionally not populated and known as risky or flood prone become populated. This puts additional pressure on the coordination between land-use and water resources planning.

Each country has to cope with this phenomenon to a greater or lesser extent. Urbanisation and expansion into untouched, natural areas is not only an issue in terms of loss of ecosystems, land-use planning and infrastructure, it also poses a threat with respect to flood and flood management as well. A number of knock-on effects take place such as:

- Flood plain encroachment
- Informal housing in hazard prone areas
- Lack of proper drainage systems
- Deforestation
- Lack of waste management that clogs canals and drainage facilities

The list could be prolonged. Each of the items is either a root cause that adversely contributes to flood formation or aggravates the effects of floods. In this context, the focus is on both riverine floods and flash floods. An example from Lao PDR is given that demonstrates the matter.





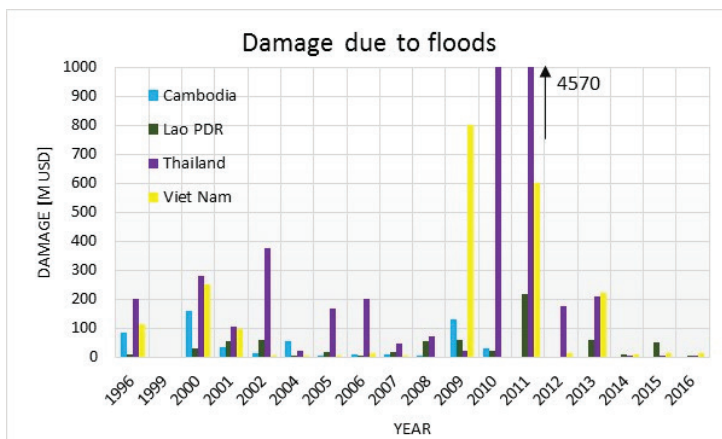
Figure 34: Encroachment of sensitive areas and increase of exposure

The process impacts runoff not linearly but exponentially. This means that when land-use changes and encroachment starts, flow behaviour changes moderately. If land-use alterations continue, flow behaviour changes over proportionally the more land is cleared.

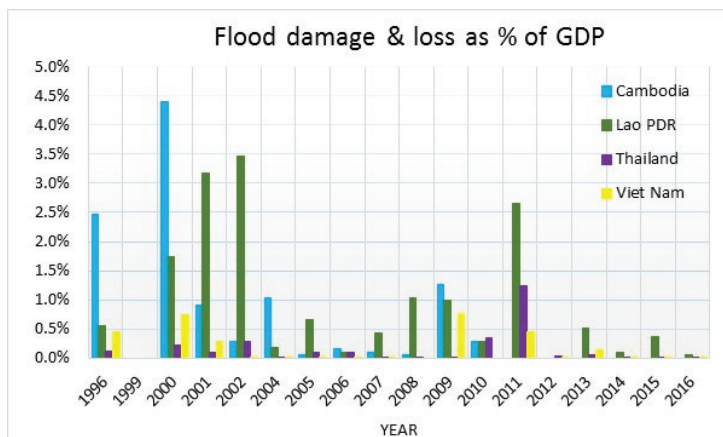
Is exposure and vulnerability reflected by flood induced damages and losses?

Costs related to floods have been collected from all AFMRs since 2005. If compared with the major flood events of 2000, 2001, 2008, 2010 and 2011, costs do not really coincide with the magnitude of the flood incidents. An indicator of the burden due to flood damages and losses a country has to bear is the ratio of flood induced costs on the Gross Domestic Product (GDP).

As can be seen in Figure 35, average losses due to floods as a share of the country's GDP have declined over the years (also as a result of data gaps). However, a declining trend of flood-related loss on GDP should not give rise to become complacent. Expanding cities and worsening climate challenges can significantly increase flood-related risks and could reverse the trend.



Data collected from AMFR since 2005



GDP taken from World Bank database  
<https://data.worldbank.org/country/>

Figure 35: Cost of flood events (source: AMFR reports)

The World Resources Institute (WRI) analysed which countries have the highest percentage of total GDP affected by river flooding on average per year.

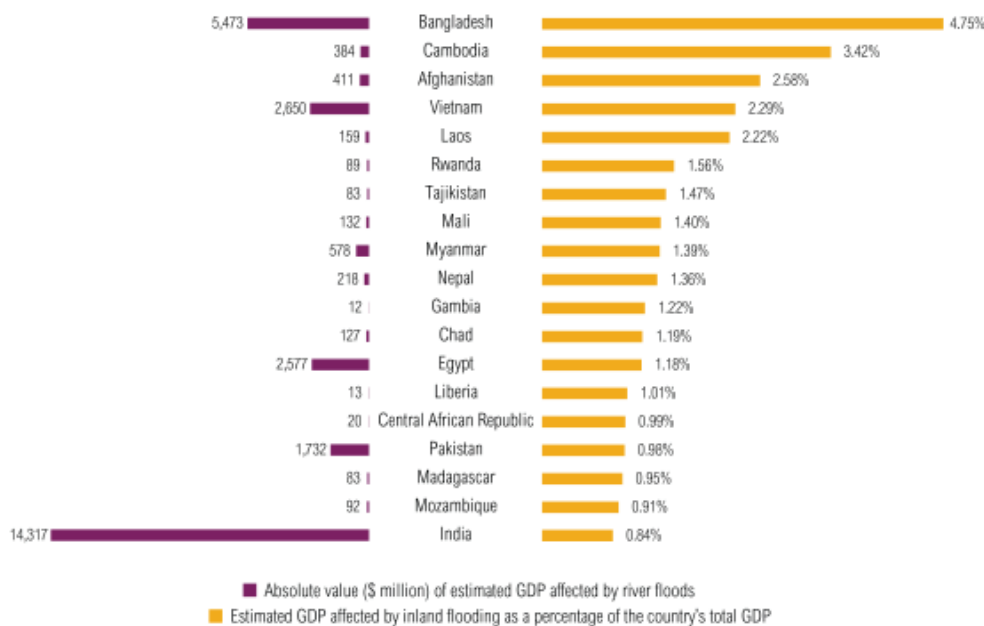


Figure 36: Top 20 countries with the most GDP affected by river floods as percentage of the country's total GDP 2010 (source: WRI, 2015)

Apart from Thailand, all other member countries are listed. Hence, to reduce exposure and thus vulnerability apparently makes sense.

Table 4: Compilation of all socio-economic figures from all AMFR

	Cambodia				
	Fatalities	Damage	Accumulated	People	Agriculture
	[-]	[M USD]	[M USD]	[-]	[ha]
1996	169	86.5	86.5	1300000	600000
1999			86.5	37527	18000
2000	347	161	247.5	3448629	

Cambodia					
	Fatalities	Damage	Accumulated	People	Agriculture
	[-]	[M USD]	[M USD]	[-]	[ha]
2001	62	36	283.5	2121952	
2002	29	12.5	296	1439964	
2004		55	351		247400
2005	4	3.8	354.8		55000
2006	11	11.8	366.6		14500
2007	10	9	375.6		9500
2008		5.8	381.4		18900
2009	43	132	513.4	180000	
2010	7	32	545.4	83557	84600
2011	250		545.4	1301205	460000
2012	29		545.4	87028	61000
2013	168		545.4	1386198	129000
2014	49		545.4	608018	87000
2015	1		545.4	2898	12000

Lao PDR					
	Death	Damage	Accumulated	People	Agriculture
	[-]	[M USD]	[M USD]	[-]	[ha]
1996		10.4	10.4		67500
1999			10.4		
2000		30	40.4		42900
2001		56	96.4		42200
2002	3	61	157.4		33700
2004		4.1	161.5		14400
2005	5	18.3	179.8		56000
2006	5	3.1	182.9		6900
2007	2	18	200.9		7500
2008	7	56	256.9		28500
2009		58	314.9		
2010	7	21	335.9		3900
2011	42	220	555.9	430000	76940
2012	5		555.9		
2013	30	62	617.9		
2014	5	12	629.9	92165	
2015	4	52.25	682.15	79938	26300

Viet Nam					
	Death	Damage	Accumulated	People	Agriculture
	[-]	[M USD]	[M USD]	[-]	[ha]
1996		113	113		

Viet Nam					
	Death	Damage	Accumulated	People	Agriculture
	[-]	[M USD]	[M USD]	[-]	[ha]
1999			113		
2000	453	250	363		2000000
2001	393	99	462		
2002	71	0.3	462.3		
2004	38	3	465.3		
2005	44	3.5	468.8		
2006	55	15	483.8		14700
2007	30	1.5	485.3		46400
2008	7		485.3		28500
2009	163	800	1285.3		106000
2010	4		1285.3		
2011	265	600	1885.3		350000
2012	38	16	1901.3		66000
2013	257	222	2123.3		
2014	34	9	2132.3		3000
2015	39	14.596	2146.896		31000

Thailand					
	Death	Damage	Accumulated	People	Agriculture
	[-]	[M USD]	[M USD]	[-]	[ha]
1996		200	200		
1999			200		
2000		280	480		
2001	192	105	585		
2002		375	960		
2004	32	24	984		528000
2005	88	170	1154		272000
2006	340	202	1356		897000
2007	62	48	1404		423000
2008	97	72	1476		1210000
2009		21	1497		
2010	79	1200	2697	5000000	
2011	657	4570	7267	4000000	1800000
2012		177	7444	371000	
2013	17	210	7654	429000	301000
2014	4	6	7660	400000	43000
2015	3	1.158	7661.158	81811	16994

Any increase in exposure to floods makes flood management more difficult. Preventive measures, zoning of risk areas and declaration of protected nature zones are rendered useless if land-use planning is not taken seriously and not enforced.

Higher costs due to floods are not only a matter of worsening climate but also have underlying socio-economic root causes. By looking at the impact floods have on the GDP, it is worth the effort to scrutinise where and how the unwanted increase of exposure can be tackled and reduced.

### 3. THE REGIONAL FLOOD SITUATION 2015

#### 3.1 Tropical storms and cyclones

In 2015, 5 tropical storms and 2 tropical depressions originated in the South China and Philippine Sea of which two typhoons impacted on the Mekong basin: typhoon Kujira and Vamco.

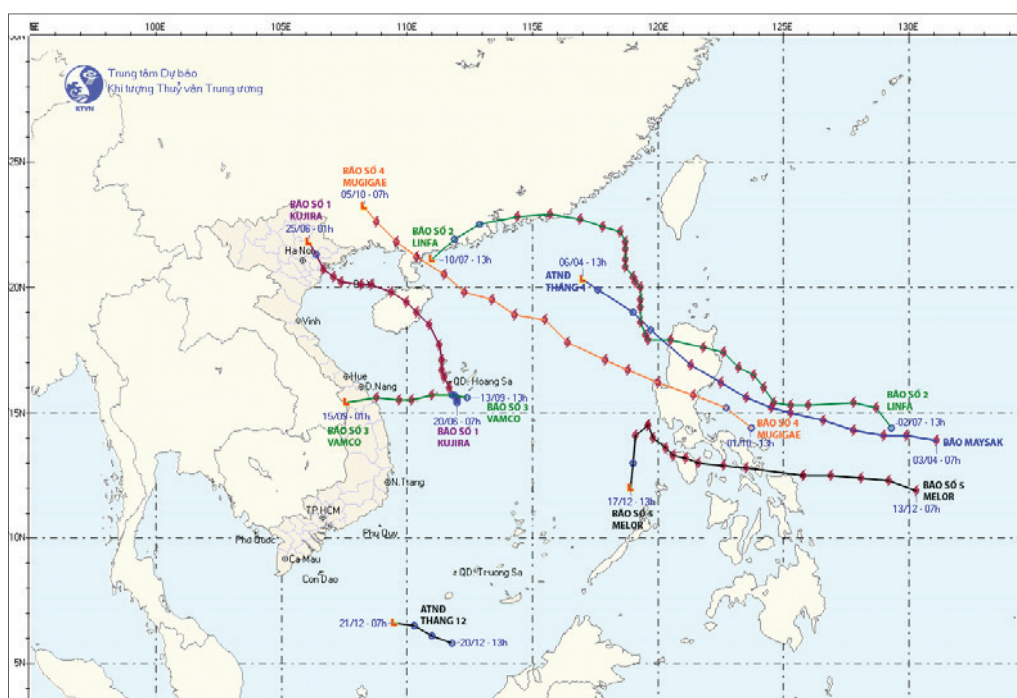


Figure 37: Tropical storms in 2015 (source: National Center of Hydrology and Meteorology Forecasting, Viet Nam, 2015)

A list of tropical storms and cyclones since 2010 with wind speed level is provided in Table 5.

Table 5. List of tropical storms and cyclones during the period 2010-2015 (source: National Center of Hydrology and Meteorology Forecasting, Viet Nam, 2015)

Sea region	Date of Occurrence	Storm name	Wind speed level
South East Sea	20/12/2015	Tropical depression	Level 6 (39 - 49 km/h)
North West Ocean	13/12/2015	Malor	Level 8-11 (74-117 km/h)
North West Ocean	03/04/2015	Maysak/Tropical dep.	Level 6 (39 - 49 km/h)
North West Ocean	02/07/2015	Linha/Tropical dep.	Level 6 (39 - 49 km/h)
Middle East Sea	13/09/2015	Vamco	Level 12-15 (133-158 km/h)
Middle East Sea	20/06/2015	Kujira	Level 8-11 (74-117 km/h)
Middle East Sea	1/12/2014	Hagupit	Level 10 (89-102 km/h)
Middle East Sea	28/11/2014	Silaku	Level 10 (89-102 km/h)
Middle East Sea	12/9/2014	Kalmaegi	Level 13 (134 - 149 km/h)
Middle East Sea	6/9/2014	Tropical depression	Level 6 (39 - 49 km/h)
Middle East Sea	27/8/2014	Tropical depression	Level 6 (39 - 49 km/h)
Middle East Sea	11/7/2014	Rammasun	Level 10 (89-102 km/h)
North East Sea	14/6/2014	Hagibis	Level 6 (39 - 49 km/h)
North East Sea	31/1/2014	Kajiki (Depression)	Level 6 (39 - 49 km/h)
Middle East Sea	14/11/2013	No15	Level 7 (50 - 61 km/h)
Middle East Sea	11/11/2013	Podul	Level 10 (89-102 km/h)
Middle East Sea	4/11/2013	Haiyan	Level? (315 km/h)
Middle East Sea	3/11/2013	Tropical Depression	Level 6 (39 - 49 km/h)
North East Sea	29/10/2013	Krosa	Level 10 (89-102 km/h)

Sea region	Date of Occurrence	Storm name	Wind speed level
Middle East Sea	9/10/2013	Nari	Level 13 (134 - 149 km/h)
North East Sea	25/09/2013	Wutip	Level 10 (89-102 km/h)
North East Sea	17/09/2013	Usagi	Level? (250 km/h)
North East Sea	16/09/2013	No 8	Level 8 (62 - 74 km/h)
North East Sea	6/9/2013	Tropical Depression	Level 6 (39 - 49 km/h)
Middle East Sea	10/8/2013	Tropical Depression	Level 6 (39 - 49 km/h)
North East Sea	9/8/2013	Utor	Level 17 (184 - 195 km/h)
South East Sea	5/8/2013	Mangkhut	Level 10 (89-102 km/h)
Middle East Sea	28/07/2013	Jebi	Level 11 (103 - 117 km/h)
Middle East Sea	18/07/2013	Tropical Depression	Level 6 (39 - 49 km/h)
North East Sea	16/07/2013	Cimaron	Level 9 (75 - 88 km/h)
North East Sea	27/06/2013	Rumbia	Level 12 (118-133 km/h)
Quang Ninh - Thanh Hoa	20/06/2013	Bebinka	Level 9 (75 - 88 km/h)
South East Sea	21/02/2013	Tropical Depression	Level 6 (39 - 49 km/h)
South East Sea	2/1/2013	Sonamu	Level 11 (103 - 117 km/h)
South East Sea	14/11/2012	Tropical Depression	Level 6 (39 - 49 km/h)
South East Sea	23/10/2012	Son Tinh	Level 13 (134 - 149 km/h)
Along East Sea	1/10/2012	Gaemi	Level 10 (89-102 km/h)
North East Sea	19/08/2012	Tembin	Level 14 (148 - 157 km/h)
North East Sea	13/08/2012	Kai-Tak	Level 12 (118-133 km/h)
North East Sea	21/07/2012	Vicente	Level 12 (118-133 km/h)
North East Sea	26/06/2012	Doksuri	Level 10 (89-102 km/h)
North East Sea	16/06/2012	TaLim	Level 11 (103 - 117 km/h)
Binh Thuan - Ca Mau	29/03/2012	Pakhar	Level 8 (62 - 74 km/h)
South East Sea	17/01/2012	Tropical Depression	Level 6 (39 - 49 km/h)
North East Sea	15/06/2011	Tropical Depression	Level 6 (39 - 49 km/h)
Middle East Sea	15/06/2011	Tropical Depression	Level 6 (39 - 49 km/h)
Middle East Sea	9/6/2011	SARIKA-1103	Level 6 (39 - 49 km/h)
North East Sea	9/6/2011	SARIKA-1103	Level 6 (39 - 49 km/h)
Binh Dinh - Ninh Thuan	12/11/2010	Tropical Depression	Level 6 (39 - 49 km/h)
North East Sea	16/10/2010	Megi	Level 12 (118-133 km/h)
North East Sea	27/08/2010	Lionrock	Level 9 (75 - 88 km/h)
Nghe An - Quang Binh	21/08/2010	Mindulee	Level 10 (89-102 km/h)
Binh Dinh - Ninh Thuan	18/07/2010	Chan Thu	Level 7 (50 - 61 km/h)
Quang Ninh - Thanh Hoa	12/7/2010	Con Son	Level 7 (50 - 61 km/h)
Binh Thuan - Ca Mau	18/01/2010	Tropical Depression	Level 6 (39 - 49 km/h)

### Typhoon Kujira (June 2015)

The tropical Storm Kujira (T1508, 08W) formed in the South China Sea. It was the first tropical storm in 2015. Kujira originated as a tropical depression on June 20, 2015, intensified gradually and moved north-eastward. Kujira developed into a tropical Storm, turned north-westward, passed Hainan Island and made landfall in South China's Hainan Province on 22 June 2015.

