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Flood Situation Report 2011

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No. 36
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Acronyms and Abbreviations

AMFR	Annual Mekong Flood Report
CFS	Climate Forecast System (National Centers for Environmental Prediction, National Oceanic and Atmospheric Administration, United States)
Cumecs	Cubic Meters
DHRW	Department of Hydrology and River Works, Ministry of Water Resources and Meteorology (Cambodia)
ENSO	La Niña and El Niño/Southern Oscillation
FEWS	Flood Early Warning System
FFGS	Flash Flood Guidance System (Regional Flood Management and Mitigation Centre, Flood Management and Mitigation Programme, Technical Support Division, Mekong River Commission Secretariat)
FMMP	Flood Management and Mitigation Programme (Technical Support Division, Mekong River Commission Secretariat)
FSR	Flood Situation Report
Haima	Name of tropical storm
IKMP	Information and Knowledge Management Programme (Technical Support Division, Mekong River Commission Secretariat)
IRI	International Research Institute for Climate and Society (Earth Institute, New York, United States)
ISIS	Software package used for river modeling (developed by Halcrow Group Ltd, (Britain)
ITCZ	Inter-Tropical Convergence Zone
LMB	Lower Mekong Basin
Mekong FFS	Mekong Flood Forecasting System
MOWRAM	Ministry of Water Resources and Meteorology (Cambodia)
MRC	Mekong River Commission
MRC FFGS	MRC Flash Flood Guidance System
MRCS	Mekong River Commission Secretariat
MRC HN	Mekong River Commission Hydrologic Network
MRD	Monthly Rainfall Distribution

NCEP	National Centers for Environmental Prediction (National Oceanic and Atmospheric Administration, United States)
NCFC	National Centers for Flood Forecasting
NGO(s)	Non-Governmental Organization (s)
NOAA	National Oceanic and Atmospheric Administration (United States)
Nock-Ten	Name of tropical storm
OM	Operations Manager (Regional Flood Management and Mitigation Centre)
OSP	Office of Secretariat in Phnom Penh, Cambodia
OSV	Office of Secretariat in Vientiane, Lao PDR
PNP	Phnom Penh, Cambodia
RFMMC	Regional Flood Management and Mitigation Centre or Regional Flood Centre (Flood Management and Mitigation Programme, Technical Support Division, Mekong River Commission Secretariat)
SST	Sea Surface Temperature
SW	South West (wind direction)
TLP	Tropical Low Pressure
TMD	Thai Meteorological Department

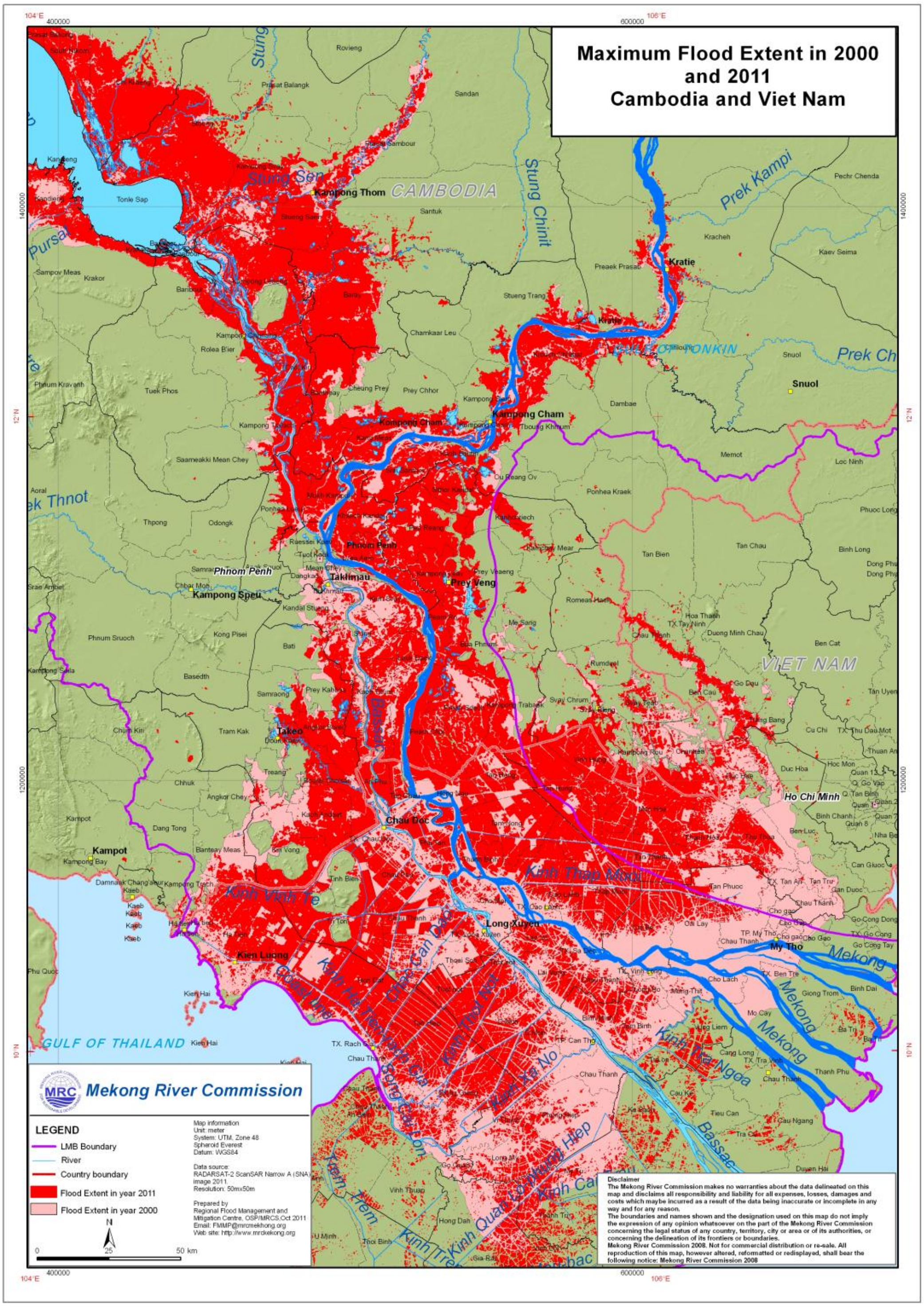


Figure 1.1 Maximum flood extent maps for the Cambodian floodplain and the Viet Nam Mekong delta of 2000 and 2011

Source: *Hatfield and MacDonald, Dettweiler and Associated Ltd., Canada*

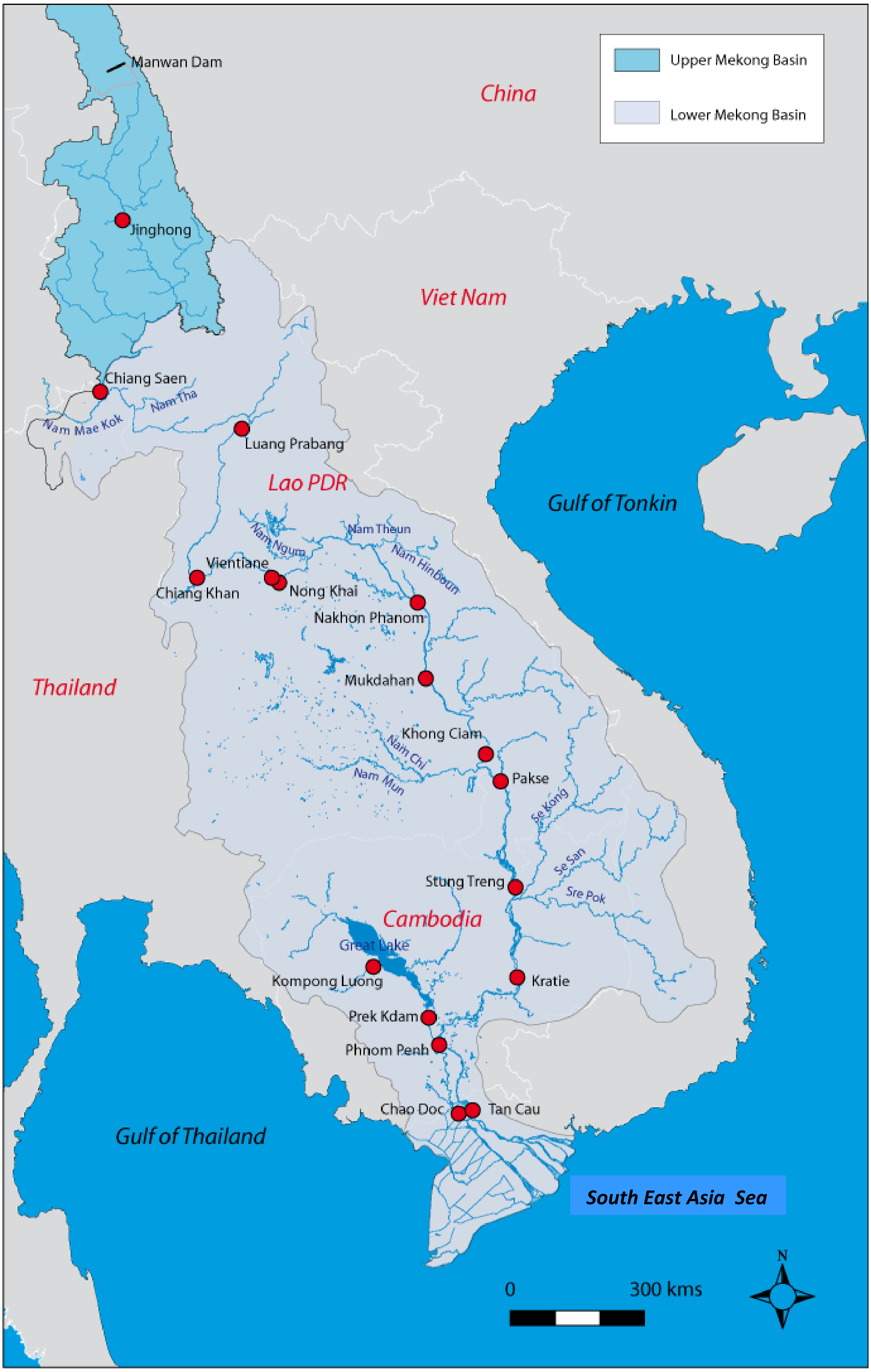


Figure 1.2 Location of gauge stations along the Mekong River

1. Summary

During the flood season in 2011, the Lower Mekong Basin faced a major mainstream flood with inundations of large areas of the Cambodian floodplain and the Mekong Delta[1]. The *Flood Situation Report, November 2011* has been produced at the request of the Cambodia National Mekong Committee. It provides information about the meteorological conditions, which caused heavy rainfall in many parts of the Lower Mekong Basin (LMB) and led to a critical flood situation, particularly in the lower part of the LMB. The report focuses on the flood in Cambodia, the response and accuracy of MRC flood forecasting during the most critical period on the Cambodian floodplain from 21 to 24 September. Data and information used in this Flood Situation Report 2011 are of a preliminary character. A basin-wide overview of flood season 2011 using consolidated data and information will be presented in the Annual Mekong Flood Report 2011, which will be presented in the 2nd quarter of 2012.