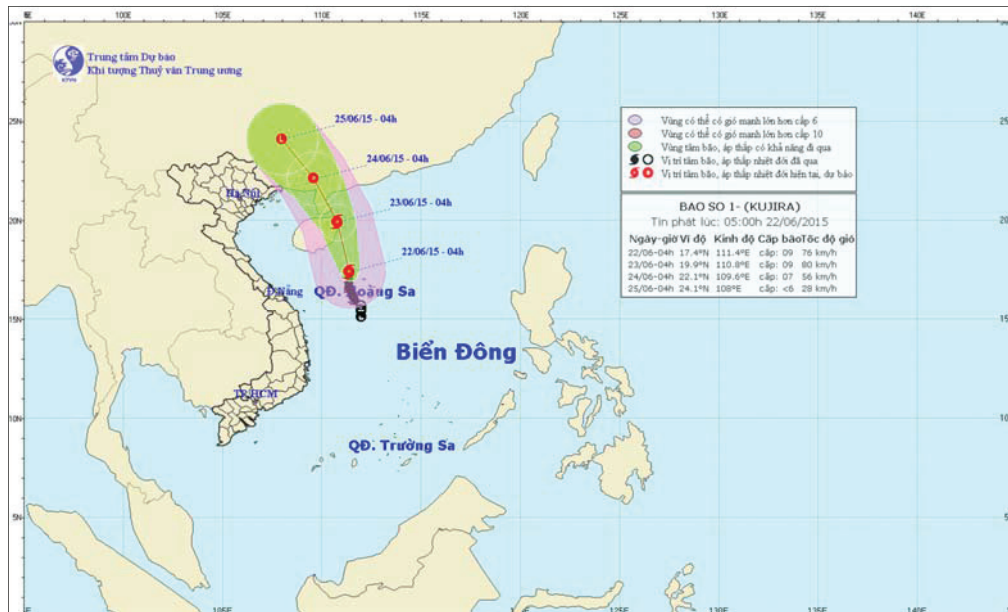


Figure 38: The direction and position of tropical typhoon Kujira (source: National Center of Hydrology and Meteorology Forecasting, Viet Nam, 2015)

### Typhoon Vamco (September 2015)

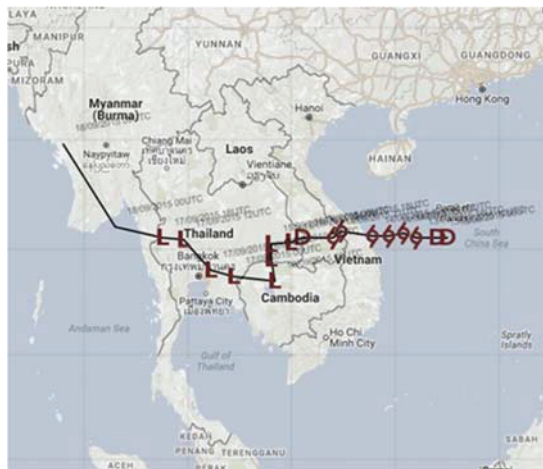


Figure 39: The direction and position of tropical typhoon Vamco (source: Thai Meteorological Department)

Vamco formed as a tropical depression on September 13, 2015, intensified and moved west-south-westward. Vamco developed to a tropical storm on September 13, 2015 in the South China Sea and made landfall in Viet Nam on September 14, 2015, crossed Viet Nam and kept moving to Dakjung District, Sekong Province of Lao PDR. Vamco finally weakened to a tropical depression, passed Salavan Province and moved towards Thailand.

The peculiarity of Vamco was its origin. The typhoon developed in the East Sea and moved straight towards the coast of Viet Nam so that lead time was remarkably short for Viet Nam.

### 3.2 The regional climate during 2015

Earth's 2015 surface temperatures were the warmest since modern record keeping began in 1880, according to independent analyses by NASA and the National Oceanic and Atmospheric Administration (NOAA). Phenomena such as El Niño or La Niña, which warm or cool the tropical Pacific Ocean, can contribute to short-term variations in global average temperature. A warming El Niño was in effect for most of 2015. The time series of annual land temperature anomalies for Asia from 1910 to 2015 ranks 2015 first.

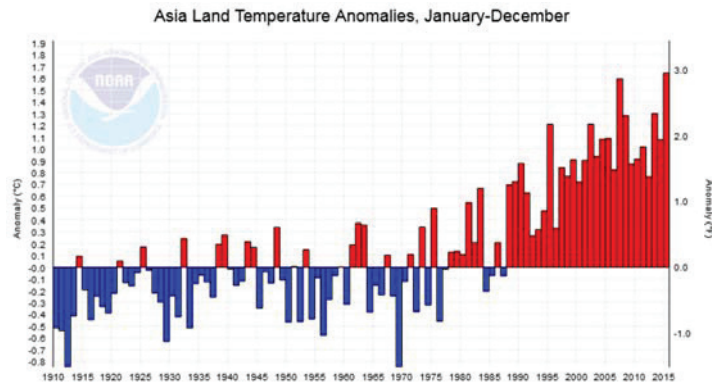
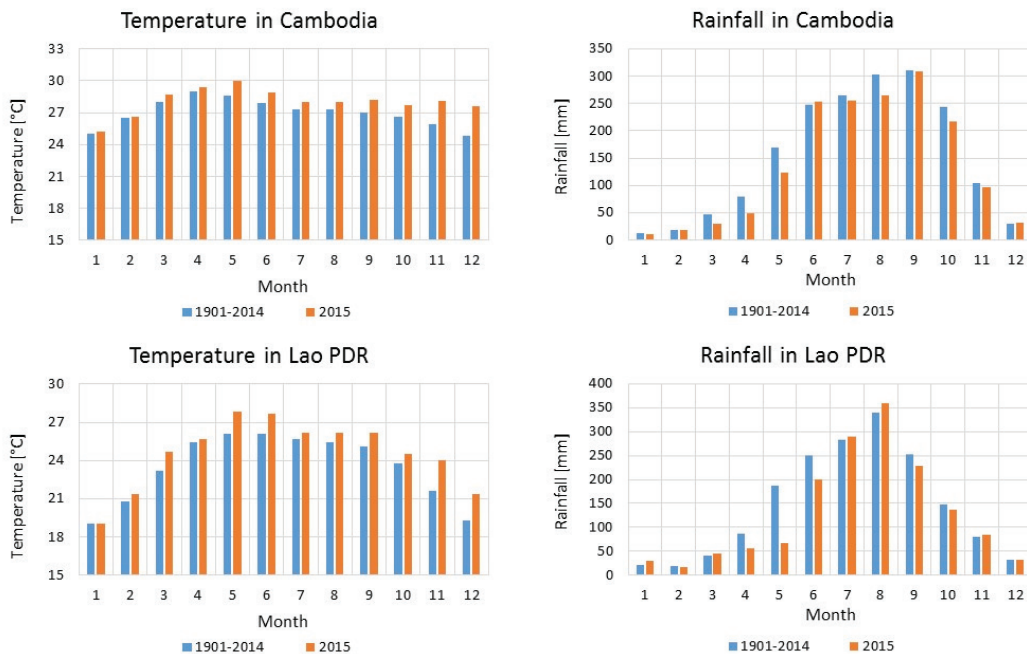


Figure 40: Asia land temperature anomalies, Jan-Dec 1910-2015 (source: NOAA)

The World Bank data portal shows temperatures above average for all four member countries from May to December and a delay of the rainy season.



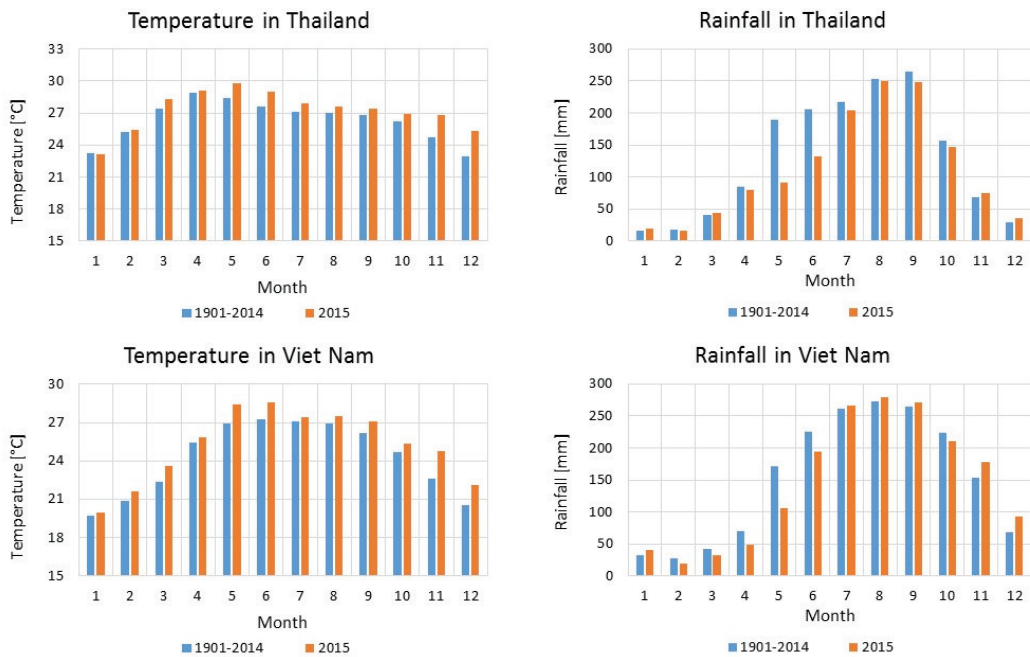


Figure 41: Monthly mean temperatures and rainfall in the countries compared with 2015

Hot and dry weather caused higher evaporation and drought conditions in Cambodia. Lao PDR also reported a drop below average in terms of annual rainfall. Thailand faced warmer and drier climate conditions than usual with approximately 11% below the 1981-2010 normal. The rainy season of 2015 began late and brought less than average rain which is revealed by analysing the anomaly of precipitation.

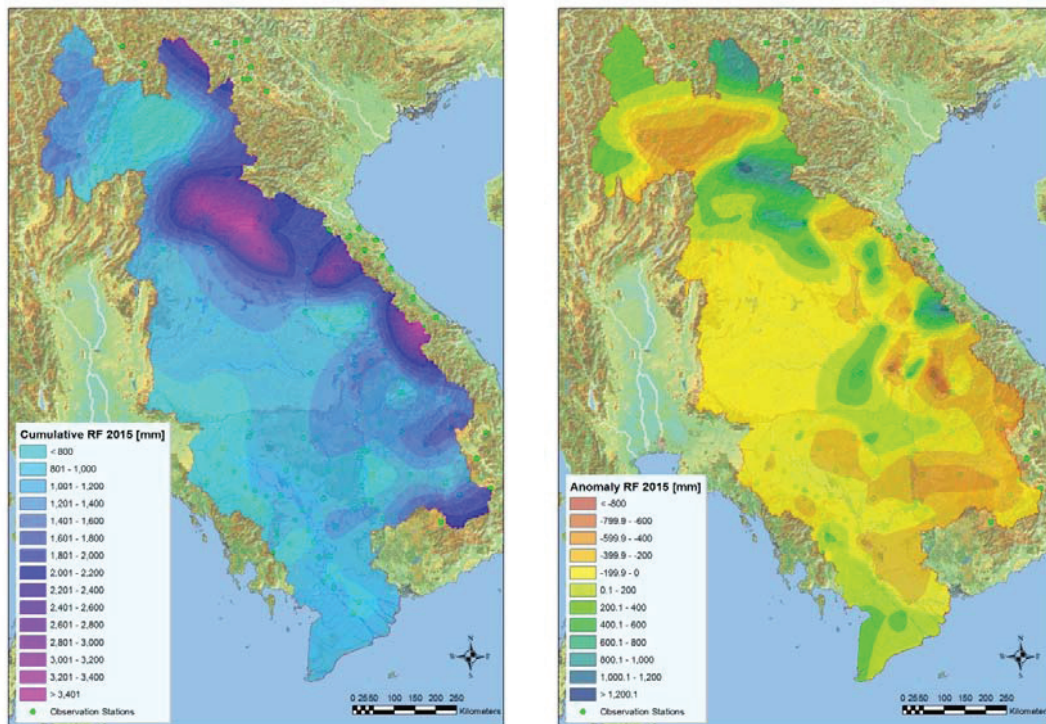


Figure 42: Cumulative rainfall and anomaly of the year 2015

The anomaly of 2015 was calculated against mean values from 2006 to 2014. Only a few areas show rainfall close to or above average. An overview of cumulative rain is provided in Figure 43. The south of Lao PDR and stations in Cambodia represent drought situations. Only the stations Luang Prabang, Nong Khai and Chau Doc reached values close to average rainfall towards the end of the rainy season and during the transition to the dry season.

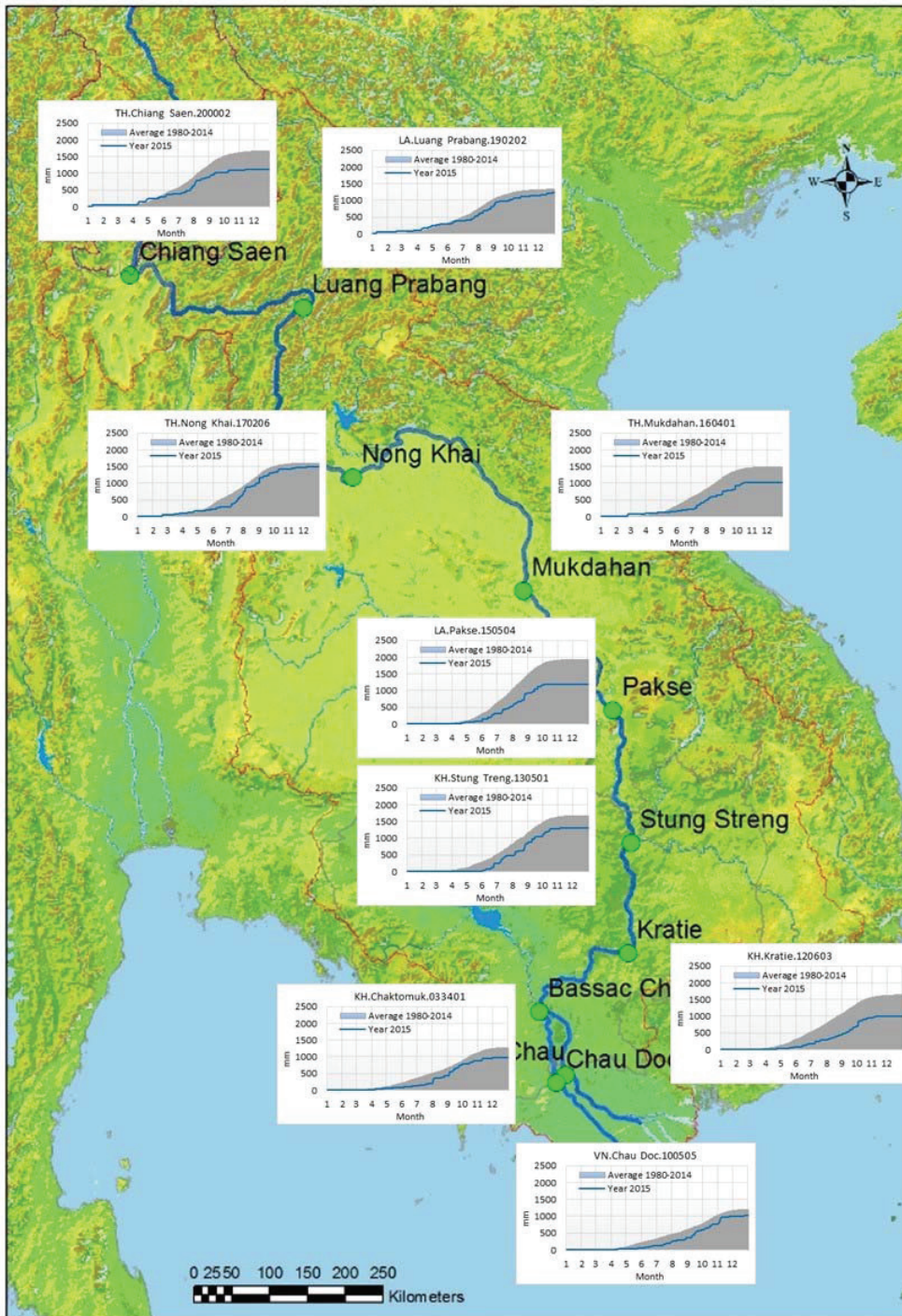


Figure 43: Cumulative rainfall 2015 and long-term average at selected stations

Rainfall intensities are shown in Figure 44, long-term behaviour is indicated in blue. The approach used is simple. All days with rain between 1980 and 2014 were sorted for each year separately and subsequently mean values were calculated for each day 1 to day 365. For example, the day with the highest rainfall in each year obtains the index 365. The mean value for index 365 is then calculated with all days with index 365. The second largest rainfall day obtains the index 364 and the mean value is calculated based on all days with index 364 and so on. By sorting all rainfall days for each year, the time reference when the rainfall occurred within a year is lost. Illustrated are the largest 100 days of precipitation. If the red line, which represents 2015, lies above blue (average), daily rainfall intensity in 2015 is higher than average or vice versa. Although the cumulative rainfall was remarkably lower than average, Stung Treng, Kratie and Chau Doc had a few days with higher intensities than usual.

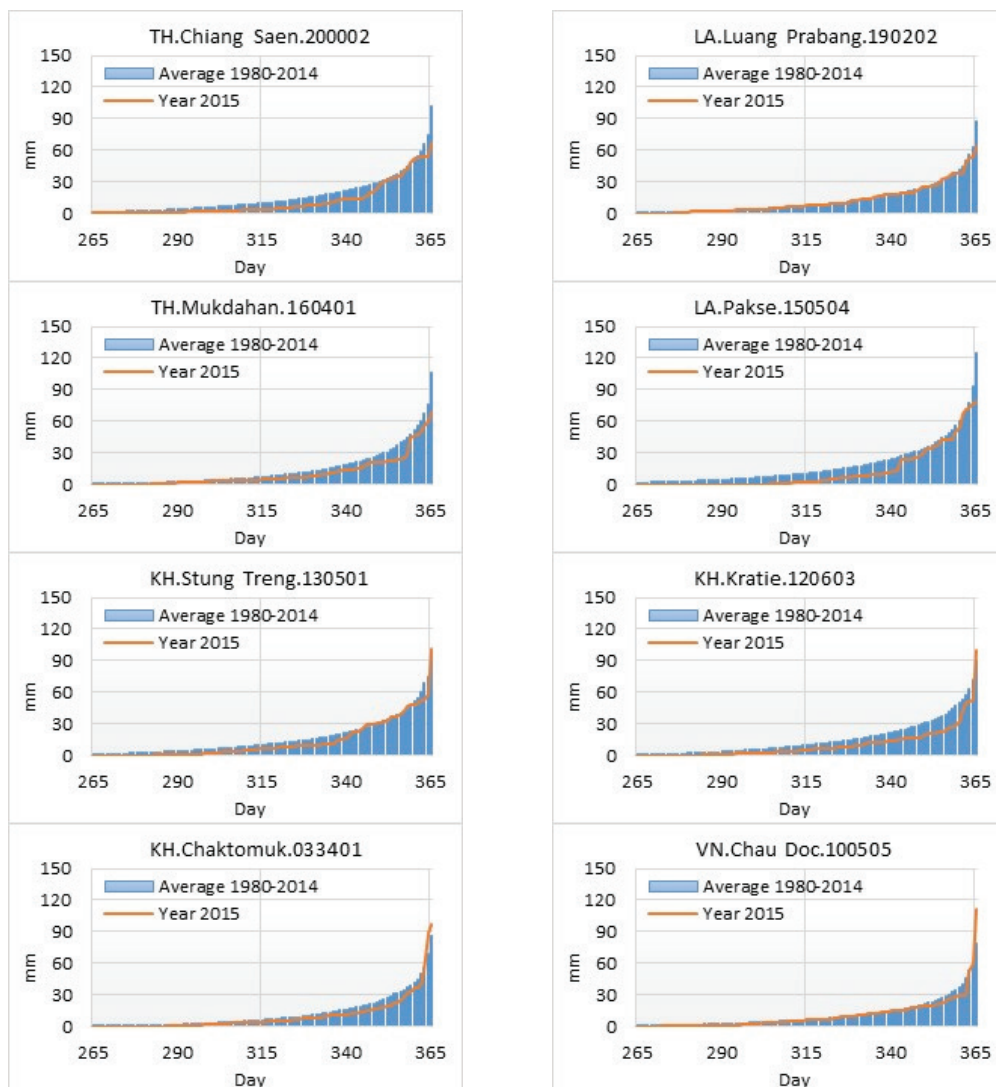


Figure 44: Rainfall intensities 2015 at selected stations

### 3.3 The flood hydrology of 2015

The year 2015 can be described as dry with discharge distinctly less than average along mainstream Mekong from Chiang Saen up to the Delta.

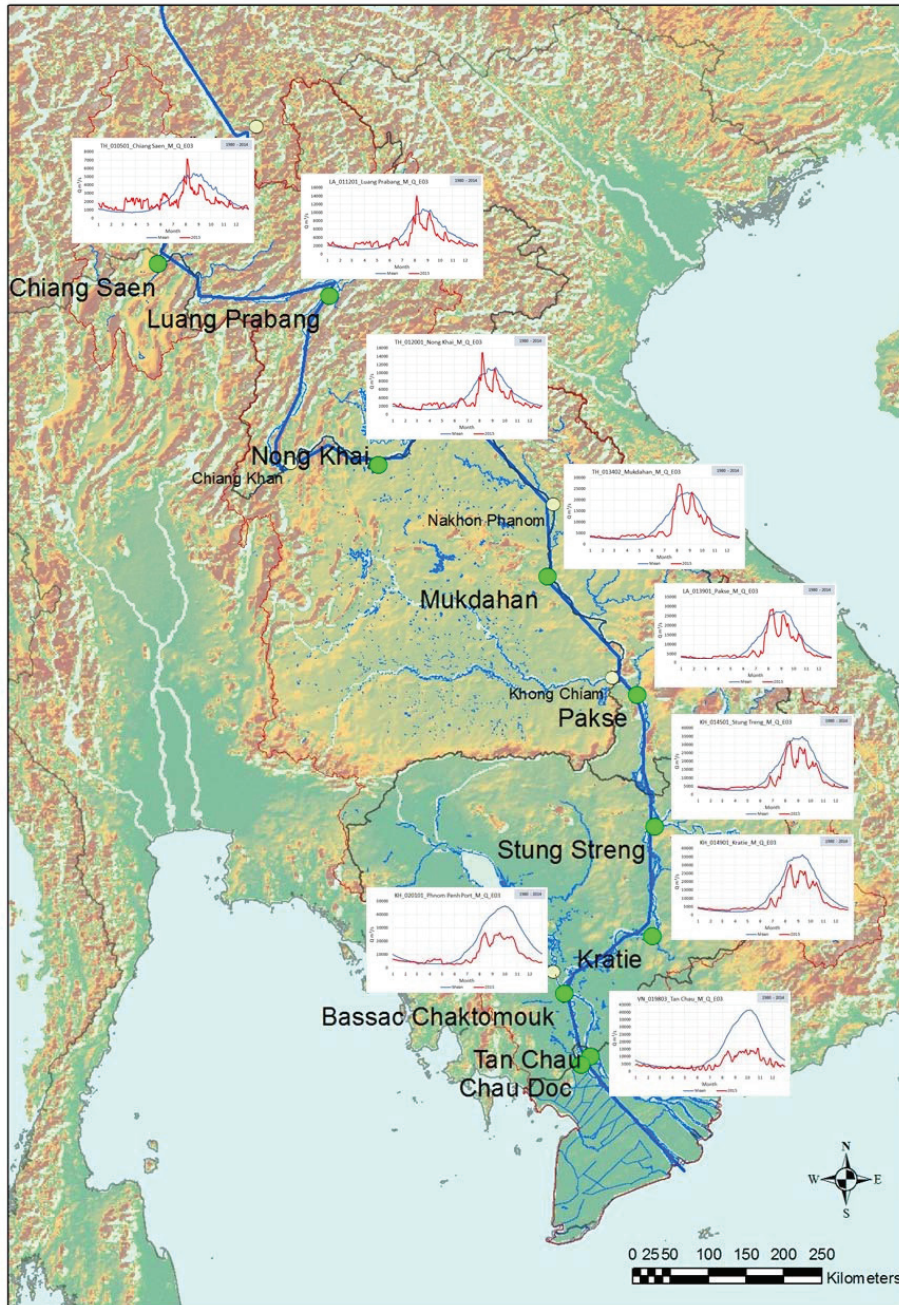


Figure 45: Hydrographs comparing mean with 2015 at selected stations

A comparison of mean annual discharge volumes from 1980 to 2014 with the year 2015 reveals the below average situation. Both schematic views in Figure 46 use the same scale. The widths of the blue bars represent the annual flow volume. The labels indicate the annual flow volume in km<sup>3</sup>. Flow from tributaries was calculated from the delta flow volume between adjacent up and downstream stations. Losses are indicated as yellow

arrows. A loss occurs if the downstream station from two adjacent stations had less annual volume than the upstream station and the delta between both becomes negative.

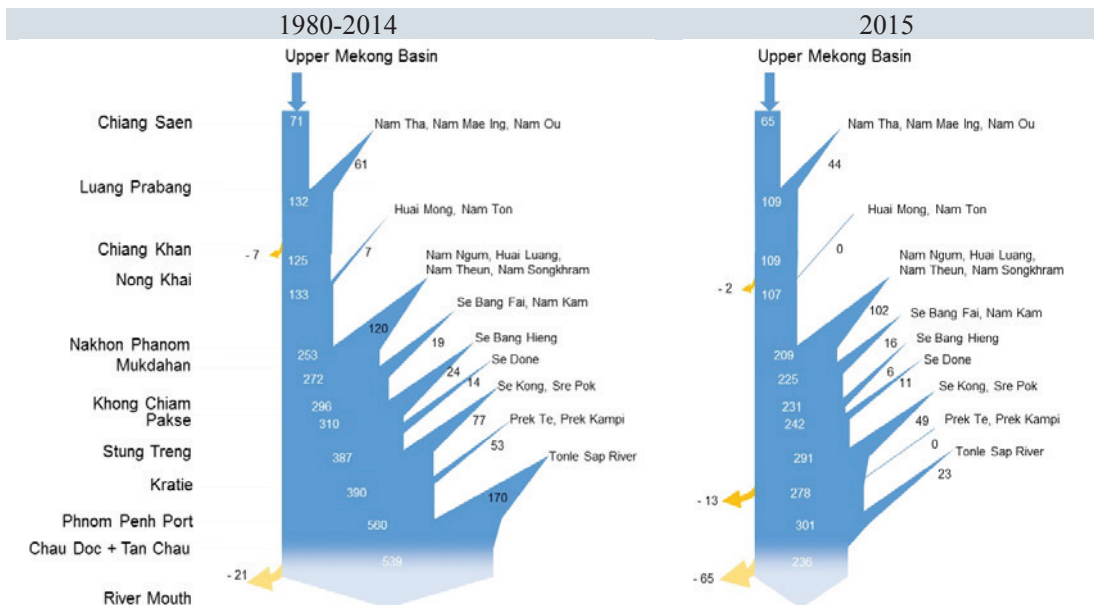
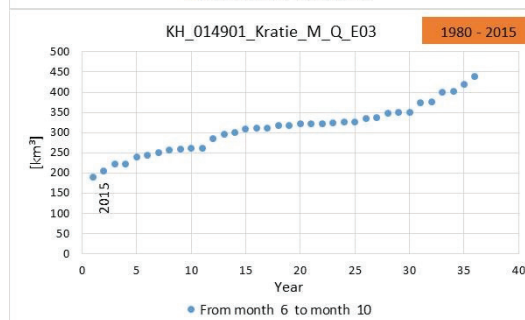
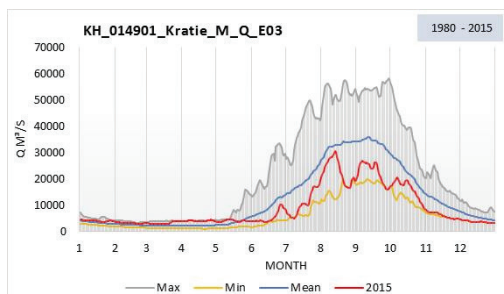
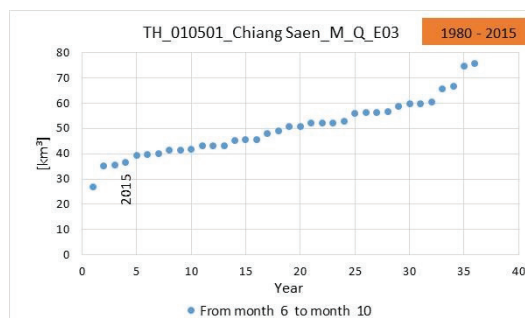
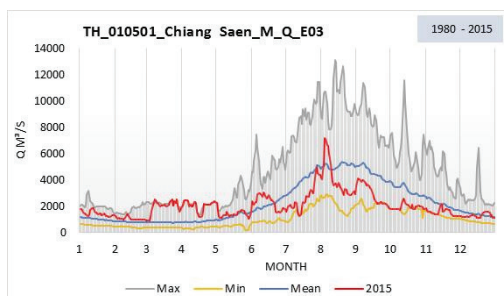


Figure 46: Comparison of annual discharge volume (1980-2014) with 2015. Values in km<sup>3</sup>.

The most prominent features of the flood season 2015 were:

- Total discharge volumes over the year ranked amongst the lowest recorded values ever, even though releases from the Lancang reservoir system augmenting flow conditions during March, April and May were high.



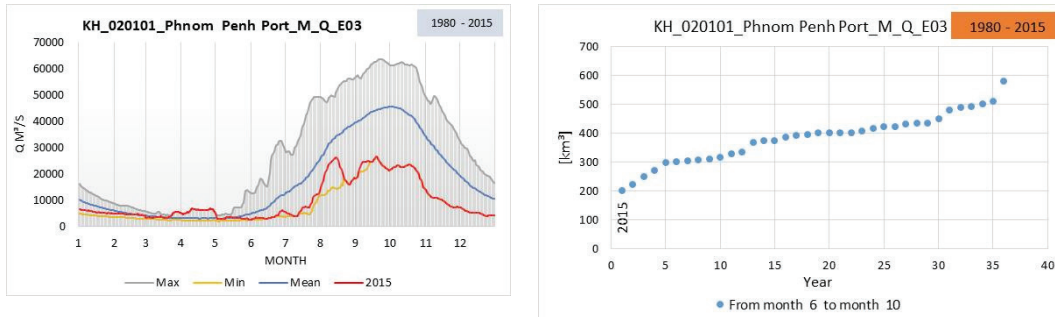


Figure 47: Hydrograph for 2015 and list of flood volumes at selected stations

In fact, the falling limb of the hydrograph at Kratie and Phnom Penh Port constituted the all-time lowest values compared with records as of 1980.

- The range between maximum and minimum discharge throughout the year along mainstream Mekong, in particular at Chiang Saen, was amongst the lowest ratios ever with a clear downward trend.

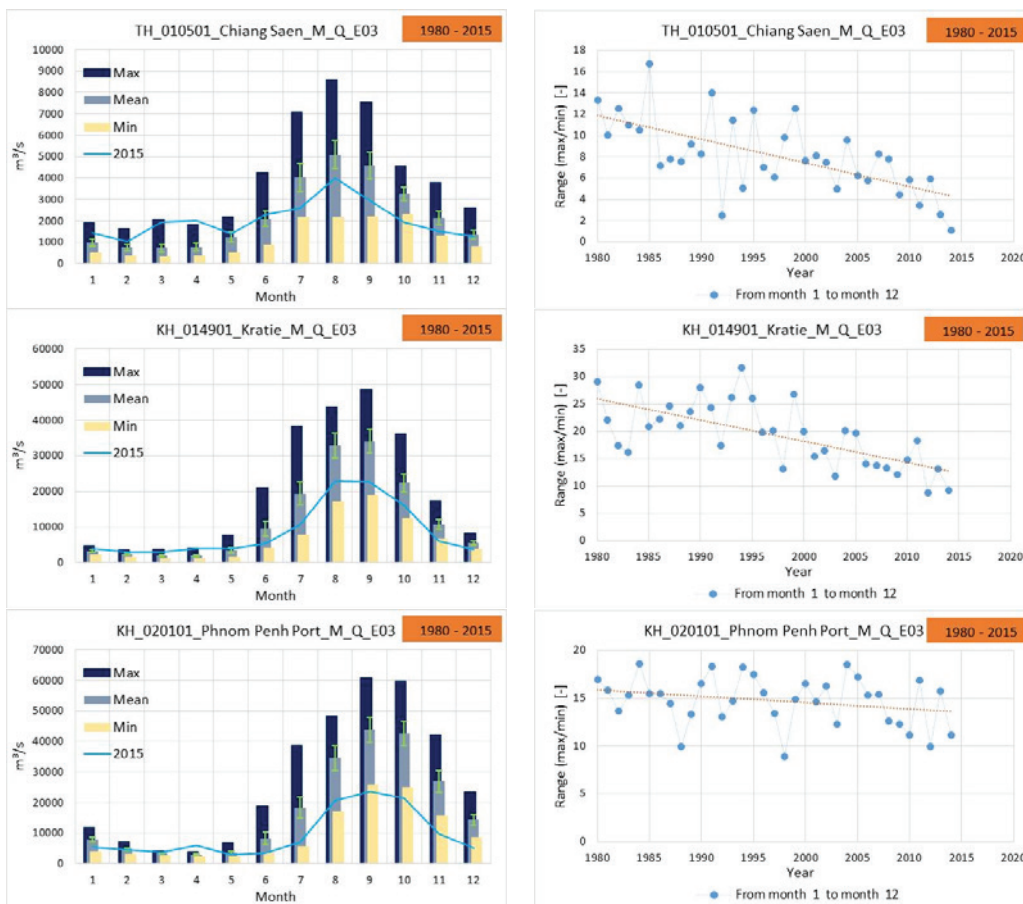


Figure 48: Range of maximum to minimum discharge per year at selected stations

Discharge at Phnom Penh Port was at minimum level over a number of months.

- In 2015, Phnom Penh Port had both lowest flood volume and lowest peak discharge. The drop in the peak discharge and flood volume is attributable to all stations but worsened further south.

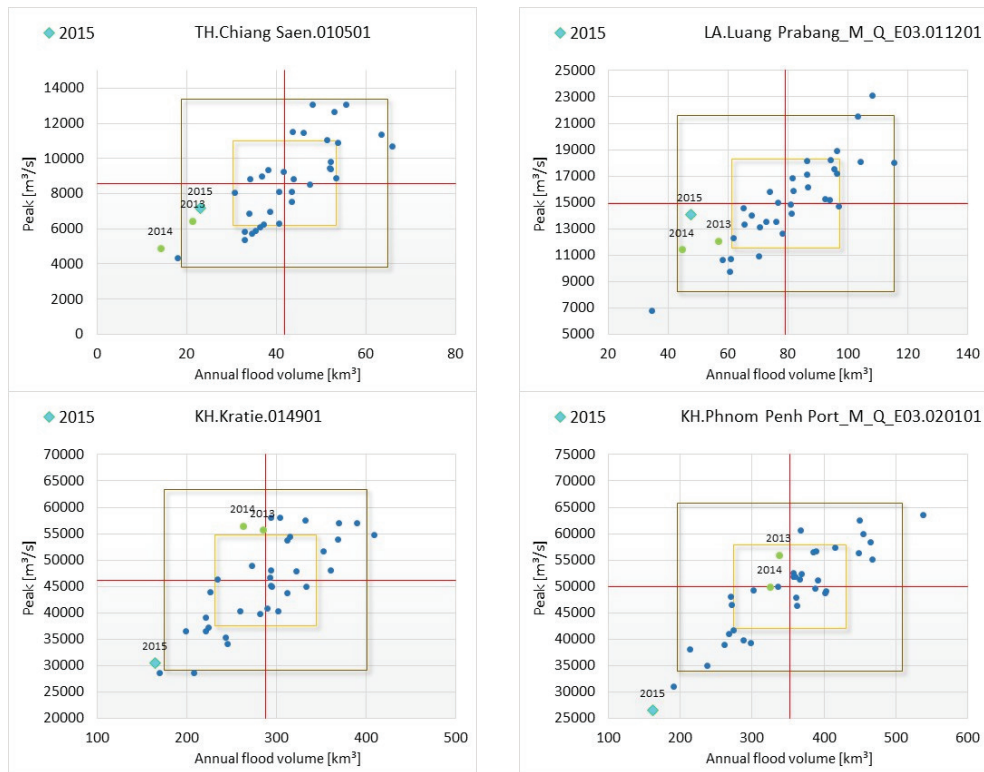


Figure 49: Flood volume / peak discharge relationship at selected stations

The inner rectangle in the chart indicates derivation in the magnitude of the standard deviation for both peak discharge and annual flood volume. The outer rectangle simply doubles the standard deviation.

### 3.4 Regional flash floods 2015

From the viewpoint of flash floods, cumulative precipitation over weeks, months or a year are not relevant. One single day with extreme rainfall in a dry year is enough to cause unwanted flooding. Figure 50 and Figure 51 show daily rainfall intensities for May until October for Stung Treng and Kratie. The values show rainfall sorted in a descending order and compared with long-term averages of rainfall intensities from 1980 to 2014.

Both stations had one day of exceptionally high rainfall which goes beyond average, Strung Treng in June and Kratie in October. The late onset of the monsoon can easily be recognised at Strung Treng in May.