From the meteorological perspective, conditions during the Mekong flood season in 2011 are characterized by two major aspects:

- the early influence of tropical storms, from the beginning of the flood season and onwards, to water levels on the Mekong mainstream that were above the long-term average, especially in the middle and lower reaches of the Lower Mekong Basin (LMB);

- the appearance of an Inter-Tropical Convergence Zone (ITCZ) during the whole of September and strong Southwest Monsoon activity, the major drivers of severe weather patterns resulting in intensive rainfall, flood and flooding, especially in the middle and lower reaches of the LMB.

During the flood season, there were roughly six tropical storms and typhoons, which came to the South China Sea and affected the Mekong River Basin in different ways. Of these, two tropical storms, Haima and Nock-Ten, were the most noticeable.

The 2011 flood season started in the upper reach reasonably close to the historic averages. At Kratie, the season started roughly 5 weeks earlier than in 2010; the flood peak in 2011 was roughly one week later than the peaks in both 2010 and 2000. The season ended in the upper reach roughly 2 weeks early, which is still within the normal range; in the lower reach, the end of the season could not be confirmed as of late October.

During the second week of October, water levels in the floodplains of Cambodia reached critical levels, particularly in Phnom Penh, Neak Luong and Koh Khel, while water levels in Tan Chau and Chau Doc in Viet Nam reached their highest levels in the third week of October. These high water levels at first persisted, but then gradually decreased.

In Kratie, the water level increased from mid-July due to increased river flows as a result of Tropical Storm Nock-Ten to the level of 21.8m on the 13 August. The water level fell to 19.7m on 7 September but then rose again to 21.8m on 12 September as a result of the strong Southwest Monsoon and the ITCZ. It reached its highest level of 22.9m on 24 September which was 0.3m higher than the highest level recorded in the extreme flood of 2000.

[1] Although many flash floods occurred during the flood season in 2011, an overview of occurrences and impacts is not incorporated in this report but will be included in MRC's Annual Flood Report 2011.

At the Chaktomuk gauge station in Phnom Penh, the water level increased from 6.0m on 16 July to 9.5m on 15 August. The water level fluctuated little until 9 September, when it started rising again, reaching its highest level of 10.8m on 29 September. The water level in Phnom Penh stayed 0.4m below the extreme flood level of 2000 and also remained 1.2m under the flood stage level of 12.0m for Phnom Penh.

Tan Chau, on the main branch of the Mekong River (Tien Giang) in Viet Nam, reached the flood stage level of 4.5m on 25 September. The water level further rose to 4.8m on 10 October and then slowly receded. In neighboring Chau Doc, on the Bassac River (Hau Giang), water started exceeding the flood stage level on 26 September, rising further to 4.3m on 8 October and then gradually falling.

Only Kampong Cham and Kratie stations in Cambodia recorded flood levels slightly higher than those recorded during the extreme flooding in 2000. In Kampong Cham, the flood level reached 0.1m higher than the 2000 level of 15.9m and was at flood stage level from 23 September until 27 September. It reached a peak of 16.0 m on 25 September, but stayed 0.2m below the flood stage level of 16.2m for Kratie.

At all other gauge stations, the water levels stayed under the extreme 2000 levels, although there was severe flooding in many places with lower crest elevation levels of the embankments or dykes in the Cambodian floodplain and the Mekong delta in Viet Nam.

The return period for the combination of the flood peak and flood volume in 2011 at the benchmark station of Kratie is estimated to be once every 10-20 years.

During the 2011 season, water levels at 21 mainstream gauge stations were forecast 1- 5 days in advance, based on the rainfall and water level data provided by the national centers for flood forecasting of the MRC Member Countries.

Based on an analysis of the flood season and on simulations of critical flood events during the 2011 season, it may be concluded that the MRC's Mekong Flood Forecasting System (Mekong FFS) provided satisfactory results overall. The forecasting results for the Cambodian gauge locations were nevertheless far from satisfactory.

During the critical situation from 21 to 24 September in Cambodia, the Mekong FFS provided both highly reliable and extremely weak forecasts. Forecasts on the MRC website during this critical period were unfortunately based on weak Mekong FFS forecasting results.

The MRC Regional Flood Management and Mitigation Centre in Phnom Penh is equipped with state-of-the-art models and systems. Considering the geographical extent of the Lower Mekong Basin, however, the daily input of rainfall and water level data remains limited. Providing satisfactory levels of accuracy, lead times and reliability of the Mekong FFS remains a constant challenge for the Flood Management and Mitigation Programme.

The recent situation demonstrates that the full understanding of the models and systems is required to minimize prevent human errors. To make the right choices in interpreting model and system results, one also needs ample experience with and solid understanding of the characteristics of the Lower Mekong Basin and its sub-basins that value meteorological, hydrological and historical data and information[2].

The development of the MRC Hydrologic Network is expected to lead to increasingly accurate data transfer from member countries. At the same time, the Regional Flood Management and

[2] Recommendations regarding professional staff requirements for the development and operations of the RFMMC have been presented in the FMMP Concept Note, dated December 2009.

Mitigation Centre (RFMMC) has made noticeable progress in coming to grips with rainfall run-off in remote areas of the Lower Mekong Basin. Better representation of tributary inflows into the mainstream will directly improve the accuracy and extension of the lead time of the Mekong FFS.

Based on the Flood Situation 2011 experience, the FMMP has taken some internal steps to enhance the forecast performance and to minimize or prevent human errors:

- Internal flood forecasting arrangements in the RFMMC have been reviewed, rationalized and responsibilities clarified.
- To tackle the lack of experience in the short term information sharing and "team work" in the RFMMC has been stimulated as well as a strict application of the operations procedures (certified work process).
- The need for more intensive communication and exchange of information between staffs of the RFMMC and staffs of National Centers during critical flood situations is recognized. Internal arrangements have been adjusted.

The following lessons learnt and recommendations have been formulated for this Flood Situation Report.

- Forecast rainfall data and resulting tributary runoff in uphill areas with few rainfall stations is still causing substantial oscillations in the forecasted water levels.
- The real-time data transfer by the automatic stations of the MRC Hydrologic Network to the RFMMC flood forecasting system during the 2011 flood season still encountered a lack of reliability of the data transfer. Only since the last week of October did the Hydrologic Network of the telemetric stations feed the RFMMC's database system according to the set criteria. The data collection and transfer systems should be verified and consolidated.
- During flood situations, the RFMMC is equipped to operate on a 12-hourly-basis for which externally arrangements will have to be made internally with MRCS and externally with the MRC Member Countries, using the real-time data from the automatic stations of the MRC Hydrologic Network.
- Based on the flood forecasting experiences during the critical flood situation for 21-24 September 2011 FMMP has identified the need to enhance forecasting capabilities with the aim of minimizing or preventing human errors by constantly analyzing forecasting performances and simulating for all stations sudden steep rises and subsequent quick falling of water levels during flood seasons.
- The relatively slow recession of the water level downstream from the Phnom Penh Chaktomuk area in Cambodia from end of September to end of October should be looked into, considering the gradual reduction of storage area and discharge capacity of the Cambodian floodplain and the Mekong Delta of Viet Nam in combination with potential impacts from climate change and sea level rising.
- The RFMMC is in the process of improving the Mekong FFS; the present iSIS model version is being replaced by an updated iSIS version, which provides a substantially improved application of flood modeling simulations.

- The RFMMC should update the flood pages before flood season 2012 (regarding maps and especially flood extent maps). The interpretation of the values of the alarm and flood levels will be further clarified on the MRC website.

- Given the overall encouraging effects of flood forecasting and flood preparedness in reducing the number of flood casualties and loss of livelihoods, continuation of these efforts and improvement of these systems by MRC seems to be recommendable. The Annual Mekong Flood Report 2011 will incorporate pay attention to the positive effect of flood preparedness during the 2011 flood situation.

- There is an urgent need for quality management of the RFMMC. The position of Operations Manager is still vacant.

- Acknowledging the weakness in securing continuity of flood forecasting expertise at the RFMMC annual refreshment courses by international experts have been organized to support the RFMMC's forecasters with detailed understanding and further improvement of the forecasting systems. As a short term measure such courses will be repeated in 2012, as well as the application of internal knowledge sharing approaches, joint analysis and simulation exercises and stimulation of team-work.

- To secure knowledge and experience for the proper operations of the flood forecasting systems for the medium and long run, recommendations have been provided in the Concept Note for the Development and Operations of the RFMMC. Building-up a regional flood forecasting knowledge base through the application of RFMMC's systems at the National Centers at the one hand in combination with longer term arrangements for expert staffs may provide a feasible option.

2. Meteorological conditions and rainfall situations

Meteorological conditions

From the meteorological perspective, conditions during the Mekong flood season in 2011 are characterized by two major aspects:

- The appearance of an Inter-Tropical Convergence Zone (ITCZ) during the whole of September and strong Southwest Monsoon activity. These were the major drivers of severe weather patterns, resulting in intensive rainfall, flood and flooding, especially in the middle and lower reaches of Lower Mekong Basin.

- During the flood season, there were roughly six tropical storms and typhoons which came to the South China Sea and affected the Mekong River Basin in different ways. Of these, two tropical storms, Haima and Nock-ten, were the most noticeable. Three other tropical storms, which are worth mentioning as their depressions impacted parts of the LMB, were Typhoon Nanmadol, Tropical Storm Haitang and Typhoon Nalgae.