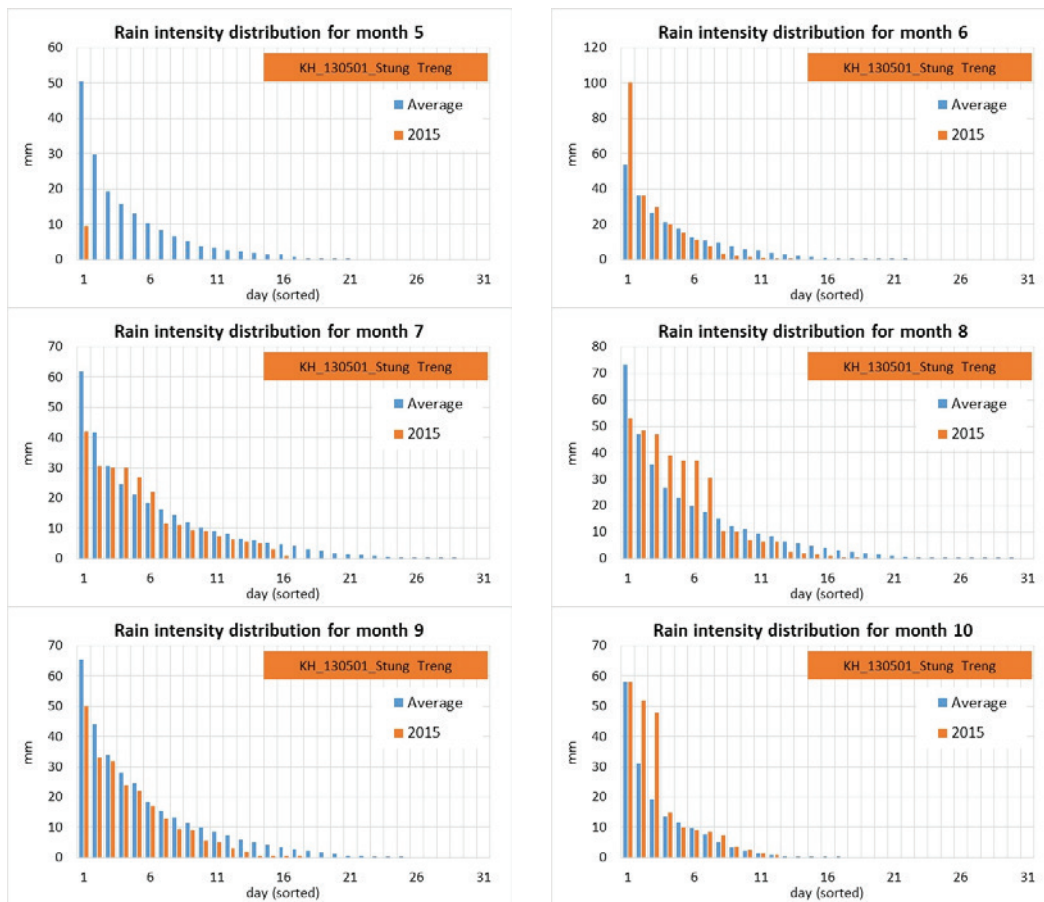
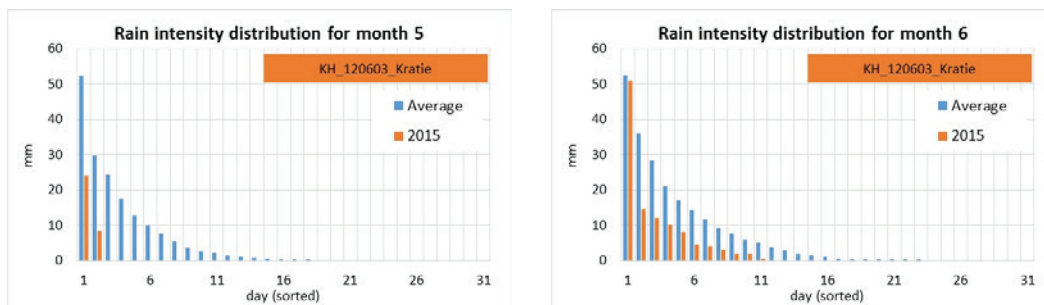


Figure 50: Rainfall intensities for each month at Stung Treng



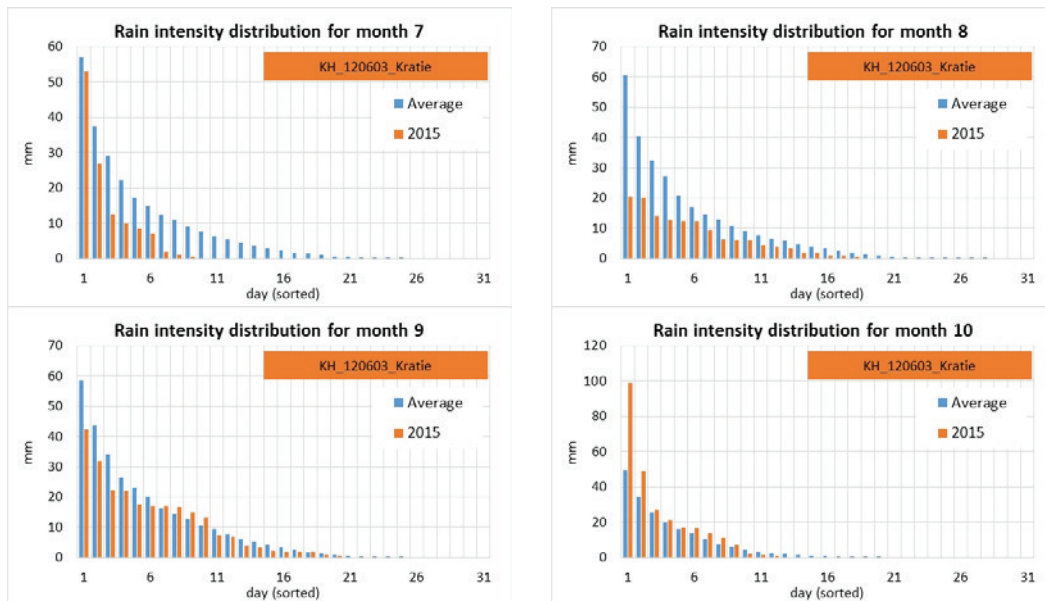


Figure 51: Rainfall intensities for each month at Kratie

The maximum daily rainfall at Stung Treng can be rated as a 5 year recurrence interval indicated in Figure 52. However, the estimate of return periods for Stung Treng has some uncertainty because the time series used only contains records for 17 years.

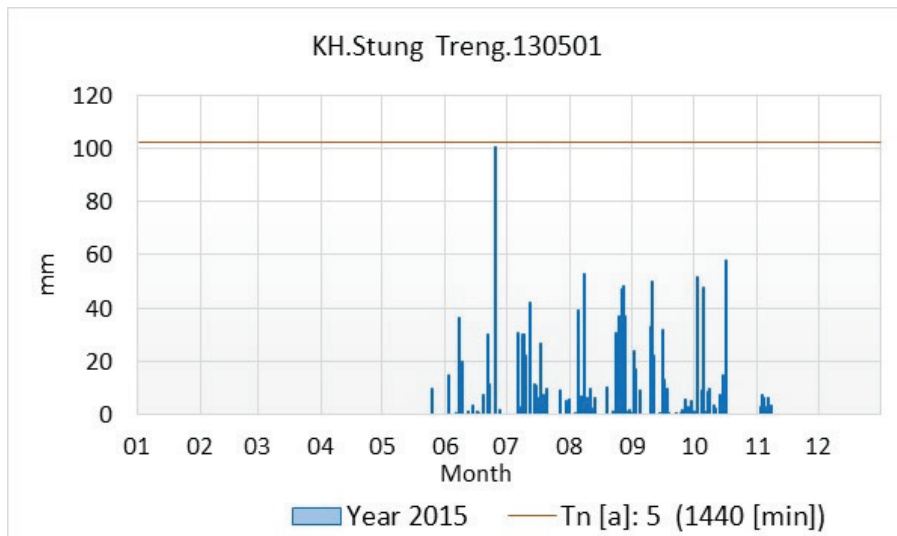


Figure 52: Daily rainfall for Stung Treng with a 5 year return period indicated as red line

Figure 53 shows rainfall at Kratie throughout the year. The situation at Kratie is comparable to Stung Treng with the difference that the daily maximum came in October.

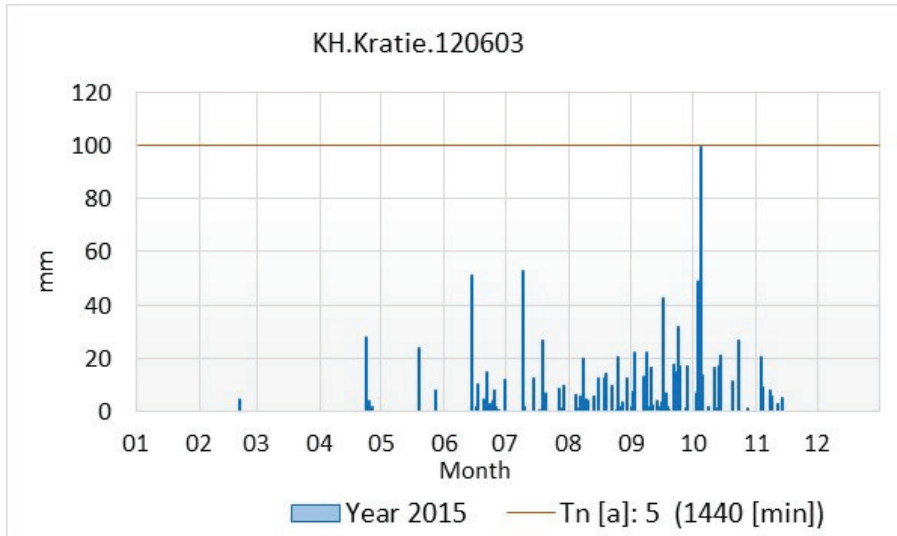


Figure 53: Daily rainfall for Kratie with a 5 year return period indicated as red line

Maximum intensities of precipitation are difficult to measure as they occur locally and are mostly very confined in terms of time and space. Ground stations observe maximum intensities only if the rain cell is located exactly above. The longer an observation station exists, the higher the chance that such a coincidence happens. If records are kept as daily sums, the inner-daily distribution is unknown and maximum intensities are levelled out. As a consequence, in terms of flash flood observation and prediction, techniques are required which allow for areal observation and records with a high temporal resolution.

Radar or satellite observations can provide both. In contrast to point measurements of ground stations, both techniques observe precipitation over an area and have the potential to generate a high temporal resolution. But as always, there is substantial effort needed to make full use of these techniques. The applications require calibration and that, in turn, requires ground stations. To arrive at predicting flash floods, additional tools are needed as flash floods follow a complex formation process. Flash floods arise due to high rainfall intensities, exceedance of infiltration capacity of the soil and conditions which favour fast runoff like steep slopes, impermeable surfaces, no plant canopy, etc. These factors are accounted for in the Flash Flood Guidance Systems (FFGS) which is in operation at MRC. The system is described in (MRC, 2014).

## **4. COUNTRY REPORTS**

### **4.1 Cambodia**

#### **4.1.1 Introduction**

The catchment of the Mekong River in Cambodia comprises 155,000 km<sup>2</sup> which is about 86% of the country's territory. The Mekong's discharge is subject to strong seasonal fluctuations. The ratio between peak and base-flow can be as high as 50:1. However, 2015 only showed ratios around 1:10. In Cambodia flood discharge may reach a magnitude of 60,000 m<sup>3</sup>/s, while low flow values of 1,000–1,500 m<sup>3</sup>/s can also be experienced.

The Great Lake on the Cambodian floodplain is the largest body of fresh water in Southeast Asia and forms one of the key features of the lowlands. The depth of the Great Lake increases from a dry season maximum of 3.6 m to more than 10 m and the water surface area increases from approximately 2,500-3,000 km<sup>2</sup> to 13,000 km<sup>2</sup>. The seasonal storage of water in the Great Lake also acts as a huge natural regulator for water flows downstream of the Tonle Sap-Mekong confluence at Phnom Penh. The Tonle Sap River reverses its flow direction when the water level in the Mekong River is high during the rainy season. This hydraulic connectivity is unique and is the main reason for the swelling of the Tonle Sap Lake. After the Mekong River water level recedes, the water drains from the Tonle Sap Lake.

Floods are commonly seen as a source of profit rather than a source of disaster. At the same time, flood vulnerable communities must prepare to face severe flooding in order to sustain and contribute to two vital sectors of the Cambodian economy: fishing and rice production.

#### **4.1.2 The flood season 2015**

##### **Availability of Data**

The data was collected from MOWRAM for the years 1985 to 2015 regarding rainfall and from 1991 to 2015 regarding hydrology. Data about effects and damages stem from the National Committee for Cambodia Disaster Management and cover the time period from 1996 to 2015. Additional data and information on floods and droughts were taken from journals, news and websites.

##### **Meteorological and hydrological conditions**

Rainfall in 2015 was predominantly lower than the average calculated with data from 2000 to 2015. Lowest values were observed at Pailin, located close to the border of Thailand and highest with over 4000 mm in Koh Kong located at the coast. Table 6 shows an overview of annual rainfall for Cambodia beginning with data from 2000.

Table 6: Annual rainfall for Cambodia from 2000-2015

No.	Station Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average 2000-2015
1	Battambang	1424	1141	1387	1058	994	1237	1219	1322	1390	1398	1332	1707	1339	1394	881	1095	1270
2	Bantey Meanchey	1489	1122	1297	998	1092	1209	1246	1273	1345	1050	1108	1476	1319	1471	619	857	1186
3	KompongCham	1506	1324	1133	1415	1183	1446	1591	1576	1503	1767	1208	1381	1694	1467	1322	1384	1431
4	KompongChhnang	1645	1310	1160	1114	1262	1349	1459	1759	1449	1651	1335	1929	1831	1583	1436	1210	1468
5	KompongThom	1755	1602	1484	1299	1206	1375	1945	1423	1677	1558	1419	2094	1395	1644	1174	4800	1741
6	KompongSpeu	1817	1723	937	883	950	1114	1178	1650	1444	1405	1215	1378	1444	1465	993	1052	1291
7	KohKong	3791	3359	2310	2953	3548	3661	5202	3860	4439	4771	3969	3073	4914	5253	5830	4466	4087
8	Kompot	2417	2309	1613	2225	1573	2079	2454	1879	1269	2240	1413	1949	1819	1999	1784	1569	1912
9	Kandal	1780	1430	1217	1066	910	1092	952	1095	1500	1180	1711	1248	1465	1318	1194	961	1257
10	Kratie	2155	1907	1829	1573	1619	1468	1663	1864	1565	1849	1392	1986	2278	1984	1697	1185	1751
11	Modulkiri							1537	1503	1108							1628	1444
12	PreyVeng	1782	1532	1378	1619	1152	1259	1188	1365	1692	1178	1887	1370	1772	1371	1674	1309	1470
13	Pochentong	2096	1599	1231	1257	1153	1386	1208	1374	1886	1456	1512	1555	1336	1420	1462	1065	1437
14	Pailin			633	1011	453	969	821	1134	1317	1330	1923	1076	1105	1464	844	961	1074
15	PrehVihear			1512	1470	1346	1452	1525	2035	1542	2070	1439	1947	1645	2051	1647	1429	1651
16	Pursat	1740	1297	1409	1485	1056	1252	1393	1496	1962	1156	1360	1488	1640	1584	1285	1226	1427
17	Ratanakiri			1826	2291	2126	2500	2792	1659	1411	1356	759	1947	2502	2630	1919	1818	1967
18	Stung Treng	2652	1872	1433	1469	1491	1389	1597	1776	1778	1698	1159	2318	1783	2241	2359	1401	1776
19	SvayRieng	2206	1568	1578	1603	1379	1712	1616	1603	1440	1476	1980	1879	1731	1467	1430	1370	1627
20	SiemReap	1637	1753	1141	1271	1610	1496	1415	1356	1716	1480	1301	1686	1466	1861	1490	1249	1495
21	SihanoukVile	3399	3397	3187	2833	3353	2956	4065	3314	2893	2307	2176	2347	2758	2682	2726	2504	2931
22	Takeo	1553	1597	1283	1384	1016	1202	1135	1501	1017	1017	1428	1487	1370	1258	1383	1284	1307
23	Odor Meanchey											1321	1190	1231	1696	1360	1096	1316
	Minimum (mm)	1424	1122	633	883	453	969	821	1095	1017	1017	759	1076	1105	1258	619	857	1074
	Average (mm)	2047	1769	1475	1537	1451	1600	1793	1720	1715	1659	1561	1751	1811	1877	1659	1605	1666
	Maximum (mm)	3791	3397	3187	2953	3548	3661	5202	3860	4439	4771	3969	3073	4914	5253	5830	4800	4087

**Flood hydrology of 2015**

The flood season during 2015 started late end of June. This is about 1.5 months later than normal. Drought conditions prevailed and caused water shortages for agricultural, livestock water supply and partly for domestic use.

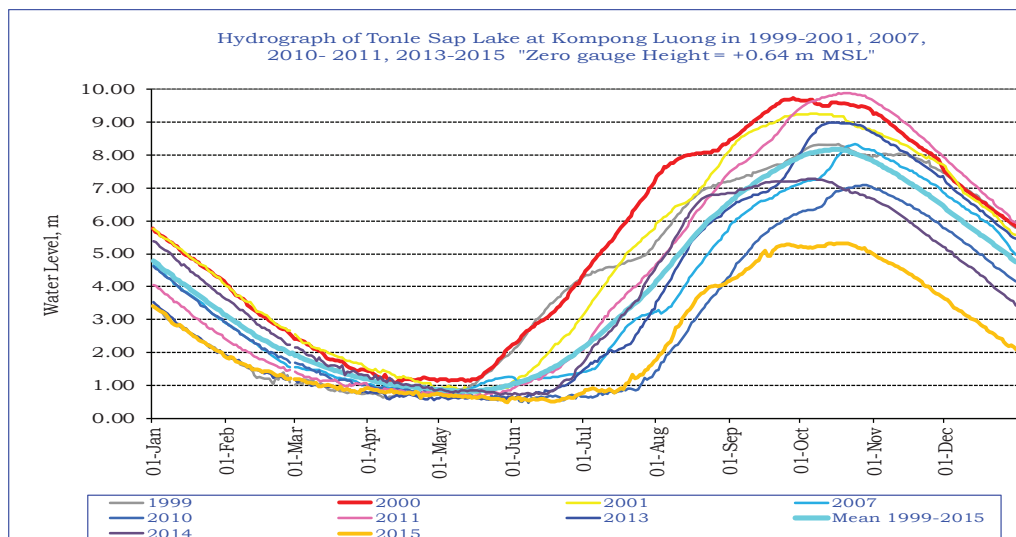


Figure 54: Hydrograph of Tonle Sap Lake at Kampong Luong in 1999-2001, 2007, 2010-2011, 2013-2015

The highest water levels observed in 2015 on the mainstream station were below the long-term average of the maximum.

Table 7: Water levels in 2015 compared to long term average of annual maximum in Cambodia at selected stations.

Station name	River name	Period of Record	Annual maximum water level, m		
			Historical average, m	2015, m	2015 as % long term average
Stung Treng	Mekong	1991-2014	10.53	8.41	80
Kratie	Mekong	1991-2014	21.34	18.21	85
Kompong Cham	Mekong	1991-2014	15.02	12.16	81
Chaktomuk	Bassac	1991-2014	9.86	7.09	71.9
Neak Loeung	Mekong	1991-2014	7.14	5.06	71
Koh Khel	Bassac	1991-2014	7.40	6.21	84
Prek Kdam	Tonle Sap	1991-2014	8.93	6.02	67

#### 4.1.3 Impact of floods 2015

An overview of the situation in 2015 is given in Figure 55

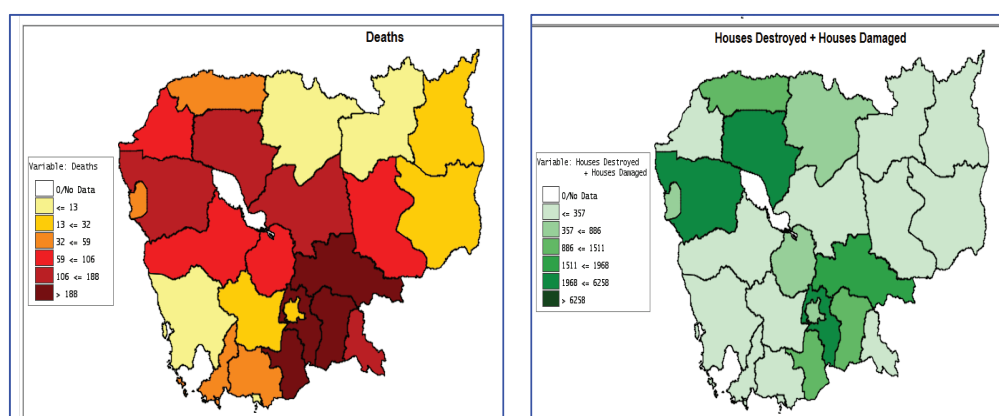


Figure 55: Number and distribution of fatalities and damages in 2015 due to flood (source: [www.camdi.ncdm.gov.kh](http://www.camdi.ncdm.gov.kh))

A compilation of disasters and their impacts is provided in Table 8.

Table 8: Impacts of floods and droughts compiled for Cambodia from 1996 to 2015

Year	Disasters	Affected/ Damages
1996	Severe flood	In the 1996 floods, continuous heavy rainfall caused inundation affecting 1.3 million Cambodians with 600,000 hectares of crops and 50,000 homes damaged or destroyed, 13 provinces were affected.
1999	Flood and Typhoon	37,527 people in 10 provinces were affected, 17,732ha of rice crop and 491 houses were destroyed
2000	Severe flood	3,448,629 people were affected, 768 houses were damaged and 347 deaths occurred
2001	Severe flood	429,698 families, equivalent to 2,121,952 people were affected. People killed: 62 (70% were children), houses destroyed: 2,251
2002	Flood and Drought	<b>Drought:</b> People affected: 442,419 families (2,017,340 individuals), <b>Flood:</b> People affected: 1,439,964 , 1,082 houses destroyed, deaths: 29
2009	Typhoon Ketsana	14 provinces affected, 43 deaths, 67 severely injured, destroyed homes and livelihoods of some 49,000 families or 180,000 people, the equivalent of 14 percent, and 80% of total land area.

Year	Disasters	Affected/ Damages
2010	Flash flood	14 provinces affected, 22,746 families affected, 6,301 houses affected, 86 houses damaged, 11 deaths, 7 injured, 272 schools affected, affected nurseries: 77,629 ha and crop damages across 6,942 ha
2011	Severe flood	18 provinces affected, 354,217 families affected, 268,631 houses affected, 1,297 houses damaged, 250 deaths, 23 injured, 1,360 schools affected, 491 pagodas, 115 health centers, seeding 431,476 ha, crops 21,929 ha, national roads 956,638m, laterite roads 5,594,119 m, ..etc.
2012	Flash flood	7 provinces affected, 23,691 families affected, 22,863 houses affected, 2 houses damaged, 27 deaths, 122 schools affected, 7 pagodas, 4 health centers, seeding 57,432 ha, crops 3,585 ha, laterite roads 25,4287 m, ..etc.
2013	Severe flood	20 provinces affected, 377,354 families affected, 240,195 houses affected, 455 houses damaged, 168 deaths, 29 injured, 1,254 schools affected, 533 pagodas, 92 health centers, seeding 37,847 ha, crops 81,244 ha, national roads 440,572 m, laterite roads 3,569,779 m, ..etc.
2014	Flash flood	13 provinces affected, 165,516 families affected, 87,333 houses affected, 185 houses damaged, 49 deaths, 4 injured, 397 schools affected, 154 pagodas, 32 health centers, seeding 77,325 ha, crops 10,077 ha, national roads 96,036 m, laterite roads 973,249 m, ..etc.
2015	Flash flood/ Drought	7 provinces affected, 789 families affected, 6,963 houses affected, 7 houses damaged, 1 death, 1 injured, affected seeding 3,707 ha, crops 7,943 ha

In 2015, the following 7 provinces faced flash floods: Kampot, Ket, Koh Kong, Preah Sihanouk, Pailin, Battambang and Banteay Meanchey.

#### 4.1.4 Flood management and response

The National Committee for Disaster Management (NCDM), which was established in 1995, is the entity responsible for emergency preparedness and response. The Ministry of Water Resources and Meteorology (MOWRAM) assumes responsibility for hydro-meteorological observation, data management and forecasts and early warning. MOWRAM issues flood and weather warnings through mass media for local authorities, line agencies, NGOs and related users. The National Committee for Disaster Management uses this information for early warning at community level.

#### 4.1.5 Lessons learnt and recommendations

Establishment of systematic flood preparedness planning processes at provincial, district and commune level is still a challenge. Understanding of flood information is limited, worsened by a lack of coordination between institutions and agencies concerned. Damages due to flash floods were estimated as being more serious than riverine floods caused by mainstream Mekong flood during the last 5 years. Data management still lacks support and needs improvement.

Land-use planning is considered as a major topic in flood risk reduction in combination with proper design codes coping with increased flood risk and climate change adaption for infrastructure development such as national and rural roads, bridges, culverts etc.

## **4.3 Lao PDR**

### **4.3.1 Introduction**

The most severe floods in 2015 were caused by two major tropical storms, namely Vamco and Kujira. In the wake of these typhoons, floods, flash floods and landslides occurred. Twelve provinces across the country were affected by these natural disasters, according to the Department of Disaster Management and Climate Change (DDMCC).

### **4.3.2 The flood season 2015**

#### **Availability of Data**

The Department of Meteorology and Hydrology provided hydro-meteorological data, flood damage and impact data were collected from the Department of Climate Change Management.

#### **Meteorological and hydrological conditions**

The climate characteristics of Lao PDR are dominated by tropical monsoons with alternating wet and dry seasons. The dry season (northeast monsoon) starts from mid-October to mid-May when atmospheric pressure is high. It is a dry period with low humidity and temperature. The temperature is lowest in December - January and highest in April. The rainy season (southwest monsoon) starts from mid-May to mid-October. It is a period of frequent and heavy rain with high humidity.

In 2015, Lao PDR was influenced by the El Nino phenomena resulting in the weather conditions below:

- The onset of the monsoon in Lao PDR started later than normal from north to central parts, while in the southern part it began and ended on average.
- The annual rainfall of the year 2015 was mostly below normal
- Two tropical cyclones impacted Lao, VAMCO number 19 (1519) and KUJIAR number 8 (1508)
- From mid-July to the end of September, a trough associated with strong southwest monsoon prevailed in northern and central parts of Lao PDR and brought heavy rainfall causing flash floods, landslides and river floods.

#### **Flood hydrology of 2015**

The water level in mainstream Mekong and its tributaries were mostly low until the third week of July. In contrast, Xebangfai River and some small tributaries in the centre and north of Lao received rain with the consequence of some local flood incidents. Provinces affected in 2015 are shown in Figure 56.

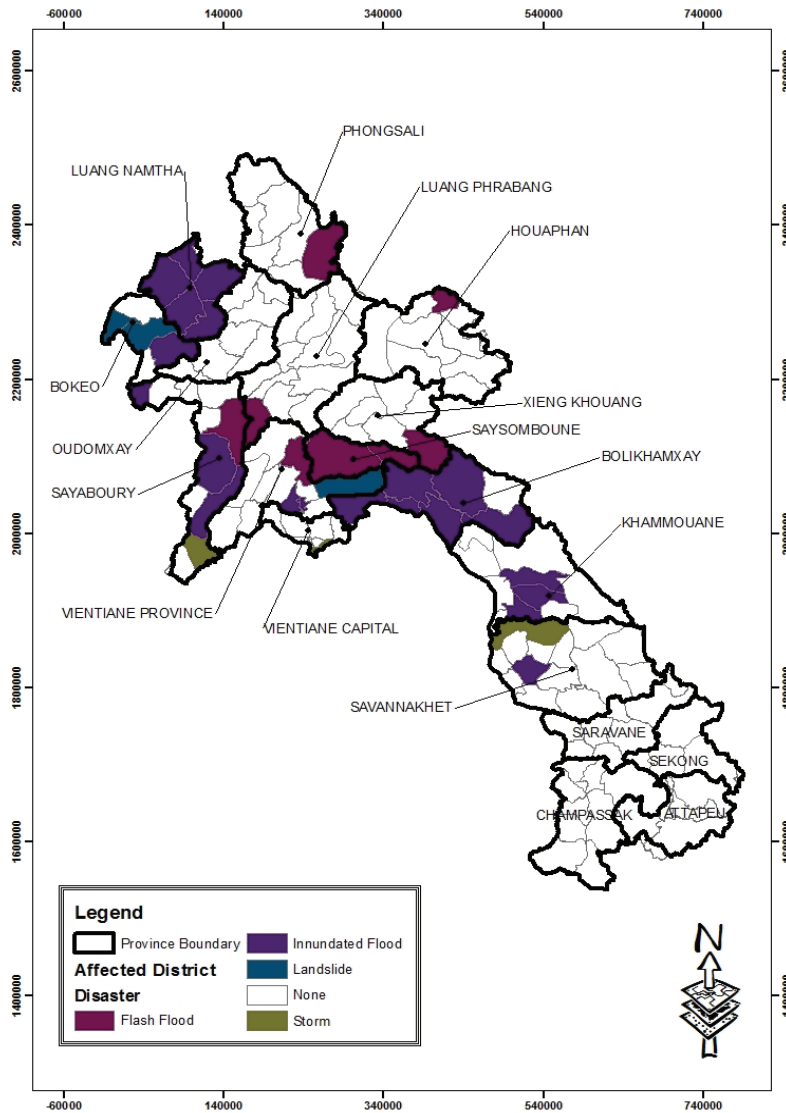


Figure 56: Affected provinces by flood events in Lao PDR 2015

Observations indicate that provinces such as Bokeo, Luangnamtha, Oudomxay and Xayabouli faced torrential rainfall with approximately 120 mm to 200 mm within three hours on 24th July 2015.

Table 9: Daily rainfall (mm) in 5 days (June 19 to 24, 2015), Lao PDR (source: Department of Meteorology and Hydrology, 2015)

Station Name	19/06	20/06	21/06	22/06	23/06	24/06
Viengsay	06.1	0	02.6	05.5	87.0	54.6
Samneua	01.3	0	00.6	00.5	22.3	20.2
Xiengkhuang	05.4	26.6	13.4	21.9	0	00.1
Pakse	01.2	42.2	24.0	04.0	08.0	08.7
Paksong	37.9	38.7	102.7	41.9	39.9	31.6
Nikhom 34	54.4	13.4	34.2	56.3	08.2	03.7
Salavanh	10.0	90.0	110.0	64.5	08.9	06.0

Station Name	19/06	20/06	21/06	22/06	23/06	24/06
Sekong	28.4	66.3	65.8	09.2	04.5	0
Thateng	34.2	34.5	52.2	0	06.5	2.1

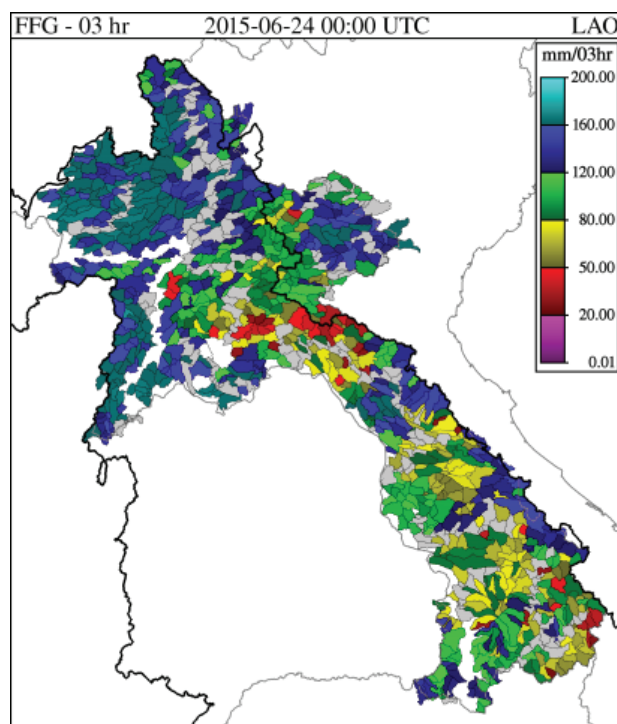


Figure 57: Rainfall intensity on June 24, 2015, source: <http://ffw.mrcmekong.org>

The typhoon VAMCO number 19 (1519) hit Lao PDR directly. VAMCO brought strong winds and moderate to heavy rainfall over central and southern Lao, caused flash floods and landslides in some areas. The Flash Flood Guidance System of MRCS indicated heavy rainfall in central and southern parts of Lao PDR with around 30 millimetres to 180 millimetres per day, for example on September 15, 2015.

#### Flood hydrology of 2015

In 2015, no warning levels were reached at the stations in Lao.

Table 10: Peak water and warning levels along Mekong River in 2015, Lao PDR

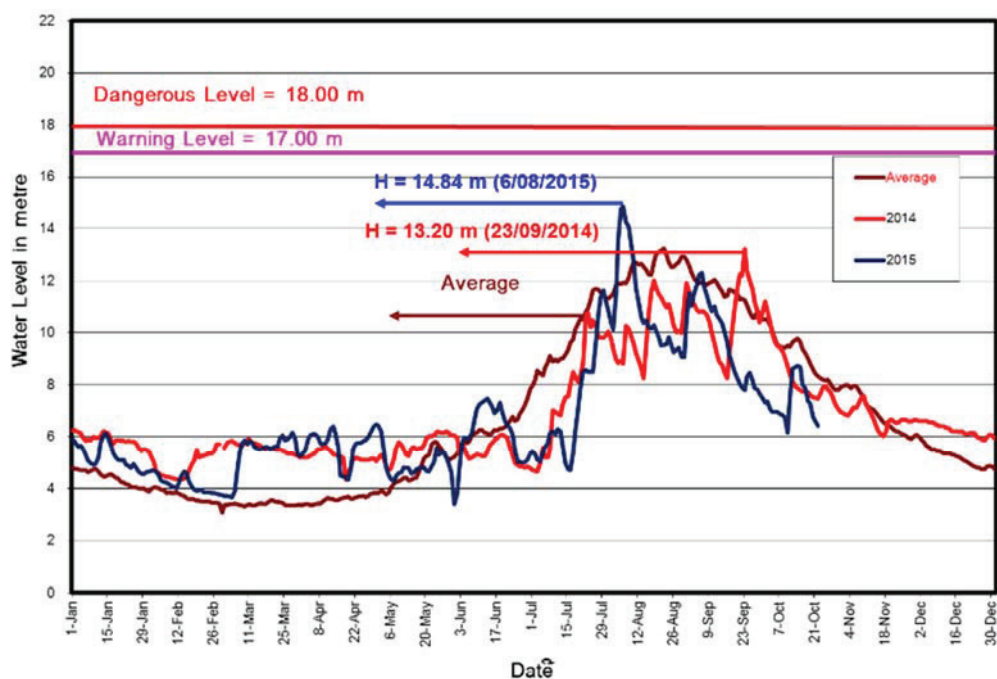
No	Name of station	Warning Level (m)	Dangerous Level (m)	Peak Water Level in 2015 (m)	Lowest Water Level in 2015 (m)	Remark
1	Mekong at Hiouisai	16.50	17.50	8.62 (05/08/15)	1.14 (13/05/15)	
2	Mekong at Pakbeng	29.00	30.00	24.64 (06/08/15)	1.15 (9/03/15)	
3	Mekong at Luangprabang	17.50	18.50	14.84 (06/08/15)	3.66 (05/03/15)	
4	Mekong at Paklay	15.00	16.00	11.92 (07/08/15)	0.01 (25/02/15)	

No	Name of station	Warning Level (m)	Dangerous Level (m)	Peak Water Level in 2015 (m)	Lowest Water Level in 2015 (m)	Remark
5	Mekong at Vientiane	11.50	12.50	10.20 (07/08/15)	-0.73(7/03/15)	
6	Mekong at Paksane	13.50	14.50	12.88 (08/08/15)	2.80 (10/03/15)	
7	Mekong at Thakhek	13.00	14.00	12.14 (05/08/15)	2.47 (11/03/15)	
8	Mekong at Savannakhet	12.00	13.00	9.85 (06/08/15)	-0.42 (21/02/15)	
9	Mekong at Pakse	11.00	12.00	9.88 (12/08/14)	1.07 (14/03/15)	

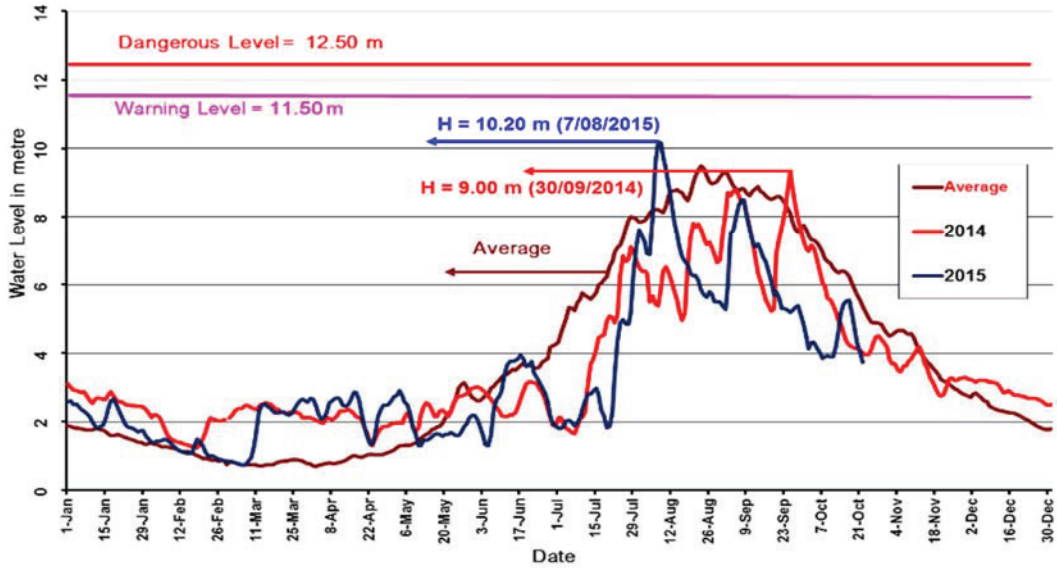
Source: Hydrology Division, Department of Meteorology and Hydrology, 2015

Time series of water levels at selected stations are illustrated below.