Haima started as a tropical depression that formed in the Philippine Sea on June 17. As it travelled through the South China Sea, it was upgraded to Tropical Storm Haima on 21 June. After moving across the China's Leizhou Peninsula on 23 June, it landed over Northern Vietnam on 24 June and was then downgraded to a low-pressure system, disappearing as it moved into the Northern part of Lao PDR on 26 June (see Figure 2.1 below).

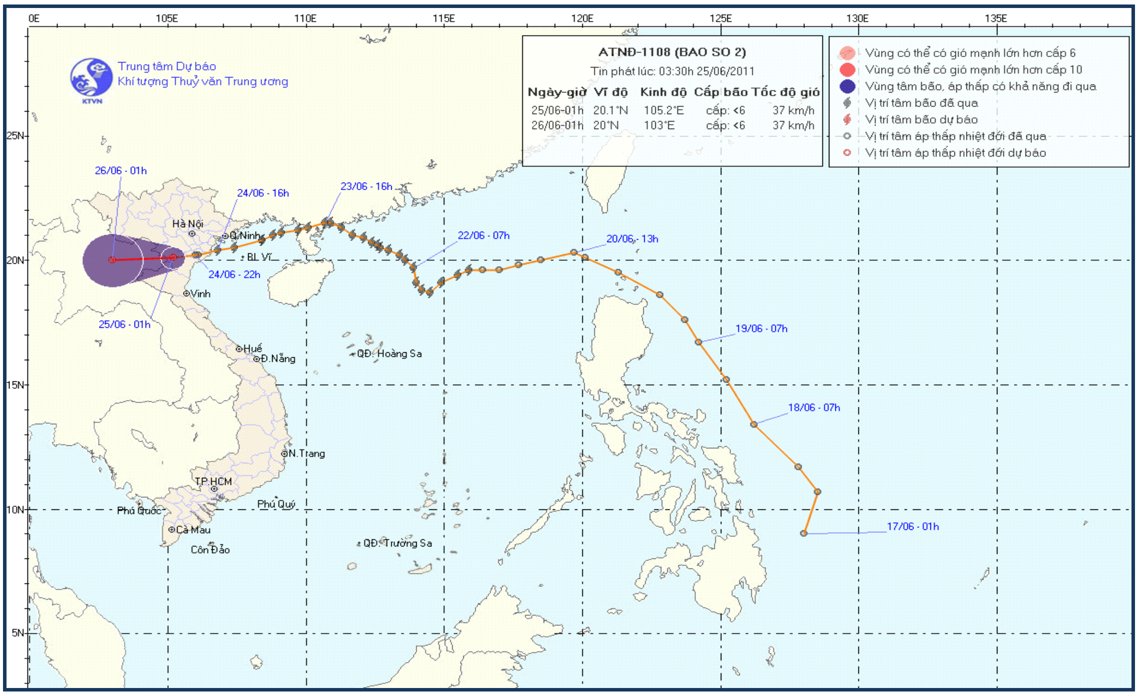


Figure 2.1. Track of Tropical Storm Haima

Source: *Viet Nam National Centre for Hydro-Meteorological Forecasting*

- Tropical Storm Nock-Ten (1108), which formed in the East Philippines on the 26 July, caused intensive damage to the Philippine island of Luzon before moving into the South China Sea on 29 July. After travelling though China's Hainan Island, it landed over the

- Northern part of Central Viet Nam on 30 July and moved inland into central Lao PDR (see Figures 2.2 and 2.3 hereafter).

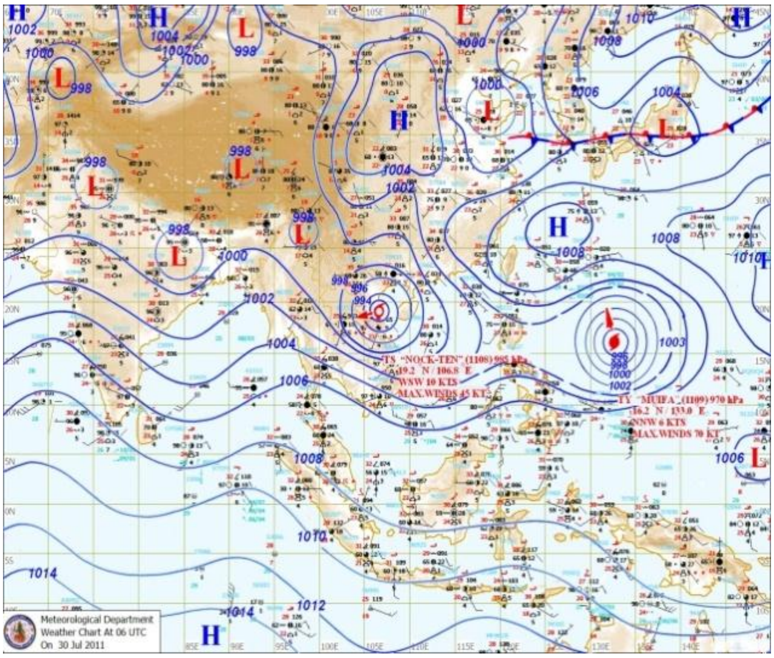


Figure 2.2 Weather map for Tropical Storm Nock-Ten at 13:00 hrs on 30 July 2011 before landing

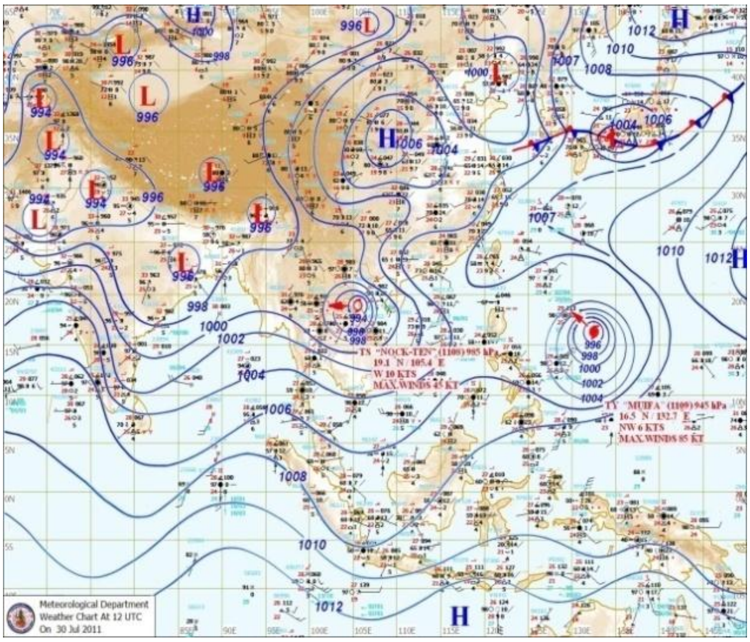


Figure 2.3 Weather map for Tropical Storm Nock-Ten at 19:00 hrs on 30 July 2011 after landing

Source: *Thai Meteorological Department.*

The Southwest Monsoon influenced the Mekong River Basin from mid-May onwards. Strong to intensive activity occurred from early June and the monsoon was almost stationary until mid-

July. This was one of the main causes of isolated heavy rain in the middle and lower reaches of the Lower Mekong Basin early in the flood season.

Tropical Low Pressure (TLP) systems and Inter-Tropical Convergence Zones (ITCZ) appeared periodically from early June to the end of August, with an average duration of 3-7 days. During most of September, continued ITCZ activity had a significant influence and resulted in continuous intensive heavy rain with water levels rising in the middle and lower reaches of the Mekong, particularly the tributaries in the middle reach of the Lower Mekong Basin (see **Figure 2.4** below).

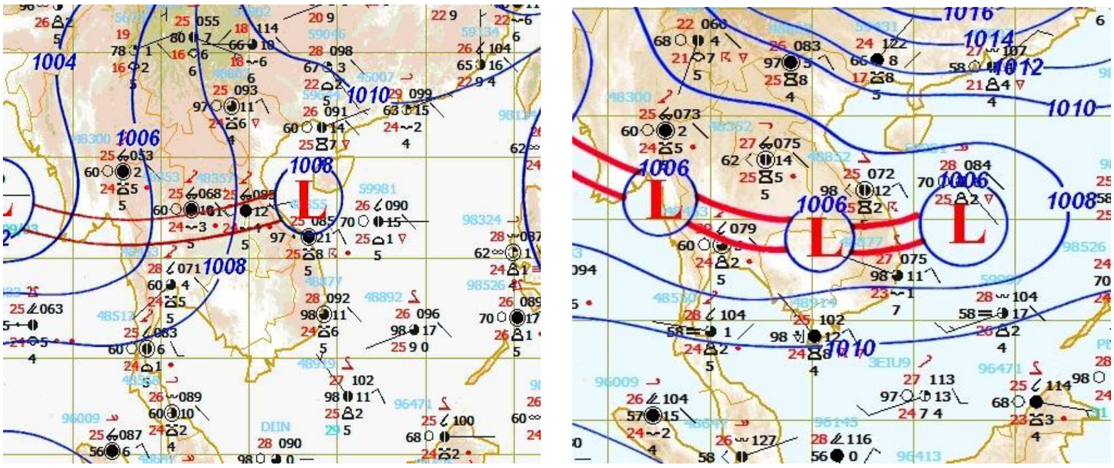
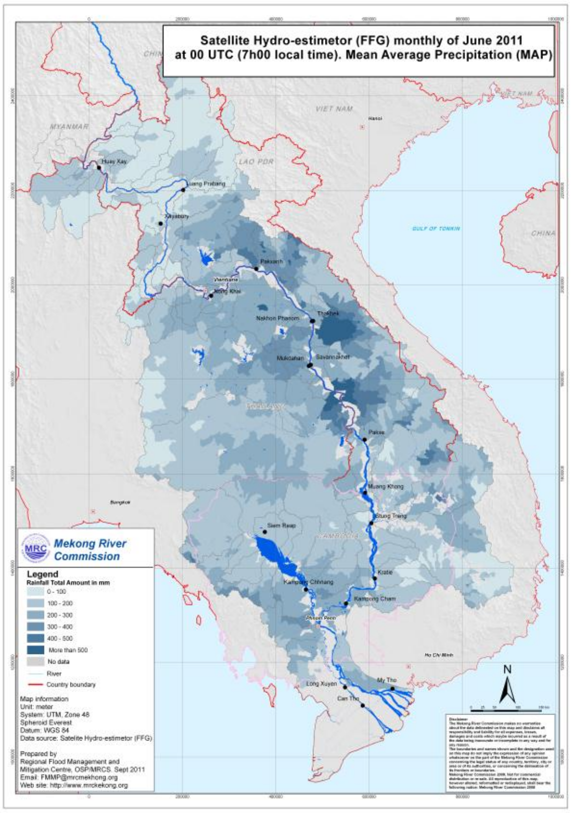