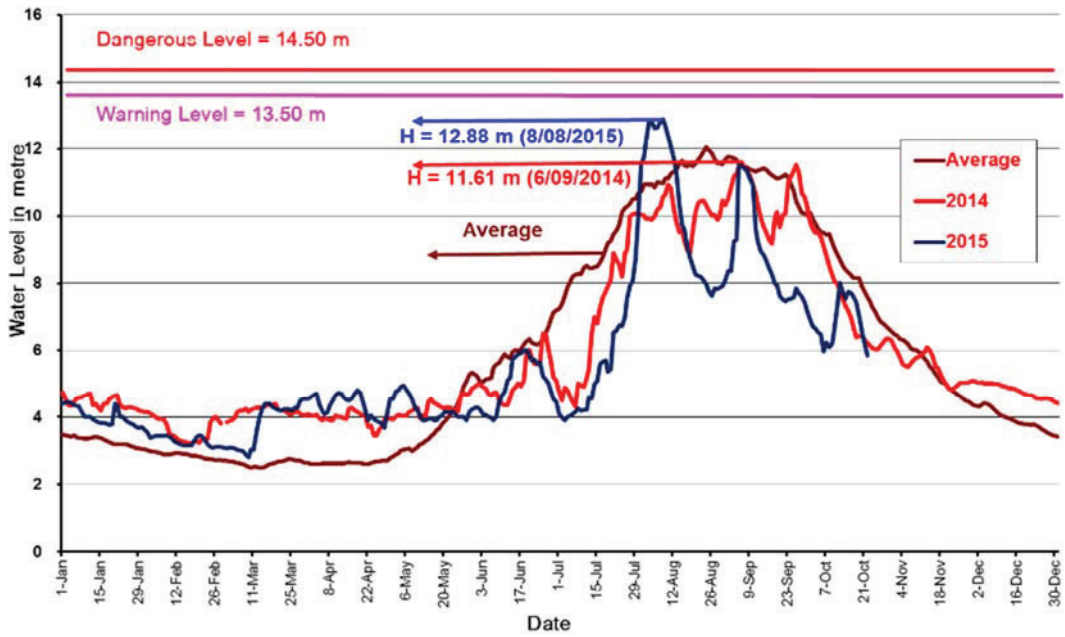
Mekong Water Level at Luangprabang Station



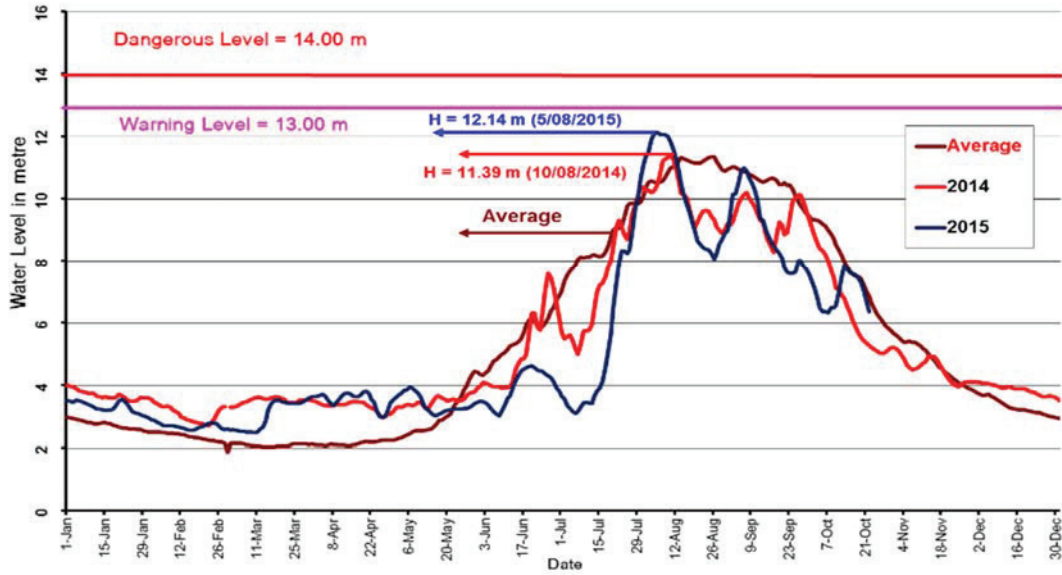
Mekong Water Level at Vientiane Station



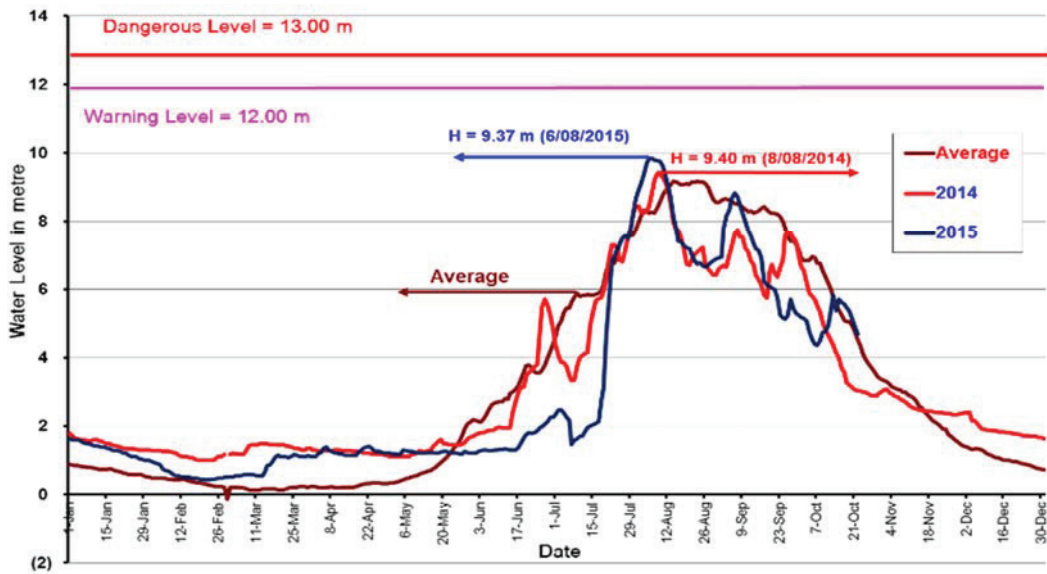
Mekong Water Level at Paksane Station



Mekong Water Level at Thakhek Station



Mekong Water Level at Savannakhet Station



Mekong Water Level at Pakse Station

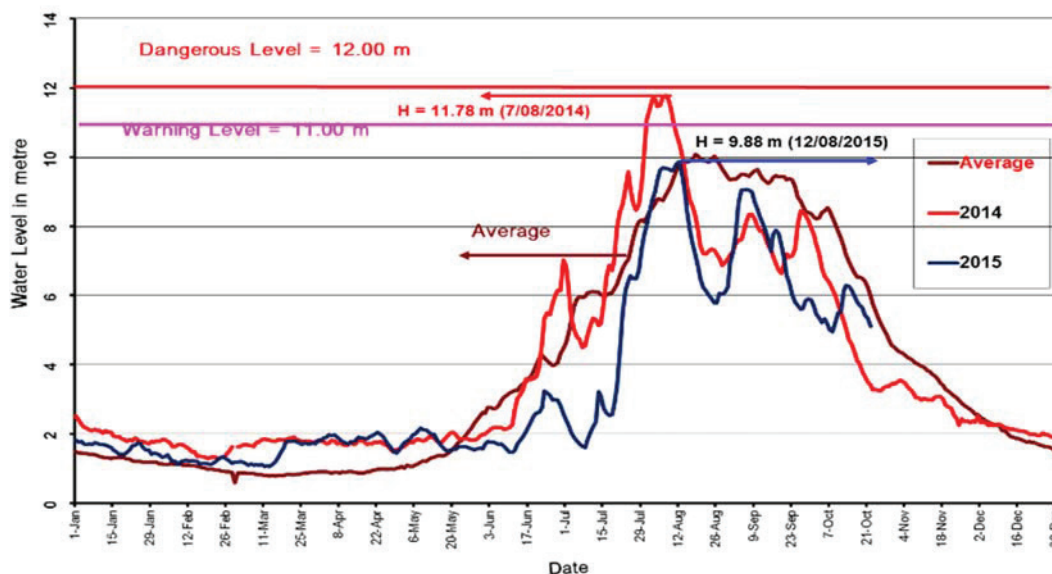


Figure 58: Water levels along the Mekong River in Lao PDR (source: Department of Meteorology and Hydrology, 2015)

In contrast to mainstream Mekong, tributaries illustrated below reached peak water levels that reached or exceeded warning or even dangerous levels. The floods occurred in early August and early September.

Table 11: Peak water level and warning levels in tributaries in 2015, Lao PDR

No	Name of Station	Warning Level (m)	Dangerous Level (m)	Peak Water Level in 2015 (m)	Lowest Water Level in 2015 (m)	Remark
1	Nam Ou at M. Ngoy	16.50	17.50	8.70 (31/08/15)	0.19 (24/03/2015)	
2	Nam Khan at Xiengngeun	11.00	10.00	-1.94 (4/09/15)	-0.14 (3-7/07/2015)	
3	Nam Song at Vangvieng	3.50	4.50	4.04 (4/08/15)	-0.55 (23/03/2015)	Flood
4	Nam Lik at Hineheup	14.00	15.00	9.80 (4/08/15)	1.62 (10/04/2015)	
5	Nam Sane at Bolikhane	7.00	8.00	10.15 (4/08/15)	-1.67 (9/05/2015)	Flood
6	Nam Ngiep at M. Mai	11.00	12.00	11.20 (4/08/15)	1.57 (12/05/2015)	Flood
7	Nam Ngum at Thalat	16.00	17.00	11.69 (5/08/15)	5.86 (29/03/2015)	
8	Nam Ngum at Pakkagnoung	11.00	12.00	9.44 (6/09/15)	3.50 (9/01/2015)	
9	Nam Ngum at Veunekham	12.00	13.00	10.62 (5/08/15)	2.34 (6/04/2015)	
10	Nam Kading at Ban Phonesi	13.75	14.75	12.40 (29/07/15)	1.08 (9/03/15)	

No	Name of Station	Warning Level (m)	Dangerous Level (m)	Peak Water Level in 2015 (m)	Lowest Water Level in 2015 (m)	Remark
11	Sebangfai at Mahaxay	14.00	15.00	14.98 (23/07/15)	2.12 (5/01/2015)	Flood
12	Sebangfai at M. Sebangfai	17.50	18.50	19.38 (4/09/15)	6.87 (5/02/2015)	Flood
14	Sechamphone at Kengkok	7.50	8.50	8.07 (4/09/15)	0.42 (4/55/2015)	Flood
15	Sebanghieng at Sepone	16.00	17.00	12.83 (6/99/15)	2.21 (5/05/2015)	
16	Sebanghieng at Kengdone	14.00	15.00	11.50(03/09/15)	0.52 (1/05/15)	
17	Sedone at Slavane	10.50	11.50	8.41 (15/09/15)	1.72 (19/06/2015)	
18	Sedone at Khongsedone	12.30	13.30	8.24 (16/09/15)	1.08 (17/06/2015)	
19	Sekong at Sekong	16.00	17.00	7.30 (15/09/15)	1.52 (15/03/2015)	
20	Sekong at Attapeu	15.00	16.00	10.04 (16/09/15)	35.68 (9/06/2015)	

Source: Hydrology Division, Department of Meteorology and Hydrology, 2015

Flash floods were reported in the northern and central parts (Oudomxay, Xayabouly, Luangprabang, Vientiane, Xiengkhuang and Bolikhamxay provinces), while the southern part was affected by riverine floods (Khammuane, Savannakhet provinces).



### 4.3.3 Impact of floods 2015

No serious damages due to river floods along the Mekong River were reported in 2015, instead, a number of flash floods occurred. These events affected 38 districts, 696 villages, 27,311 households and 92,165 people, agricultural areas, infrastructure and resulted in five fatalities. The total cost was estimated at USD 48 million.

Heavy rains with hail and strong winds occurred in Vientiane’s Hadsaiyong district on 18 Feb 2015, damaging hundreds of buildings. The storm began early morning at around 5am and lasted for approximately 30 minutes leaving minor injuries and hundreds of houses and buildings without roofs or power. Over 563 households in a total of 13 villages were affected by heavy rain, hail stones and wind. The villages of Somsanouk, Salakham, Bo-O, Dongphonlao, Donkhasay, Nongvaeng, Dondou and Dongkhamxang were hardest hit. Educational institutions including Bo-O lower secondary school and Salakham primary and secondary schools also suffered damages. The rain and wind uprooted trees and cut off power supply lines and caused traffic difficulties.



Figure 59: Flood Damage in Hadsaiyong district, Vientiane Capital (source: Department of Disaster Management and Climate Change, 2015)

Table 12: Estimated socio-economic impacts in Vientiane

No.	Affected	Quantity	Amount (LAK)	Remarks
1	25 villages	1483 households	3,315,100,000	
2	7 public schools	11 buildings	937,000,000	3 schools damaged
3	Hospitals	2	3,000,000	
4	Companies, factories and markets	11 units	10,560,880,000	

No.	Affected	Quantity	Amount (LAK)	Remarks
5	Agriculture	200 households	433,622,436	
6	Farms	32	1,963,000,000	
7	Electricity system		500,000,000	
8	Temples	8	122,500,000	
	<b>Total</b>		<b>17,835,102,436</b>	

Source: Department of Disaster Management and Climate Change, 2015

On Monday June 15, 2015, there was heavy rain over 3 villages (Kengsao, Takdath and Buamlao village) in the Paklay and Kenethao districts, Xayabouly Province. The damage is estimated to reach up to 229,620,000 kips or 28,700 US dollars. Another incident was reported in Huaphan district, with costs of around 17,253,709,750 kips or 2,156,714 US dollars.



Figure 60: Flood Damage in Kenethao district, Xayabouly Province (source: Department of Disaster Management and Climate Change, 2015)



Figure 61: Flood in Khammouan Province (source: Department of Disaster Management and Climate Change, 2015)



Figure 62: Flood and landslides in Savannakhet (left) and Vientiane Province (20 Jul 15) (right) (source: Department of Disaster Management and Climate Change, 2015)



Figure 63: Flood and landslide in Bolikhamxay Province (22 and 30 Jul 15) (source: Department of Disaster Management and Climate Change, 2015)



Figure 64: Flash flood in Bokeo Province (left) and Luangnamtha Province (3 Aug 15) (right) (source: Department of Disaster Management and Climate Change, 2015)

Table 13: Summary of flood damages in Lao PDR, 2015

Provinces affected	12 provinces: Xayabouly, Bokeo, Louangnamtha, Huaphan, Xiengkhuang Louangphabang, Vientiane Province, Vientiane Capital, Borikhamxay, Khamnouan, Savannakhet, Phongsaly
The most seriously affected provinces	Bokeo
Districts affected	30
Villages affected	203
People killed	4
Households affected	8197
People affected	79938
Agriculture	
Hectares of rice paddy fields affected	22649.28 ha
Hectares of upland rice and crop damaged	3760.7 ha
Livestock	
Cattle and poultry	1770 heads lost; 132 (cattle) and 1638 (poultry)
Infrastructure	
Houses affected	29 sites
Schools affected	5 sites
Health Care Centers affected	10 sites
Roads affected	113 sites
Weirs damaged	56 sites
<b>Total damages</b>	<b>426,000,000,000 Kips or 53,250,000 US Dollars</b>

#### **4.3.4 Flood management and response**

The Government of Lao PDR coordinates disaster preparedness and response activities through two key entities: the National Disaster Management Committee (NDMC) chaired by the Vice Prime Minister and the Department of Disaster Management and Climate Change (DDMCC) within the Ministry of Natural Resources and Environment (MoNRE), which also acts as secretariat to the NDMC. Disaster management committees are established to inform and implement preparedness, assessment, and response efforts of the Government at the provincial, district levels and Village Disaster Management Committees (VDMCs) at the village level.

The DDMCC has a key communication role in reporting disaster situations, planned emergency responses and recovery activities to line ministries, including through the NDMC. In coordination with the Department of Meteorology and Hydrology (DMH), it is responsible for disseminating early warning information to the Provincial Disaster Management Committees (PDMCs). The DDMCC is responsible for providing technical and capacity building support to provinces and districts.

The Department of Meteorology and Hydrology (DMH), located within MoNRE, is responsible for weather related early warning information, including weather forecasts, precipitation levels and flood risk. During the wet season, daily updates are issued to DDMCC, via email, fax or phone.

#### **4.3.5 Lessons learnt and recommendations**

There are some lessons learnt such as:

- In Laos, radio and internet (Facebook) seem to be the most powerful tool for informing the public about weather, flood forecasts and weather/flood warnings.
- The timely dissemination of forecasts and warnings provided by DMH was very helpful
- Information about floods and related impacts should be improved at local level
- The MRC Flash Flood Forecast guidance turned out to be very useful for Lao

It would be desirable for the disaster management committee to engage more in capacity building with the focus on local communities in flash flood preparedness, emergency response, and flood damage data collection techniques. These skills will help decision makers or relevant parties to better plan and respond to floods in the future.

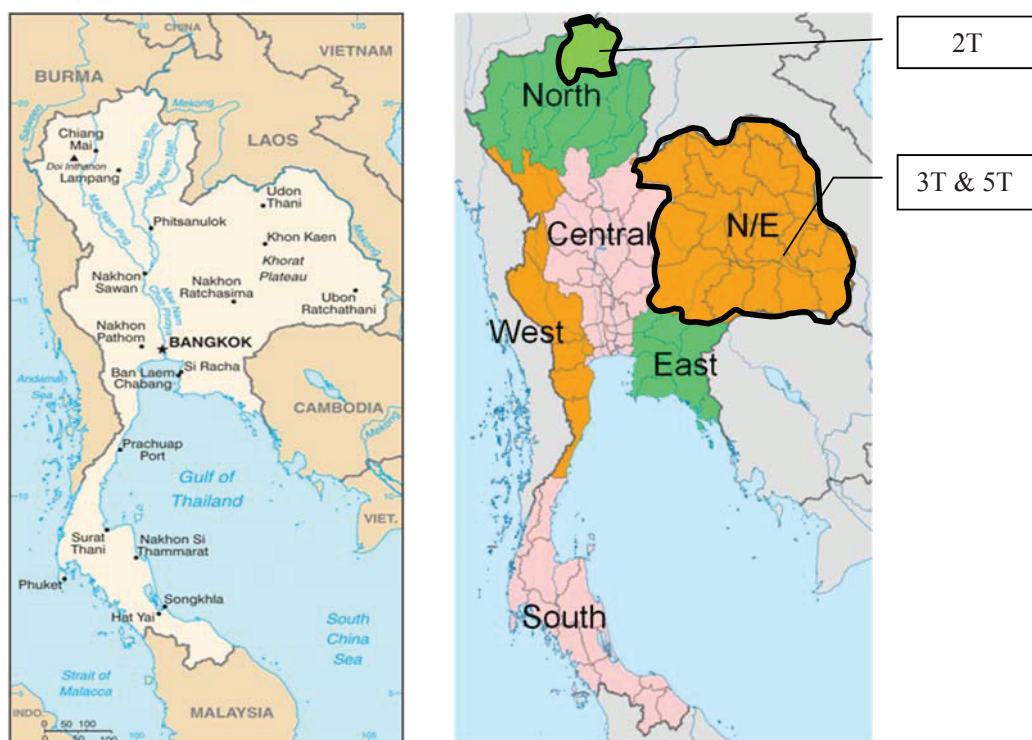
The flood forecasting system should be improved. It is regarded as beneficial to link the national early warning system with regional systems to ensure effective early warning, preparedness and emergency response.

## 4.4 Thailand

### 4.4.1 Introduction

Thailand is located in the tropical area between latitudes 5° 37' N to 20° 27' N and longitudes 97° 22' E to 105° 37' E. The total area is 513,115 square kilometres. The boundaries of Thailand with adjacent countries are: North: Myanmar and Laos. East: Laos, Cambodia and the Gulf of Thailand. South: Malaysia. West: Myanmar and the Andaman Sea.

According to the climate pattern and meteorological conditions, Thailand can be divided into 5 parts of which two belong to the Lower Mekong Basin.



Northern Part (Only Chiang Rai province located in 2T MRC-Sub basin)

This part is divided into 15 provinces i.e. Chiang Rai, Mae Hong Son, Chiang Mai, Phayao, Lamphun, Lampang, Phrae, Nan, Uttaradit, Phitsanulok, Sukhothai, Tak, Phichit, Kamphaeng Phet and Phetchabun. Most areas are hilly and mountainous and are the source of several important rivers. The highest mountain, about 2,595 meters above mean sea level, is Doi Inthanon in Chiang Mai.

Northeastern Part (3T&5T MRC-Sub basin)

This region is a natural high level plain called northeast plateau. The northwest to southeast oriented Phu Phan ridge in the north-eastern portion separates this part into two basins. One is a large high level plain in the west. The other is smaller and drains towards the east. This part is divided into 20 provinces i.e. Nong Khai, Bung Karn, Loei, Udon Thani, Nong Bua Lam Phu, Nakhon Phanom, Sakon Nakhon, Mukdahan, Khon Kaen, Kalasin, MahaSarakham, Roi Et, Chaiyaphum, Yasothon, Amnat Charoen, Ubon Ratchathani, Sri Sa Ket, Nakhon Ratchasima, Buri Ram and Surin.

The climate of Thailand is under the influence of monsoon winds of seasonal character i.e. southwest monsoon and northeast monsoon. The southwest monsoon which starts in May brings a stream of warm moist air from the Indian Ocean towards Thailand causing abundant rain over the country, especially on the windward side of the mountains.

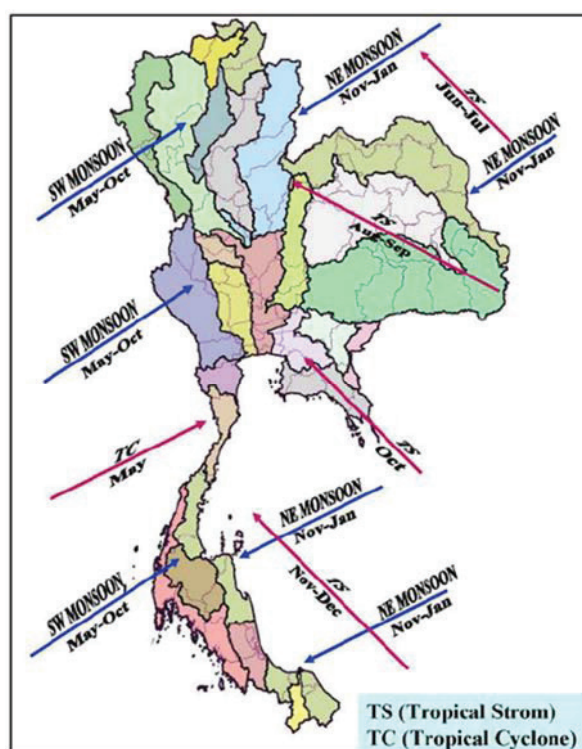


Figure 65: Prevailing meteorological conditions in Thailand (source: Thai Meteorological Department, 2015)

#### 4.4.2 The flood season 2015

##### Availability of data

Data was collected in six groups to identify the causes of floods, flood areas and flooded damages, consisting of; (1) Storm track hit into Thailand, (2) Satellite images to show the clouds from the influence of the storm, (3) Weather map, (4) Pressure and rainfall map, (5) Flooded image from satellite monitoring and (6) Spatial data and photos to show flooded areas.

##### Meteorological and hydrological conditions

In 2015, the majority of Thailand was much warmer and drier than usual. Annual rainfall averaged over the country was approximately 1,400 mm which is roughly 11% below the 1981-2010 normal. During early rainy season due to a combination of the absence of the monsoon trough influences and El Nino episode, unusually dry and warm conditions occurred in Thailand. The annual mean temperature of 27.9 °C, 0.8 °C above normal, was the second warmest year in Thailand based on records from 65 years. The warmest year until then was 1998. The mean temperature was above normal for all months, especially December and November, which were 2.1 and 1.9

°C above normal, respectively. The maximum temperature reached the new highest record in several areas. Besides, there was only one tropical cyclone namely “VAMCO” that moved into north-eastern Thailand at Ubon Ratchathani province on 15 September 2015.

Abundant rainfall and flash floods in some areas of central, eastern and southern Thailand arose due to tropical storm “VAMCO” which moved to Thailand as a tropical depression at Khong Chiam, Ubon Ratchathani province in the morning of 15 September 2015 before moving further to Myanmar and the Gulf of Bengal on 18 September. Monthly rainfall in July and September was 5% and 4% above normal respectively. The highest daily rainfall of 2015 was 300.3 mm at Rattanawapi district in Nong Khai province on 28 July 2015.

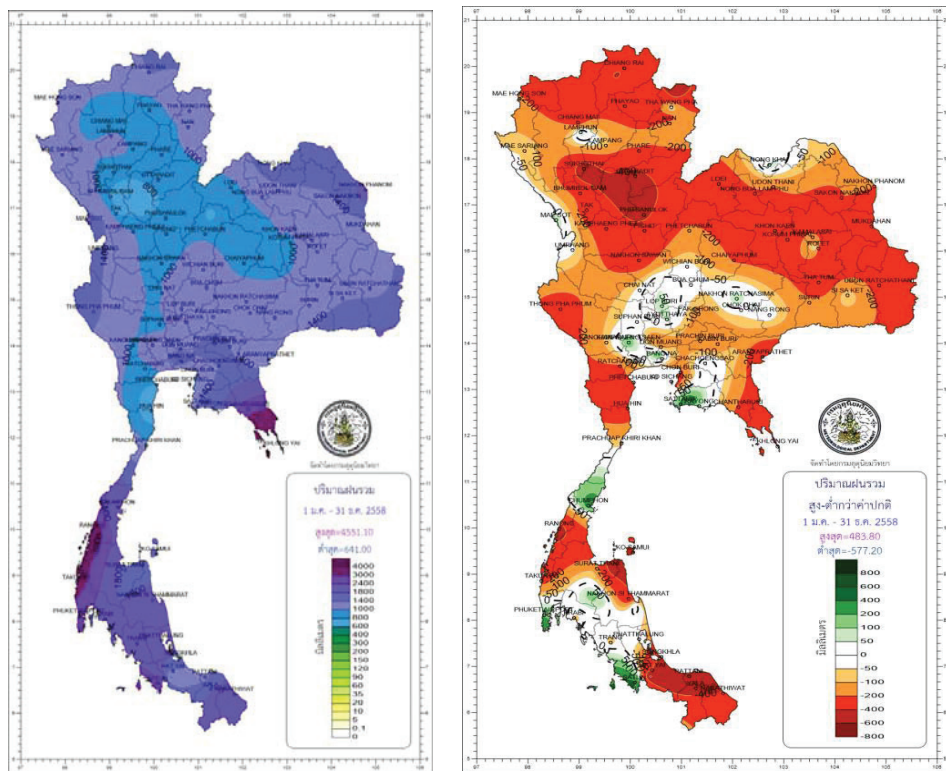


Figure 66: Annual Rainfall (mm) and Annual Rainfall anomalies (mm) in 2015 in Thailand (source: Thai Meteorological Department, 2017)

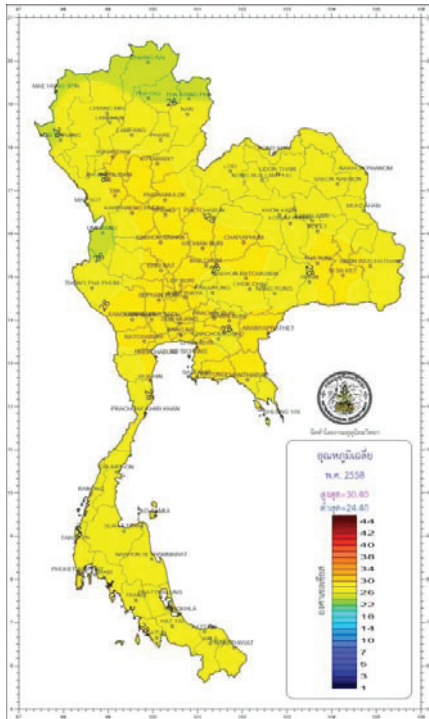


Figure 67: Annual 2015 temperature (°C) in 2015 in Thailand (source: Thai Meteorological Department, 2017)

#### 4.4.3 Impact of floods 2015

Floods impacted 11 provinces, 56 districts, 242 sub-districts and 1,654 villages. The number of people affected is estimated at 35,982 households and 81,811 persons. Moreover, the flood situation affected infrastructure including roads, bridges, drainage systems, building, schools and temples. The preliminary cost was estimated at 40.5 million Baht (1.158 million USD).



Flood area in NakornRatchasima



Flood area in NakornRatchasima



Flood area in NakornRatchasima



Flood area in NakornRatchasima

Flood area in NakornRatchasima

Flood area in NakornRatchasima

Figure 68: Flood in Nakorn Ratchasima province on September 2015 caused by tropical storm VAMCO (source: Tipaporn Homdee, 2017)

Table 14: Summary of flood damages in Thailand, 2015

Description	Damages	Unit
Affected villages	1,654.00	village
Affected people	81,811.00	person
Affected families	35,982.00	household
Evacuated victims	3.00	person
Evacuated families	-	household
Fatalities	3.00	person
Missing	-	person
Wounded	-	person
Houses (totals)	-	each
Houses (partial)	97.00	each
Commercial buildings	-	each
Industrial buildings	-	each
Hotels	-	each
Livestock	50.00	each
Poultry	500.00	each
Stalls	-	each
Motorcycles	-	each
Cars	-	each
Agricultural buildings	-	each
Fishing boats	-	each
Fishery ponds	95.00	each
Rice	103,776.00	rai
Plants	271.00	rai
Vegetation	2,164.00	rai
Total agriculture affected	106,211.00	rai
Roads	199.00	line
Bridges	18.00	each
Dams	-	each
Weirs	13.00	each
Mining	-	each
Temples	1.00	each
Schools	-	each
Hospitals	-	each
Government buildings	1.00	each
Dikes	7.00	each
Water resources	-	each
Drainage pipes	12.00	each
<b>Estimated damages</b>	<b>40,531,483.00</b>	<b>Thai Baht</b>
<b>Estimated damages</b>	<b>1,158,043.00</b>	<b>USD</b>

Remarks; 1 USD = 35 Thai Baht  
1 ha = 6.25 rai. (Area in Thai unit)

#### **4.4.4 Flood management and response**

In response to the 2011 flood, the Royal Thai Government drafted a Master Plan on flood management, after which it established the National Water Resources and Flood Policy Committee (NWFPC) and the Water and Flood Management Commission (WFMC). These bodies formulate policies, approve investment projects and monitor implementation and evaluate projects. Besides these national committees, there are three major ministerial departments involved in flood management:

- The Royal Irrigation Department (RID), under the Ministry of Agriculture and Cooperatives, plays a significant role in constructing and maintaining waterways and flood protection systems.
- The Department of Disaster Prevention and Mitigation, Ministry of Interior, is responsible for the coordination during disasters and recovery management.
- The Department of Water Resources (DWR), Ministry of Environment and National Resources, monitors flood mitigation in the 25 river basins.

In terms of flood management, Thailand still has many agencies to respond. The government has designated the Ministry of Interior by the Department of Disaster Prevention and Mitigation to collaborate and coordinate with the provincial office, Bangkok Metropolitan Authority and the Military to support proactive flood emergency response and provide all-inclusive victim assistance.

#### **4.4.5 Lessons learnt and recommendations**

In the past, the AMFR's focused on the negative impacts of floods. It is suggested highlighting both negative and positive effects. In addition, linking flood related topics to socio-economic aspects seems worth mentioning, in particular at the national and regional level.

It is suggested to link national activities with efforts of MRC in terms of flood forecasts and early warning. This could lead to positive synergy effects.

The impact of the Chinese dams and their operation affects streamflow and will become more important. This is why a review and re-analysis of flood discharges and flood volumes including dam operation at key stations seems to be required.

The MRC has no mandate to manage flood risk in the LMB, it can only assist the riparian countries to do so. Therefore, capacity building is deemed to be an important element.

## 4.5 Viet Nam

### 4.5.1 Introduction

Viet Nam's climate can be divided into a tropical and a temperate zone. It is characterised by strong monsoon influences, has a considerable amount of sun, a high amount of rainfall and high humidity. Regions located near the tropics and in the mountainous regions have a slightly cooler, more temperate climate. There are two seasons in Viet Nam, the cold season occurs from November to April and the hot season from May to October. The difference in temperature between the two seasons in south is almost unnoticeable, averaging 3°C. The most noticeable variations are found in the north where differences of 12°C have been observed.

The annual average temperature ranges from 22°C to 27°C year-round. There are almost no significant differences in temperature in the southern parts of Vietnam, while the northern regions can be quite cold in the winter. There are essentially four distinct seasons, which are most evident in the northern provinces.

In the Mekong Delta, the mainstream floods and on-farm flooding phenomena occur yearly, with long durations and low intensities. Flooding in the Mekong Delta is a result of the upstream flow regime, Great Lake regulation, local rainfall, tidal effects and human intervention.

Flood classification is based on water levels at the main stations in the Mekong Delta. 24 large floods ( $H_{max} > 4.5$  m MSL) and four extreme floods ( $H_{max} > 5.0$  m MSL) occurred during the past 87 years. The year 2000 flood is considered as a historical flood event in the Mekong Delta with 453 fatalities and more than US\$ 250 million losses and damages according to the Central Steering Committee for Flood Prevention and Mitigation Losses, 2010.

Table 15: Main hydrological parameters at the main stream stations of three past extremes in the Mekong Delta

Year	Tan Chau (Mekong River)		Chau Doc (Bassac River)		Moc Hoa (Vaico River)	
	$H_{max}$ (cm)	$Q_{max}$ (m <sup>3</sup> /s)/Date	$H_{max}$ (cm)	$Q_{max}$ (m <sup>3</sup> /s)/Date	$H_{max}$ (cm)	Date
1961	512	28,800 12/10	489	7,840 13/10	2.43	* 19/10
1966	511	* 27/9	484	* 28/10	2.50	* 3/10
2000	506	25,500 23/10	490	7,660 23/9	3.27	* 25/9
2011	486	* 12/10	427	* 29/9	280	* 28/10
2013	435	* 4/10	385	* 7/10	*	*
2014	395	* 15/8	320	* 17/8	*	*
2015	255	* 15/10	235	* 30/9	*	*

Source: National Center for Hydro Meteorological Forecasting, 2016; \* No data

## 4.5.2 The flood season 2015

### Availability of data

The data and information concerning the flood season 2015 was collected from a variety of sources. They stem from the following line agencies of government or local administrations:

- National Center of Hydrology and Meteorology Forecasting (NHMFC);
- Southern Center of Flood and Storm Control (SCFSC);
- Viet Nam Mekong Committee (VNMC);
- Others as the Southern Institute of Water Resource Research (SIWRR); Southern Institute of Water Resource Plan (SIWRP), Institute of Hydrology – Meteorology Science and Climate Change; and the provincial and central newspaper’s websites.

### Meteorological and hydrological conditions

#### The Mekong Delta

The rainy season started later than average. At the beginning of the season, the rain was distributed irregularly, while the first rain with a wide areal coverage occurred from June 12, 2015 onwards. Total rainfall over ten months from the beginning of 2015 totalled about 700 – 1900 mm in the Mekong Delta region.

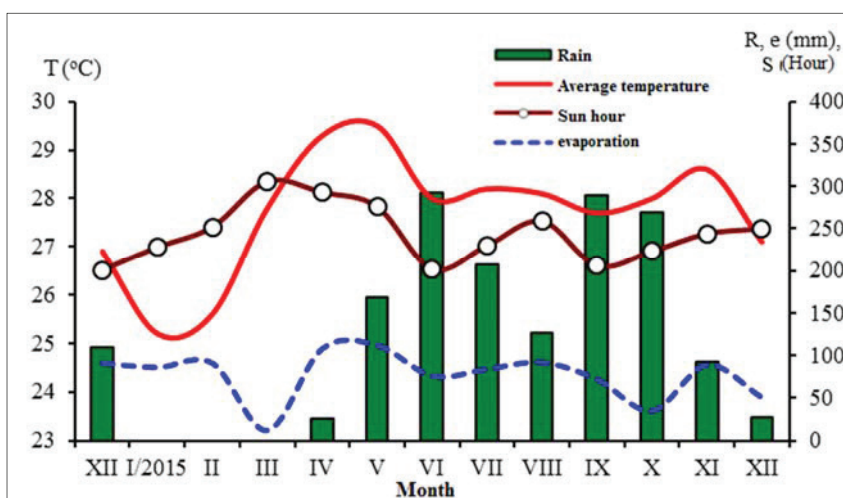


Figure 69: Rain and meteorological data measured at Can Tho station in 2015 during storm VAMCO (Source: Institute of Hydrology – Meteorology Science and Climate Change, 2015)

#### Central Highland

Due to a prolonged El Nino phenomenon, precipitation was about 20-30% less than average, while the average temperature was distinctly higher. Total rainfall in Kon Tum province ranged from 650-1300 mm, in Gia Lai between 640 and 1600 mm, in Dak Lak about 800 – 1600 mm, in Dak Nong about 1000 – 1800 mm and in Lam Dong reached about 900-2500 mm. That means precipitation was 200 to 500 mm less compared with the same period in 2014. In the northern highlands (Gia Lai and Kon Tum), rainfall only reached 50-60% of the long-term average. In spite of low totals, high rainfall intensities resulted from tropical storm Vamco.

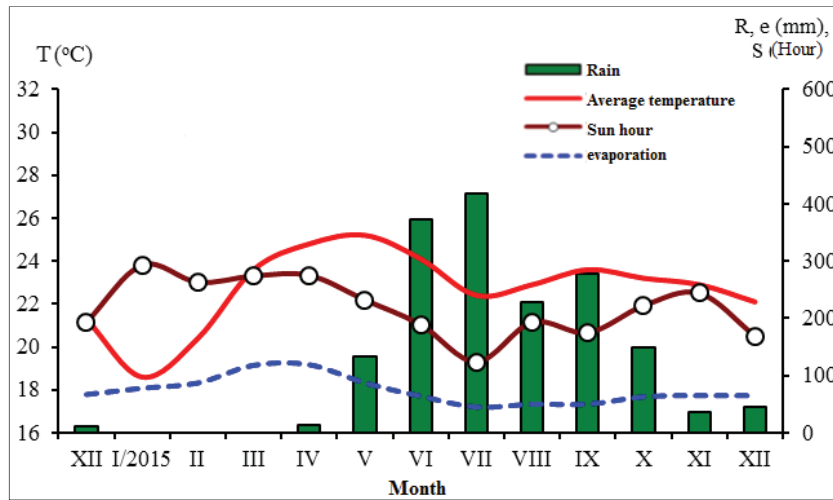


Figure 70: Rainfall and meteorological data observed at Play Cu station in 2015 (Source: Institute of Hydrology – Meteorology Science and Climate Change, 2015)

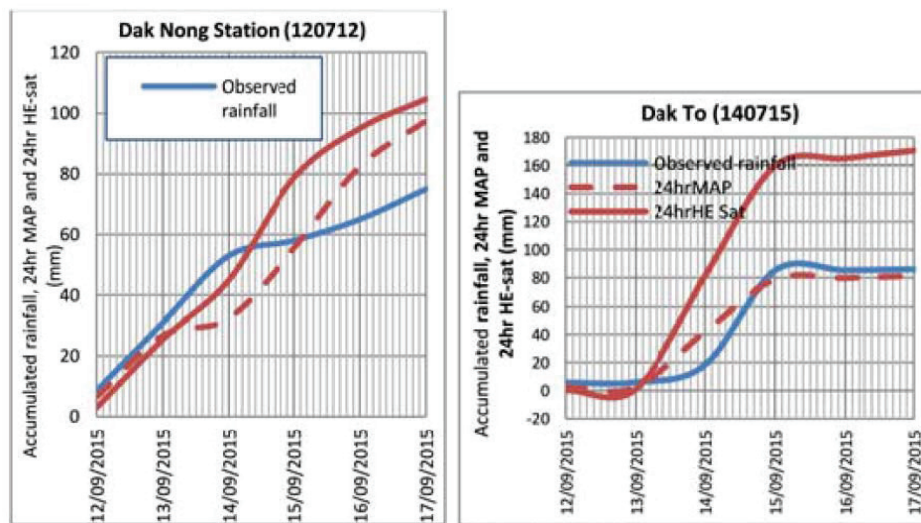


Figure 71: Rainfall and meteorological data observed at Dak To station in 2015 (Source: RFMMC, 2015)

**Flood hydrology of 2015**

**Mekong Delta**

Early August 2015, high flow from upstream in combination with high tides gave rise to an increase of the water level at Tan Chau. The water level rose up to 245 m (15/8) at Tan Chau and at Chau doc to 209m (16/8). All water levels remained below warning level, though.