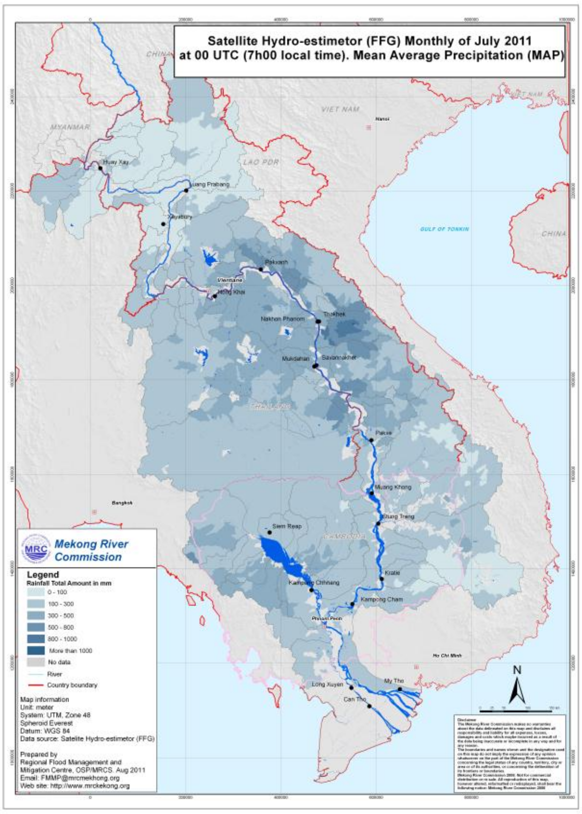
Figure 2.4 Weather maps for ITCZ at the beginning of June and mid September

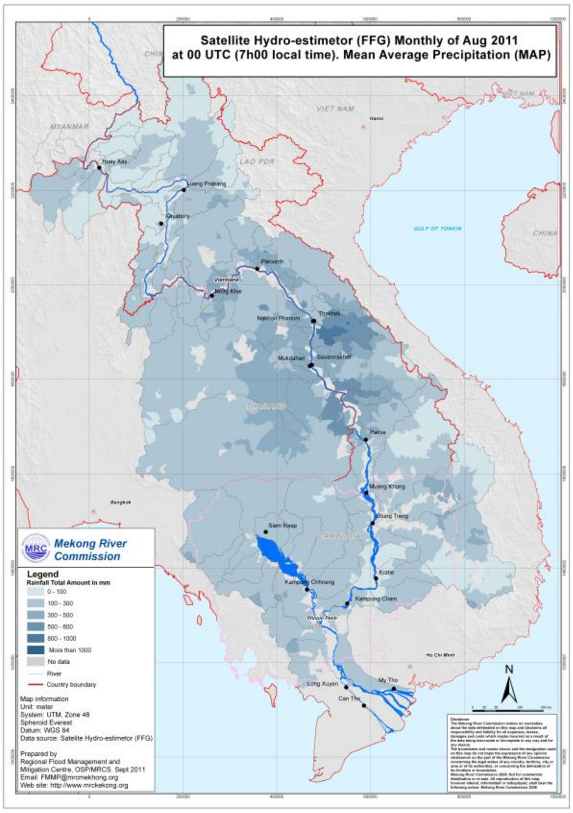
Source: *Thai Meteorological Department.*

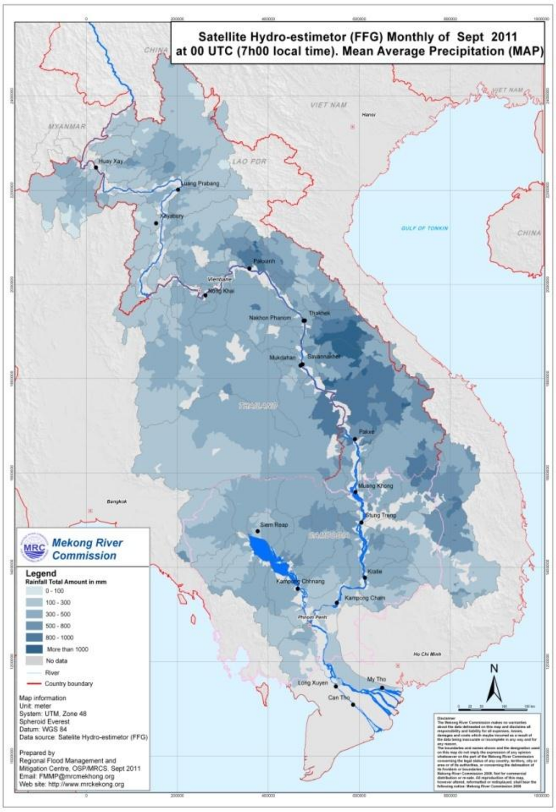
Rainfall situation and soil moisture

In June, heavy rain mostly occurred in the upper reach of the Lower Mekong Basin and some tributaries in the middle reach from Khong Chiam to Pakse. From July to September, intensive rain was mostly concentrated on tributaries in the middle reach from Paksane to Pakse. During August and September, continued rainfall covered the entire basin with more frequent heavy rains over the lower reach. In October, rainfall mostly occurred between Pakse in the middle reach to Phnom Penh in the lower reach, especially in the Tonle Sap area (see Figure 2.5 below).


Satellite Hydro-estimetor (FFG) monthly of June 2011
at 00 UTC (7h00 local time). Mean Average Precipitation (MAP)
Mekong River Commission
Legend
Rainfall Total Amount in mm
0 - 100
100 - 200
200 - 300
300 - 400
400 - 500
More than 500
No data
River
Country boundary


Satellite Hydro-estimetor (FFG) Monthly of July 2011
at 00 UTC (7h00 local time). Mean Average Precipitation (MAP)
Mekong River Commission
Legend
Rainfall Total Amount in mm
No data
River
Country boundary


Satellite Hydro-estimetor (FFG) Monthly of Aug 2011
at 00 UTC (7h00 local time). Mean Average Precipitation (MAP)
Mekong River Commission
Legend
Rainfall Total Amount in mm
No data
River
Country boundary


Satellite Hydro-estimetor (FFG) Monthly of Sept 2011
at 00 UTC (7h00 local time). Mean Average Precipitation (MAP)
Mekong River Commission
Legend
Rainfall Total Amount in mm
No data
River
Country boundary

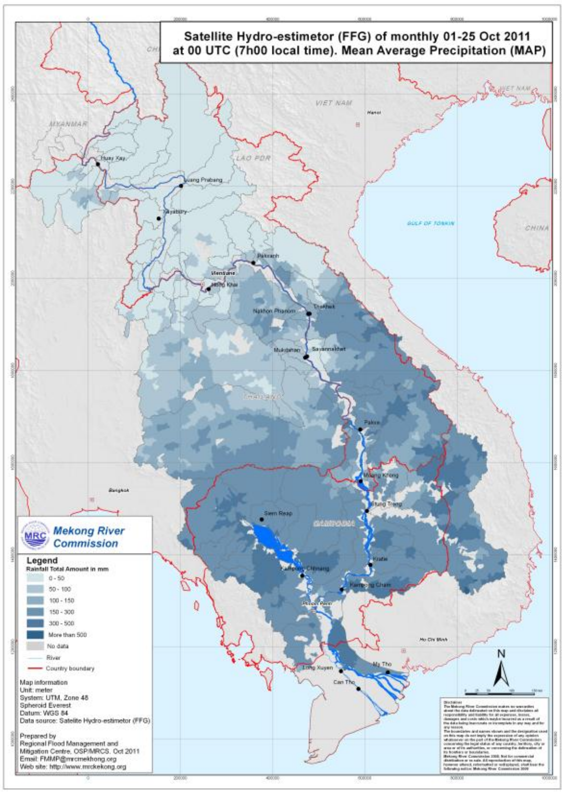


Figure 2.5 Monthly Rainfall Distribution in 2011 flood season (from June to October).

Source: *Thai Meteorological Department.(June, July, August 2011)*

Source: *https://ffg.mrcmekong.org/MRCFFG/ MRC Flash Flood Guidance System (September, October 2011)*

Soil moisture conditions during five months of the flood season are illustrated by soil moisture ranking percentiles in Figure 2.6. These indicate that the catchments in the middle reach of the basin were saturated since August, when the LMB was affected by critical weather patterns such as Tropical Storm Haima and Nock-Ten as well as Southwest Monsoon activity. As a result, flood runoff in the Mekong reached an annual peak by mid-August between Nakon Phanom/Thakhek and Pakse. In September, the saturated conditions can be recognized in the middle and lower reaches, particularly in the Tonle Sap area. This is one of the causes of the flood situation in the downstream area from the beginning of October.

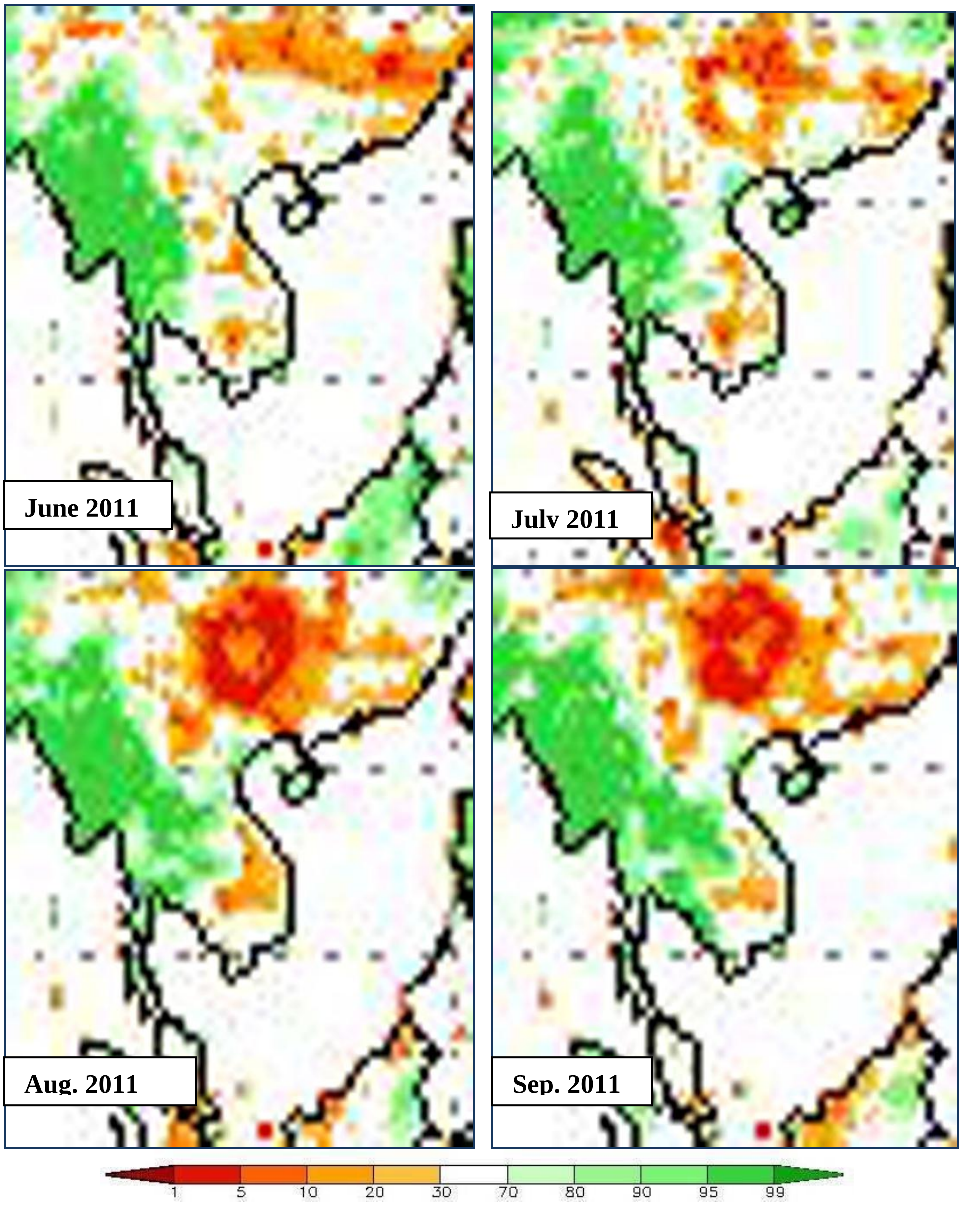


Figure 2.6 Monthly soil moisture ranking percentile from June to September in 2011.

Source: *http://www.cpc.ncep.noaa.gov/*

The spatial variation of rainfall strongly indicates that the intensity of heavy rainfall along the Mekong River from upstream to downstream took place as a function of time. Figure 2.9 shows accumulated rainfall diagrams at 6 representative stations along the Mekong mainstream. These compare the amount of rainfall across the basin during the 2011 flood season with other flood seasons in years of abundant, average and less rainfall. In general, the amount of rainfall in 2011 was above the long-term average, particularly in the area from Nakon Phanom/Thakhek in the middle reach to Kratie in the lower reach which includes the Tonle Sap area and is illustrated by total rainfall at Prek Kdam on the Tonle Sap River. Further downstream in Tan Chau and Chau Doc in the Mekong Delta in Viet Nam, the amount of rainfall was around the long-term average.

The Tropical Storm Haima entered the LMB on 26 June 2011 as a tropical depression. In Thailand, the tropical depression Haima associated storm rainfall of higher than 100mm/day covered the whole area in the northern part, such as Chiang Rai, Nan, Tak, Prea, Sukhothai, Phitsanulok and Pichit. As a result many areas were flooded starting from Yom and Nan River basins, excess volume of water drained down the area and caused floods in areas along its flow path during the end of June to mid of July.

In Lao PDR, the heavy rain affected some tributaries of the LMB, especially tributaries located in the middle part of Lao PDR, such as the Nam Nhiep, Nam Cadine, Nam Sane and Nam Ngum catchments, where water levels rapidly increased 4-5 meters overnight (from 7:00hrs pm 25 June to 7:00hrs am of 26 June). Especially Nam Cadine catchment had faced high risk to flash flood occurrences, which were detected by the MRC Flash Flood Guidance System (MRC FFGS). One week after Tropical Storm Haima passed the LMB low pressure cause heavy rainfall in the central part of Lao PDR, such as Nam Nhiep, Nam Cadine, Nam Sane and Nam Ngum, and flash floods occurred at some tributaries.

Tropical Storm Nock-Ten entered the LMB as a tropical depression. The tropical depression Nock-Ten entered the LMB on 31 July 2011 just a little south of the earlier tropical depression Haima. Heavy rainfall also happened almost in the same area, as earlier affected by Haima, but also included the Northeastern part of Thailand. As a result of saturated soil caused by Haima and heavy rainfall from Nock-Ten many areas in the Northern part of Thailand were flooded and this huge volume of excess water drained to the Gulf of Thailand and flooded areas along its path.

Severe weather conditions occurred in mid-September when strong Southwest Monsoon activity and ITCZ systems appeared frequently. As a result, heavy rain covered both upper and middle parts of the LMB, especially from Luang Prabang to Savannkhet/Mukdahan. Between 12 to 19 September, accumulated rainfall of more than 300mm was recorded at Paksane (360mm), Nong Khai (352.7mm), Thakhek (304mm), Nakon Phanom (357.8mm), Ban Tha Kok Daeng (429.5mm), Ban Phone Si (370.1mm) and Muong Mai (583.4mm). See Table 2.1 below.

Table 2.1 Accumulated recorded rainfall at stations in upper and middle part of the Lower Mekong Basin from 12 to 19 September, 2011

Site	Location	Cumulative rainfall from 12–19 Sep. 2011 in mm
Paksane	W-Central, Lao PDR	360
Nong Khai	NE Thailand	353
Thakhek	W-Central Lao PDR	304
Nakon Phanom	NE Thailand	358
Tha Kok Daeng	NE Thailand	430
Ban Phone Si	W-Central Lao PDR	370
Muong Mai	W-Central Lao PDR	583

See Figure 2.7 for weather maps and rainfall distribution in the LMB for 12-19 September, 2011.

In Lao PDR the ITCZ caused heavy rainfall in the southern part and also in Sekong, Sre Pok and Se San catchments; especially in the Sekong the water levels at the hydrological stations in the upper part of the Sekong catchments increased rapidly from 3.30m at 7:00hrs am on 23 September to 8.90m at 7:00hrs am on 24 September 2011. The MRC FFGS detected during the last week of September high risk areas to flash floods in the middle part of the LMB, such as Se Bang Hieng, Sekong and Se San catchments.