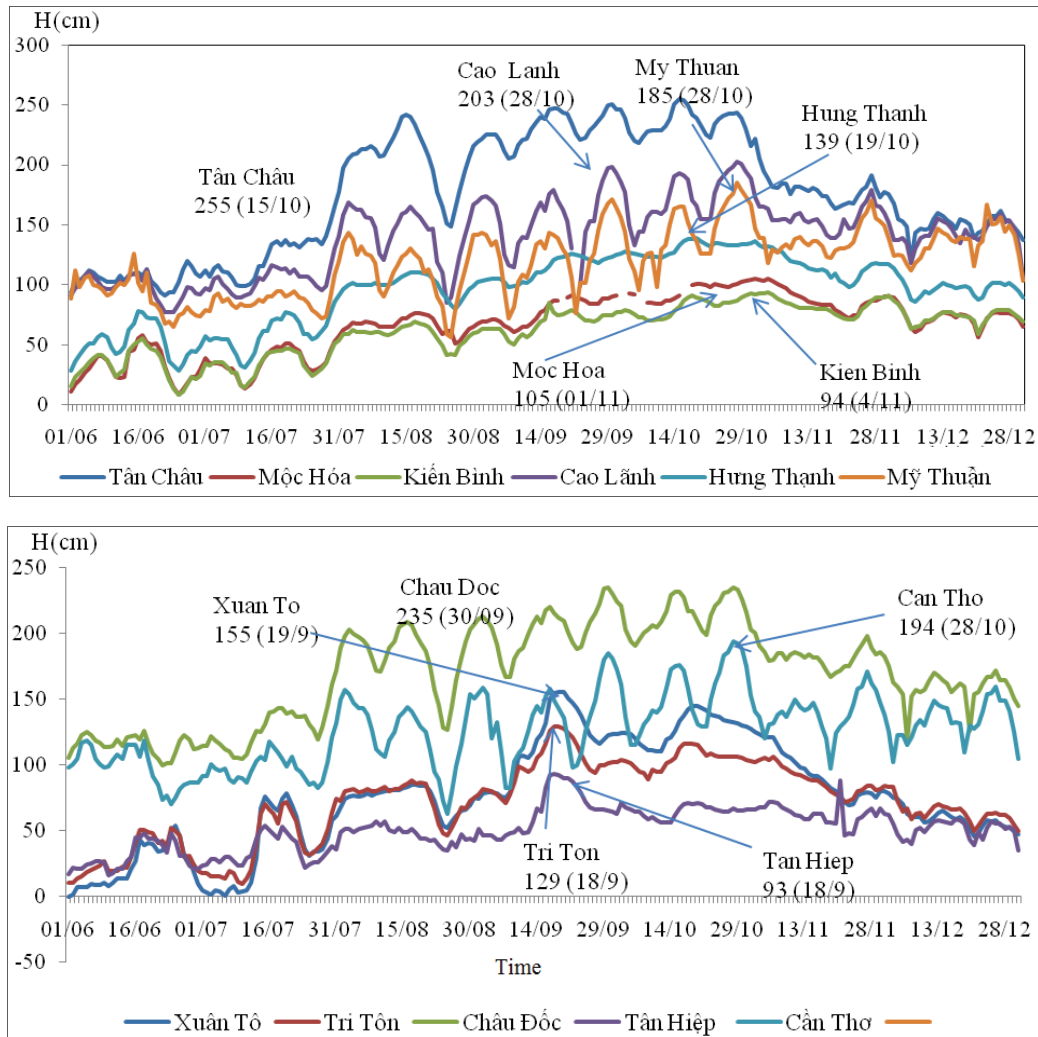


Figure 72: Water levels in the Mekong Delta (Tien and Hau River), 2015 (source: National Center of Hydrology and Meteorology Forecasting, 2015)

### **Central Highland**

No severe flood event occurred during the flood season in 2015 in any rivers in Central highland and Highland area of Viet Nam. Only small to medium floods were recorded. The associated flood peaks reached approximately alarm level 1 with the exception of the period 13 – 18 September 2015. The tropical storm VAMCO cause a quick increase of flow at many rivers in Central Highland. Particularly, the water level at the Kon Tum station located at DakBla River rose rapidly to a height of 17.7 m on 15 September 2015.

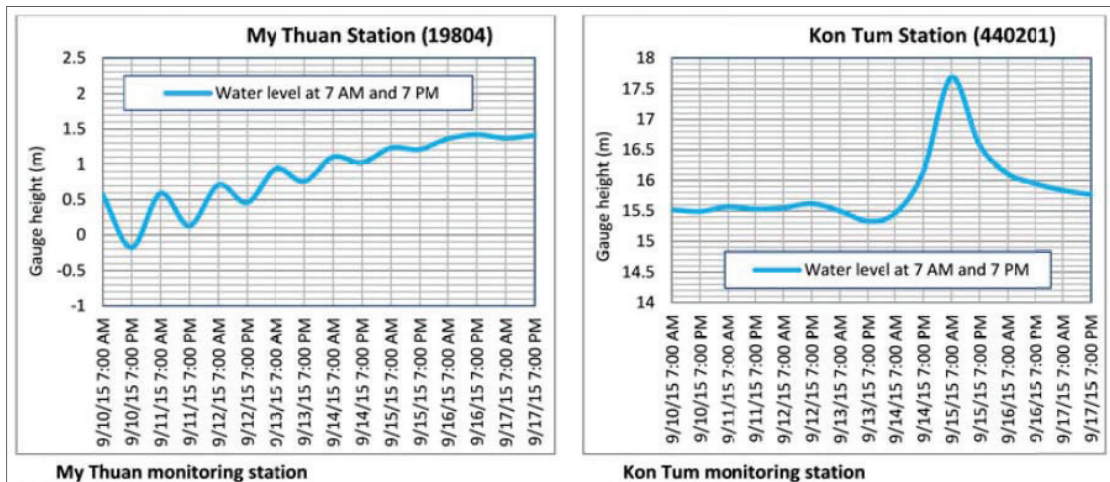


Figure 73: Water level at My Thuan and Kon Tum stations, 2015 (source: RFMMC, 2015)

### 4.5.3 Impact of flood 2015

#### Flash floods



Son La province – the northern mountain province of Viet Nam – had to face flash floods in June 2015. The districts Moc Chau and Thuan Chau were affected, more specifically Lóng Sập, Chiềng Khừa, Chiềng Sơn (Mộc Châu communes and In Bon Pặng, Chiang Pắc (Thuan Chau district), leaving 5 people dead and 3 people missing.



Dien Bien province experienced flash floods in the Tuan Giao district. Preliminary estimates of damages and losses added up to over 100 billion VND (4.38 million USD). At 7 AM 1/8/2015, the Huoi Cu earth dam failed and caused a serious flash flood. According to preliminary information from the community's administration, about 100 families in several villages were exposed to and affected by the resulting flood wave. (<http://www.nhandan.org.vn/xahoi/tin-tuc/item/27041002-huyen-tuan-giao-dien-bien-thiet-hai-lon-do-mua-lu.html>).



Lai Chau province. Between 30/7 – 1/8/2015, heavy rain up to 139 mm at Muong Te, 160 mm at Muong Mo and 115 mm at Ta Tong was estimated. Near the Hua Bum community in the Nam Nhun District, a landslide damaged the main road and cut off the village. In Nam Ban commune, the wood bridge crossing the Nam Ban stream was swept away.



Lao Cai province. Lao Cai province experienced bad weather conditions with storm, torrential rain and thunderstorms resulting in flash floods and landslides. According to preliminary estimates of the Central Steering committee for flood prevention and Mitigation Losses, 12 people died or were injured. Particularly, Bat Xat district reported 9 people dead or missing, Sa Pa district reported 2 people dead or missing.



Son La province. According to the report of the Central Steering committee for flood prevention and Mitigation Losses, precipitation was estimated to total about 101 mm up to 125 mm.



Ha Giang province. According to the report of the provincial Steering committee for flood prevention and Mitigation Losses, flow in the Minh Tien village, Thuan Hoa commune (Vi Xuyen) rose up to 3 m suddenly at night on 7/9/2015, leaving 1 family missing.

### **Mekong Delta**

Bank erosion along the Tien and Hau Rivers in Mekong Delta increased in recent years. A analysis based on “Changing morphology and flow mechanism river bank system during both dry and flood seasons” carried out by Southern Institute for Water Resources Research concluded as follows:

- Number of erosion areas is increasing
- Erosion mechanism has changed in both space and time
- Erosion level has been changing
- Erosion phenomena occur year-round, with more serious erosion during the rainy season

Table 16: Summary of flood related losses and damages in the Mekong Delta and Highland parts of Viet Nam, 2015

Category	Item damaged	Unit	MK	Highland	Total
People	Killed	Person	38	1	39
	Injured	Person	28		28
	Missing	Person	8		8
	Affected	households	186		186
Housing	Houses collapsed, drifted	No	670	3	673
	Houses submerged and damaged	No	1,968	120	2,088
School	School collapsed	Room	1		1
	School submerged and damaged	Room			

Category	Item damaged	Unit	MK	Highland	Total
Hospital, clinics	Clinics collapsed	No			
	Clinics submerged and damaged	No			
Agriculture	Rice fields submerged	Ha	30,039	253	30,292
	Farms submerged, damaged	Ha	502	118	620
	Fruit tree area	Ha	220	400	620
	Food (salt) damaged by water	Ton			
Irrigation	Dyke damage	m	4,579		4,579
	Small channel damaged	m	738		738
Transportation	Land drifted	m <sup>3</sup>			
	Bridge, sewer collapsed	Unit			
	Roads damaged submerged	m			
Aquatic product	Shrimp, fish pool broken	Ha	309		309
	Ships sunk, lost	Unit			
	Ships sunk, damaged	Unit			
	<b>Total damage</b>	10 <sup>6</sup> USD	<b>4.775</b>	<b>9.821</b>	<b>14.596</b>

Source: Centers for Flood Control (2016)

Table 17: Summary of storm, flash flood and landslide related losses and damages in Viet Nam, 2015

Category	Item damaged	Unit	Total
People	Killed	Person	67
	Injured	Person	55
	Missing	Person	7
	Affected	house	1,166
Housing	Houses collapsed, drifted	No	568
	Houses submerged and damaged	No	20,623
School	School collapsed	Room	59
	School submerged and damaged	Room	
Hospital, clinics	Clinics collapsed	No	
	Clinics submerged and damaged	No	
Agriculture	Rice fields submerged	Ha	20,042
	Farms submerged, damaged	Ha	11,446

	Fruit tree area	Ha	457
	Food (salt) damaged by water	Ton	
Irrigation	Dyke damage	m	1,724
	Small channel damaged	m	73,202
Transportation	Land drifted	m3	1,044,708
	Bridge, sewer collapsed	Unit	83
	Roads damaged submerged	m	39,736.5
Aquatic product	Shrimp, fish poll broken	Ha	3,175.85
	Ships sunk, lost	Unit	2,267
	Ships sunk, damaged	Unit	
	<b>Total damage</b>	10 <sup>6</sup> USD	183.5

Source: Central Steering committee for flood prevention and Mitigation Losses (2015)

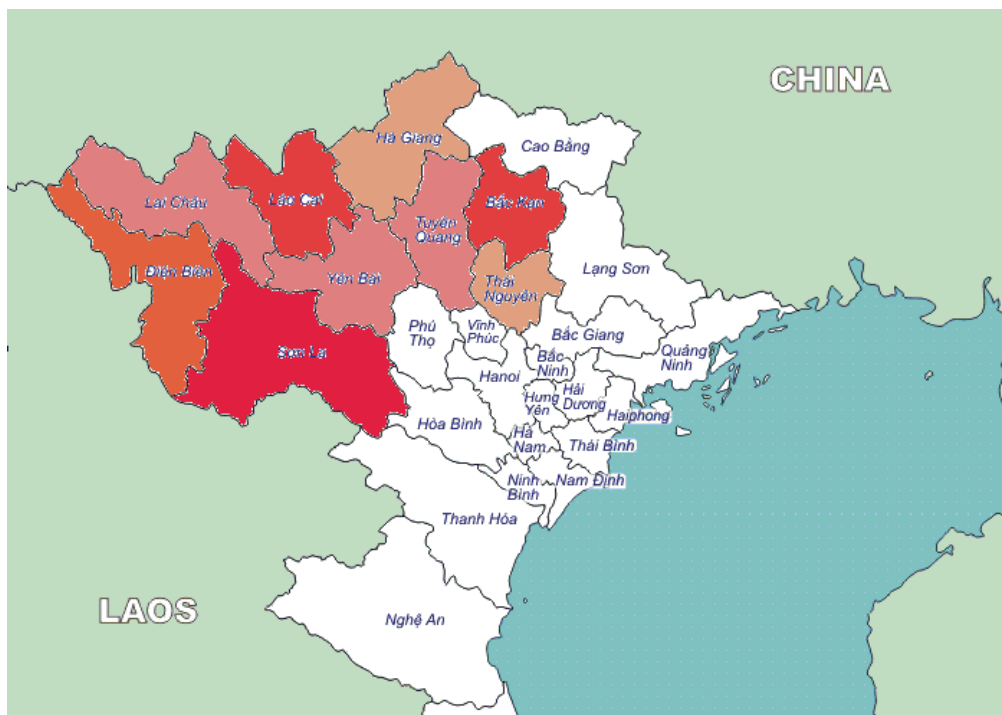


Figure 74: Most affected provinces by flash floods in Viet Nam, 2015

#### 4.5.4 Flood management and response

The Central Steering Committee for Flood and Storm Control (CSCFSC) is responsible for emergency response in relation to floods and storms.

The National Committee for Search and Rescue (NCASR) is responsible for coordinating, controlling and implementing the national warning system and provides technical assistance/expertise to search and rescue victims of natural disasters. This

agency was formed based on the Strategy and Action Plan for Mitigating Water Disaster in Viet Nam.

The Department for Dyke Management, Flood Control and Storm Preparedness (DDMFCSP) oversees development in flood prone areas. This statute also empowers the authority to take necessary steps to prepare for floods and typhoons and to participate in emergency repairs and protective works. The DDMFCSP approves the Disaster Management Plans.

At province, district or community level, the chairman of a province, district and commune people's committee issues the decision to establish the committees for flood and storm control. The members of the Committee include: the chairman of people's committee, Chief of water sector is the vice chairman and the members are the chief or vice chief of sectors related to the flood and storm control work of local nature. Committees for flood and storm control at local levels have the responsibility to assist, develop and implement flood and storm control measures; to protect industrial, commercial and residential areas; overcome the aftermaths of floods and storms and to implement preparedness.

#### **4.5.5 Lessons learnt and recommendations**

Vietnam's Mekong Delta, where millions of people live, suffers from floods, droughts and salt penetration. Vietnam pays attention to the Mekong cooperation and has pledged to join hands with regional countries to realise the Mekong Agreement: preserve the Mekong River to connect different cultures and represent regional solidarity, friendship, cooperation, prosperity and integration.

The disaster related situation is increasingly complex in the mountainous provinces of Vietnam. Especially landslides, hail, floods and flash floods occur frequently and cause serious damage to people, property and the environment. Flash floods and landslides are a result of intense rainfall. It must be noted that people's activities, lack of understanding of natural disasters, ignoring risks, mining, logging and wrong design of infrastructure contributes to and increases damages and losses.

Based on previous experiences and the increasing number of flash floods, it is suggested to pay more attention to flash floods and training regarding forecasts of flash floods.

From 2002 to 2014 and 2015 there was no large flood in the Mekong delta. However, flood preparedness plans should be followed and continued.

The MRC flood forecasts should be extended to include tributaries into their mandate.

The development of the MRC-FFGS should be continued to further improve the system.

## 5. CONCLUSIONS

A retrospective view has shown that significant changes have taken place.

The flow regime has changed due to the development of large water infrastructure projects. To a certain extent the previously uncontrolled flow of the Mekong River is being transformed into a regulated river. The impacts of dam operation affect not only the upstream river reaches at Chiang Saen but also propagate further downstream. The ratio between peak discharges and low flows are gradually diminishing. From the perspective of managing water courses, this could be seen as an advantage. The reduction of the natural flood pulse, however, might pose risks to other sectors like fishery, ecosystems and so on which are not instantly visible. In order to prevent impacts which, cause irreversible degradation, careful integrated planning is required more than ever.

In the wake of water infrastructure development, coordinated operation of cascade dams is most likely one of the big tasks of the future, establishing data exchange mechanisms about operation and releases and including a common operation and dam safety framework.

In terms of conducting forecasts for mainstream Mekong, integrating dam operation is a must. There is no way around this if the member countries wish to keep the level of forecasts up to the standard as it is.

Coordination and exchange of experience related to flood management is another topic which requires attention. Each country faces challenges which are in some way or another quite similar. Experience with ecosystem –based disaster risk reduction might be developed in one country but not in all. It is worth exchanging the knowledge or learning from international best practices. The approach to harness nature has become a widely accepted and internationally promoted field. This is not only due to its advantage of offering cost-effective solutions, but also due to the fact that it requires cross-sectoral planning. The integration of land-use planning, water sector, agriculture, energy and ecosystems, often called the nexus, is the only way to achieve development without irreversibly destroying the fundamentals of well-being.

Another lesson learnt is preparedness. It is an illusion to believe that 100% flood protection is possible. This was not true in the past and remains unfeasible in the future for both technical and economic reasons. What can be increased at rather low costs compared to damages and losses from previous flood events, however, is preparedness. It starts with a good monitoring system and well-established early warning procedures. It affects all levels and basically, adverse impacts arrive first at the community level. As a consequence, emergency preparedness plans at all levels down to communities are required with risk maps, capacity building campaigns, notification trees and response actions plans to accomplish risk-sensitive planning and decision-making and to enable people in their effort to prepare for the next disaster.

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