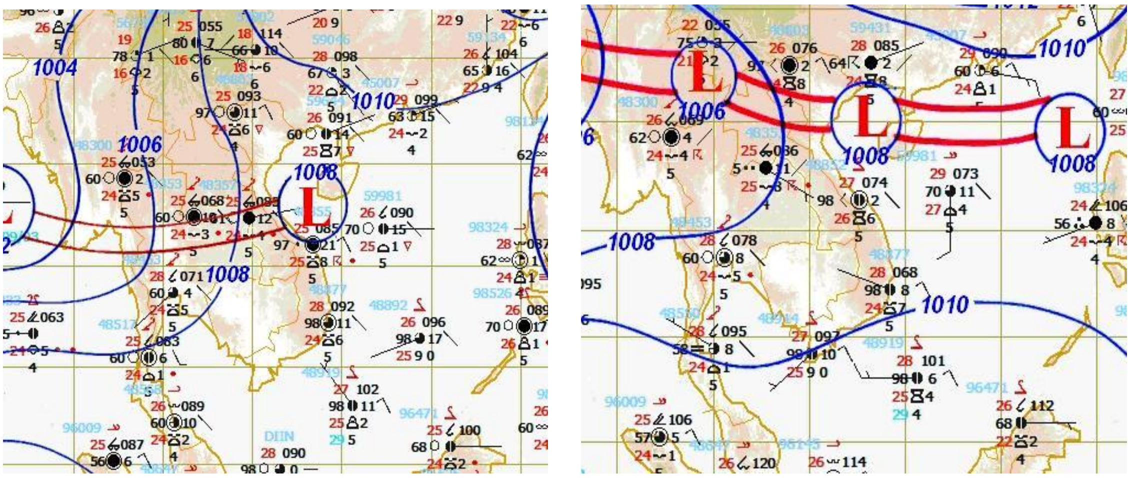


Figure 2.7 Weather maps for 12-19 September, 2011

Source: *Thai Meteorological Department.*

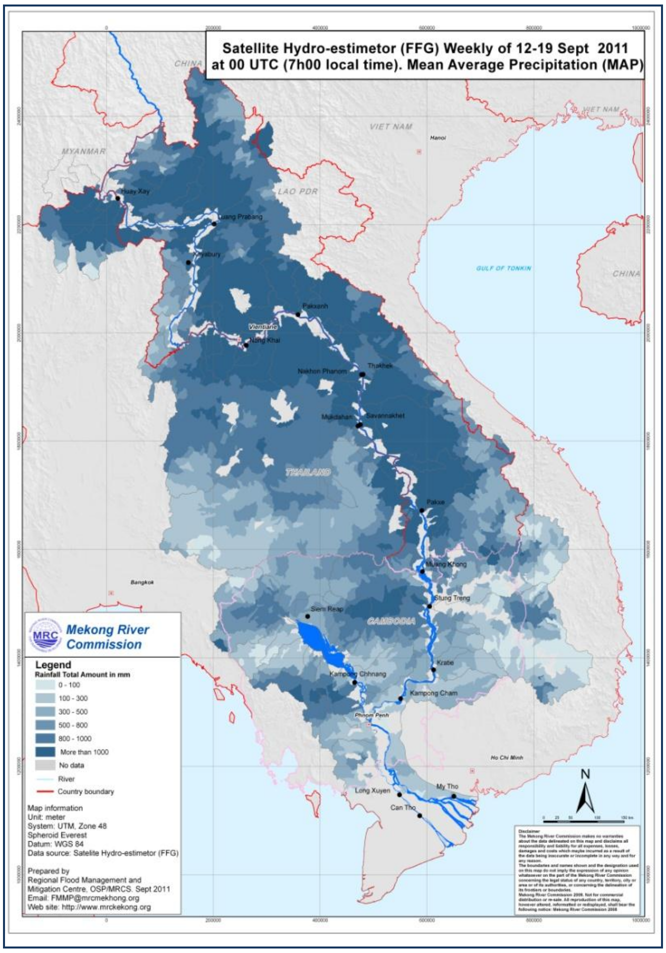


Figure 2.8 Rainfall distributions over the LMB, for 12–19 September, 2011

Source: *https://ffg.mrcmekong.org/MRCFFG/ MRC Flash Flood Guidance System*

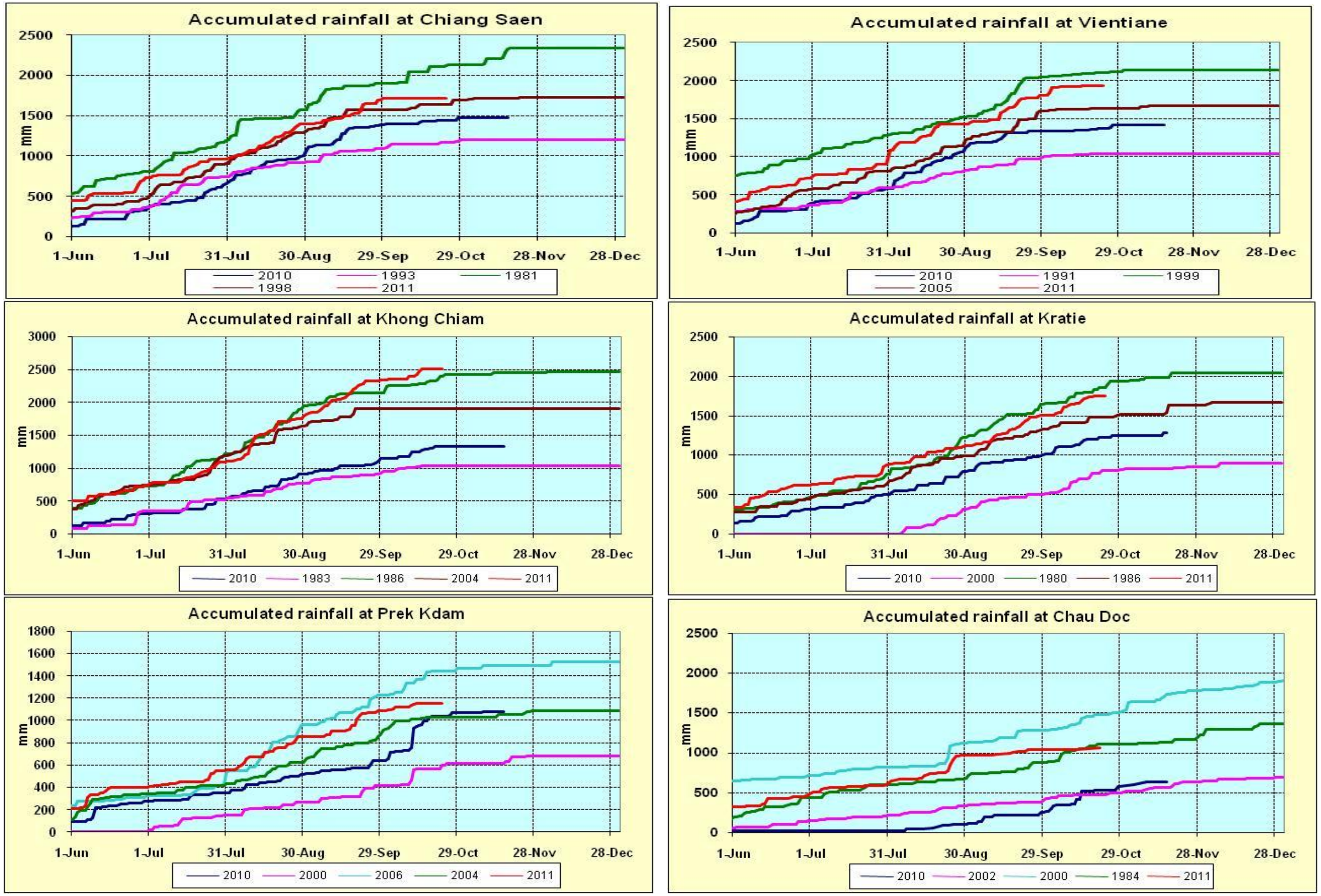


Figure 2.9 Diagrams of accumulated rainfall at 6 representative stations along the Mekong mainstream from upstream to downstream.

3. El Niño and La Niña

Both El Niño and La Niña impact global climate patterns. In many locations, especially in the tropics, La Niña (cold episodes) produces the opposite climate variations from El Niño (warm episodes). For instance, parts of Indonesia and Australia (and according to the Annual Mekong Flood Report 2010, the Mekong region as well) are prone to drought during El Niño. These regions are typically wetter than normal during La Niña. This year has been a strong La Niña, being significantly wetter than the eight previous years, which were relatively dry. Based on the lack of data correlation for the benchmark station of Kratie, however, the Annual Flood Report 2010 concluded that there was no consistency between La Niña and the climate of the Mekong region. Special attention has nevertheless been given this year to the developments and values of La Niña and El Niño/Southern Oscillation (ENSO).

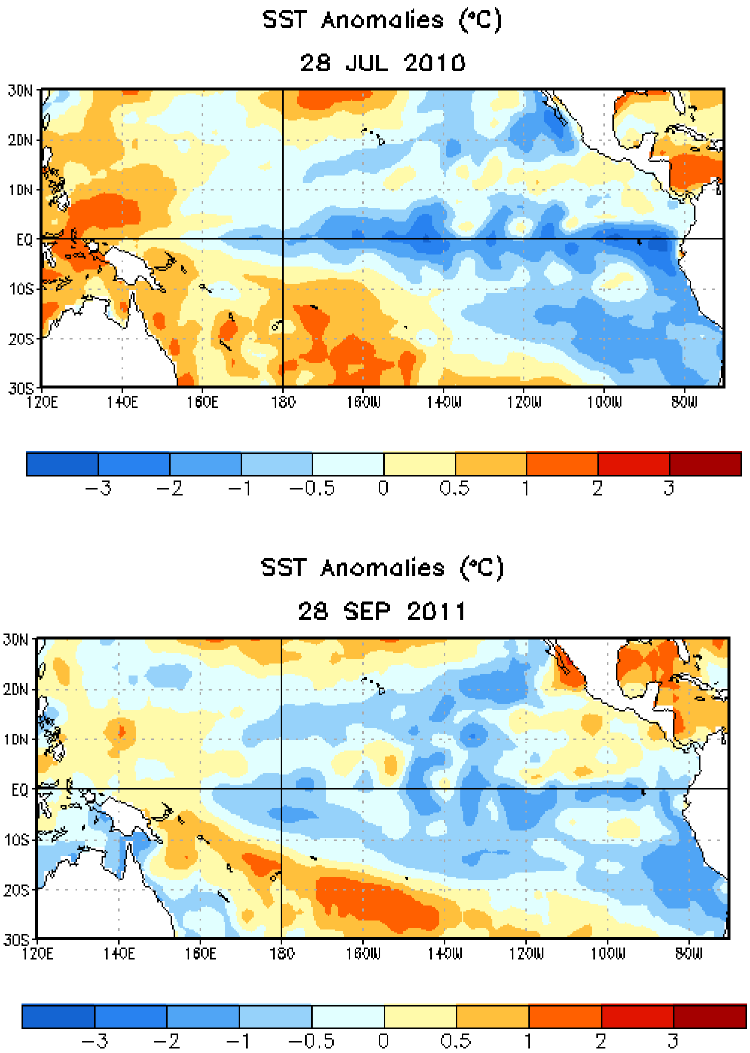


Figure 3.1 Average sea surface temperature (SST) anomalies (°C) for the week centered on 28 July 2010 and 28 September 2011. Anomalies are computed with respect to the 1971-2000 base period weekly means (Xue et al. 2003, *J. Climate*, 1601-1612).

Source: *Climate Prediction Center, NOAA, USA.*

Starting in July 2010, La Niña conditions continued until October 2011, although they were intercepted by ENSO-neutral conditions in June-July 2011 (see Figure 3.1 Figure 3.1).

In September 2011, La Niña conditions strengthened, as indicated by increasingly negative sea surface temperature (SST) anomalies across the eastern half of the equatorial Pacific Ocean. The weekly El Niño indices continued cooling and were all at or below –0.5°C in October. Consistent with this cooling, oceanic heat content (average temperature anomalies in the upper 300m of the ocean) remained below average in response to a shallower thermocline across the eastern Pacific Ocean. Also, convection continued to be suppressed near the International Date Line, and became more enhanced near Papua New Guinea. In addition, anomalous low-level easterly and upper-level westerly winds persisted over the central tropical Pacific. Collectively, these oceanic and atmospheric patterns reflect the continuation of La Niña conditions.

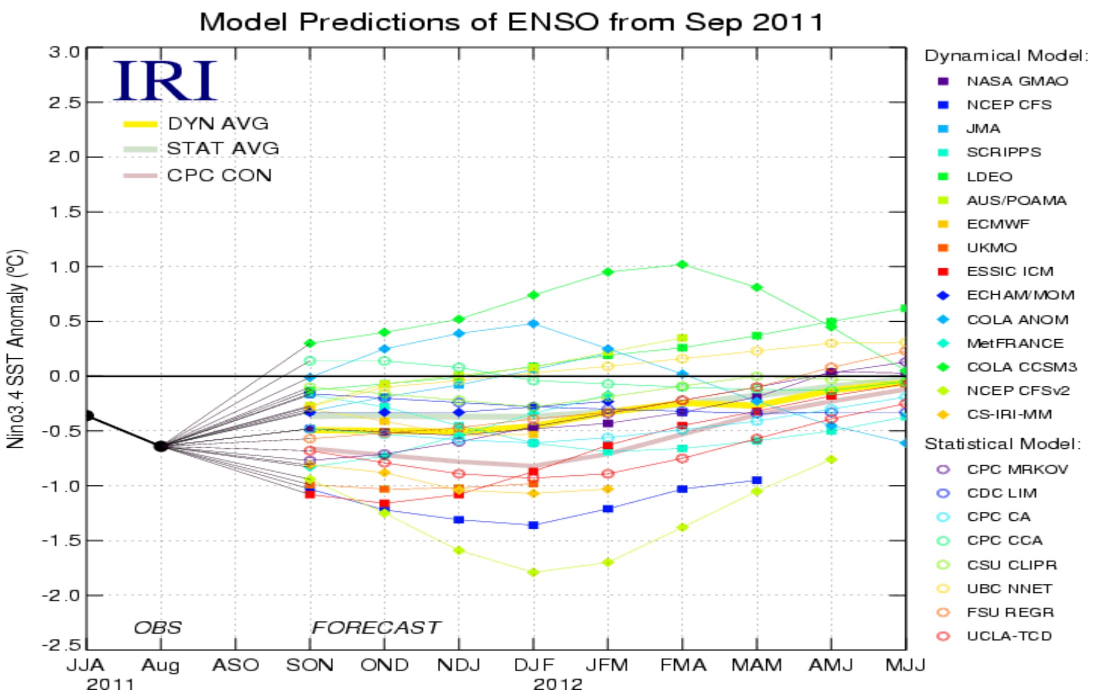


Figure 3.2 Forecasts of sea surface temperature (SST) anomalies for the Niño 3.4 region (5°N-5°S, 120°W-170°W). Figure courtesy of the International Research Institute (IRI) for Climate and Society. The Figure is updated on 13 September 2011.

Source: *Climate Prediction Center, NOAA, USA.*

As of October, La Niña was not as strong as it was in September 2010. About half of the models predict that La Niña will strengthen during the Northern Hemisphere autumn and winter (see Figure 3.2). Of these models, most predict a weak La Niña (3-month average in the Nino-3.4 region less than -0.9°C). In addition, weaker second La Niña winters have occurred in three of the five multi-year La Niñas in the historical SST record since 1950.

However, the NCEP Climate Forecast System (CFS.v1) predicts a moderate-strength La Niña this winter (between –1.0°C to –1.4°C) and CFS.v2 predicts a strong La Niña (less than –1.5°C), which rivals last year's peak strength. For CFS forecasts made at this time of year, the average error for December-February is roughly ±0.5°C, so there is uncertainty as to whether this amplitude will be achieved. Thus, at this time, a weak or moderate strength La Niña is most likely during the Northern Hemisphere winter. See for information regarding FMMP's anticipation of a wet flood season 2011 the last paragraph of Section 10 of this report.

Although the relationship of the observed annual flood peak and volume observed for the years 1924 to 2010 with the El Niño / La Niña years for the benchmark station Kratie is “neither straightforward nor consistent” (ref. Dr. P. Adamson, Annual Mekong Flood Report 2010) the Year 2011 flood coincided with relatively strong La Niña conditions. The monitoring of eventual El Niño / La Niña conditions during the dry season and flood season to anticipate higher or lower flows in the Mekong River is therefore to be continued.

4. Water levels

The 2011 flood season started in the upper reach reasonably close to the historic averages. At Kratie, the season started roughly 5 weeks earlier than in 2010; the flood peak was roughly one week later than the peaks in both 2010 and 2000. The season ended in the upper reach roughly 2 weeks early, which is still within the normal range; in the lower reach, the end of the season could not be confirmed as of the end of October.

These starting dates (onsets) and end dates are defined in the usual way, as shown in Figure 4.1. On this basis, the two dates become random variables from year to year. Reference is made to Annual Mekong Flood Reports including those with Dr. P.T. Adamson as contributing author.

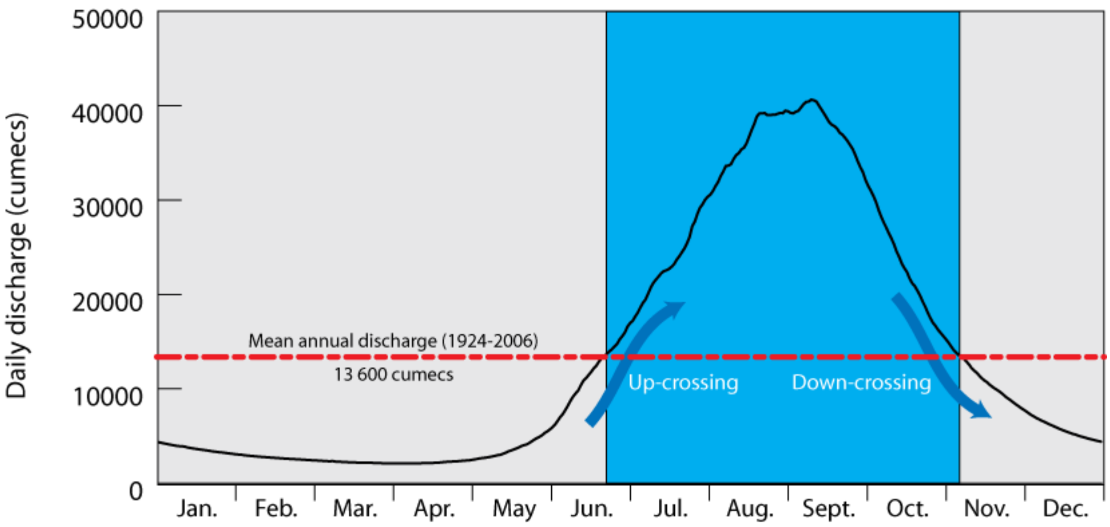


Figure 4.1 Definition of the flood season, with the mean annual hydrograph at Kratie as the example. The onset is the date of the up-crossing of the long term mean annual discharge (or water level) and the end, the down-crossing. In a typical year, there is only one such crossing in each case.

Table 4.1 provides the onset and end of the flood season 2011, compared to the historical averages for some locations along the mainstream.

Table 4.1 Onset and End dates of the 2011 flood season compared to their historical mean and standard deviation at selected mainstream stations.

Site	Onset of flood season			End of flood season		
	Historical average	Standard deviation	2011[3]	Historical average	Standard deviation	2011[4]
Chiang Saen	28th June	13 days	27th June	14th Nov	14 days	4th Oct
Vientiane	3rd July	14 days	26th June	11th Nov	15 days	23rd Oct
Pakse	29th June	16 days	26th June	5th Nov	11 days	23rd Oct
Kratie	1st July	16 days	20th June	7th Nov	12 days	Tbd
Phnom Penh	10th July	14 days	1st July	15th Dec	14 days	Tbd
Chau Doc	23rd July	17 days	6th Aug	19th Dec	12 days	Tbd

[3] Onset dates are estimates; more accurate details will be provided in the Annual Mekong Flood Report 2011.
[4] End dates are estimates; more accurate details will be provided in the Annual Mekong Flood Report 2011.

Water levels during 2011 were among the lowest in 10 years in Jing Hong, China, which reduced negative flood impacts downstream (see Figure 4.2). Water levels were close to average in Chiang Saen and above average from Vientiane downwards. The highest water levels in 2011 occurred at the end of September in Stung Treng, Kratie and Kampong Cham.

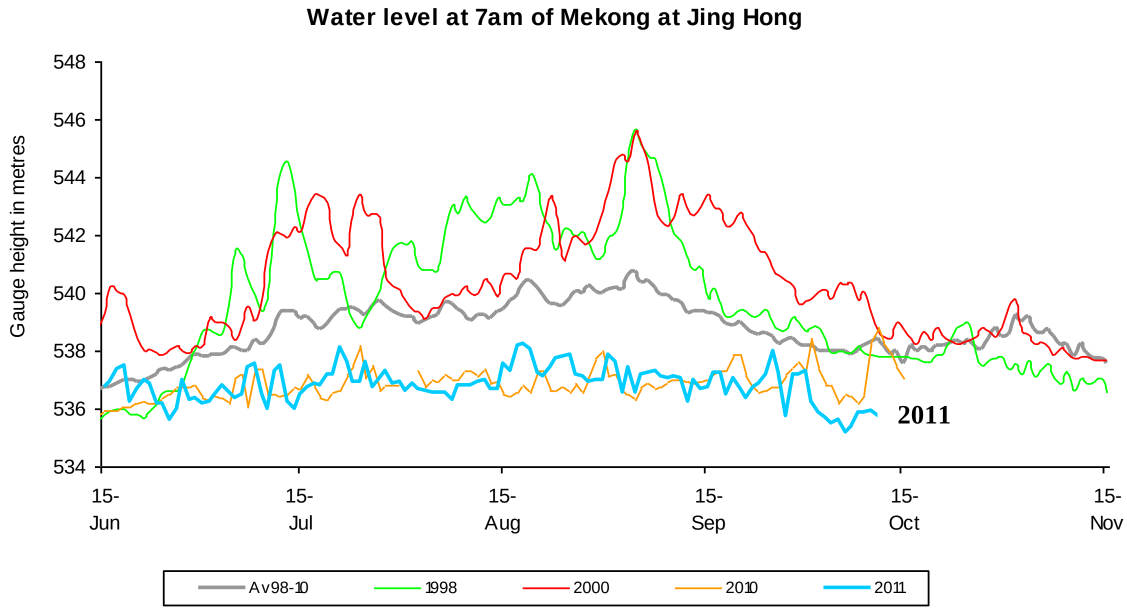


Figure 4.2 Water levels at Jing Hong from 15 June to 15 October, 2011

In the Cambodian floodplain and the Mekong Delta in Viet Nam, water levels remained above average from June to September and October. During the third week of September, floodwaters reached critical levels in Phnom Penh, Neak Luong and Koh Khel. Water levels in Tan Chau and Chau Doc peaked a few days later and persisted at first before receding gradually.

At Kratie, the water level rose steadily in July as river flows increased, especially as a result of Tropical Storm Nock-Ten. On 13 August, it reached 21.79m and then fell to 19.48m on 7 September. As a result of the strong Southwest Monsoon and ITCZ activity, the water level resumed rising, reaching 21.80m on 12 September and a record 22.88m on 24 September. This was 0.9m higher than the highest level recorded in 2000, although the flood stage level of 23.00 was not exceeded (see Figure 4.3).

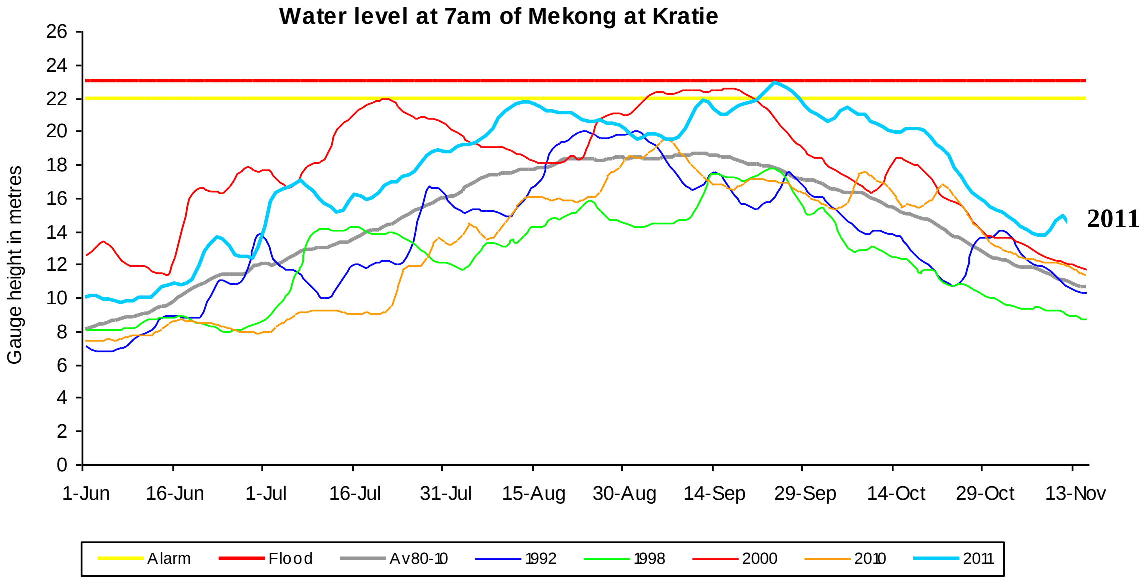


Figure 4.3 Water levels at Kratie from 1 June to 14 November, 2011

At the Chaktomuk/Bassac gauge station in Phnom Penh, the water level rose from 6m on 16 July to 9.47m on 15 August. There were few fluctuations until 9 September, when it started rising again, reaching 10.85m on 28 September. The water level remained 0.35m below the peak in 2000 and 1.15m below the flood stage level of 12.00m for Phnom Penh. Elsewhere on the Cambodian floodplain, flood stage levels were exceeded at Neak Luong and Prek Kdam but were not as high as the peak levels in 2000.

Water levels also exceeded flood stage levels in the Mekong Delta in Viet Nam. At Tan Chau, on the Mekong's main branch (Tien Giang) in Viet Nam, the flood stage level of 4.53m was reached on September 25. The water level rose further to 4.78m on 10 October before receding slowly. In neighbouring Chau Doc, on the Bassac River (Hau Giang), the waters started overtopping the flood stage level of 4.00m on 26 September, rising further to reach 4.24m on 8 October before falling gradually (see Figure 4.6).

In Kampong Cham and Kratie, the peak water levels were slightly higher than those recorded in 2000 but did not reach flood stage levels. In Kampong Cham, it was 0.1m higher than the 2000 level but did not exceed the flood stage level (see Figure 4.5).

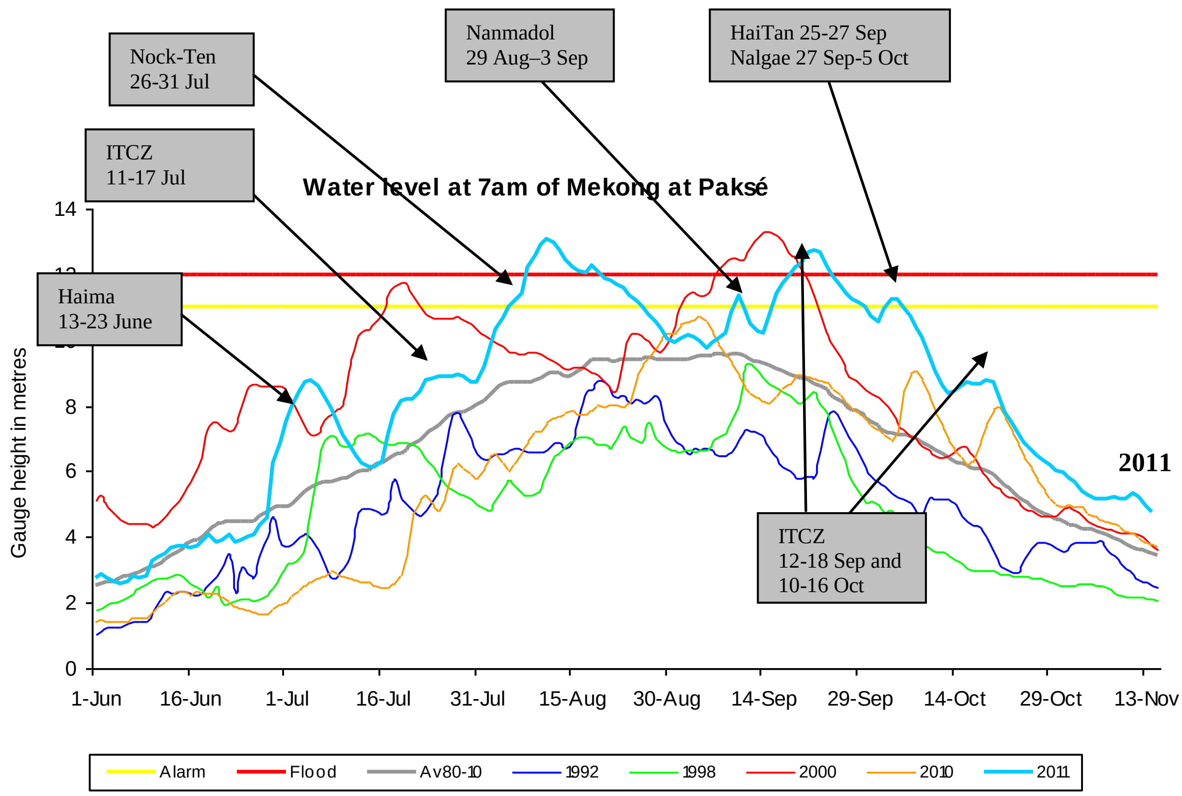


Figure 4.4 Water levels at Pakse from 1 June to 14 November, 2011

In the middle reach of the Lower Mekong Basin in Lao PDR and Thailand, the flood stage levels at Mukdahan and Pakse were exceeded during the 2011 flood season. At Pakse, overtopping occurred twice, causing substantial flooding. The first peak of 13.11m was on 11 August and the second of 12.72m was on 22 September. The first peak was 0.23m lower than the highest level in 2000. Overtopping lasted 16 days, from 8 to 19 August and from 19 to 24 September. The relationship between water levels and various meteorological events in Pakse is in Figure 4.4.

At all other gauge stations, water levels stayed under the levels of 2000. While flood stage levels at many gauge stations were not reached, flooding in many places with lower crest levels of embankments or dykes led to severe flooding in the Cambodian floodplain and the Mekong Delta in Viet Nam. Water levels at Prek Kdam, Tan Chau and Chau Doc exceeded the flood stage level from the last week of September and remained high until the last week of October.

Water levels at Koh Khel and Neak Luong showed a similar pattern but remained below the flood stage level of the gauge stations. The number of days that the flood stage level was exceeded in Pakse was comparable to 2000, although there were two peaks instead of one.

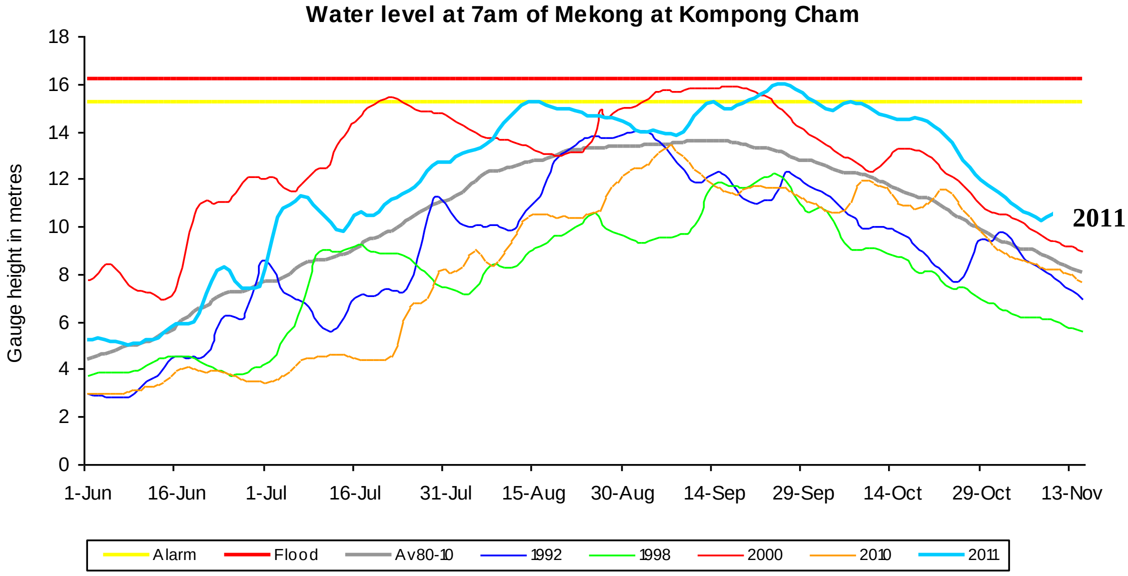


Figure 4.5 Water levels at Kampong Cham from 1 June to 14 November, 2011

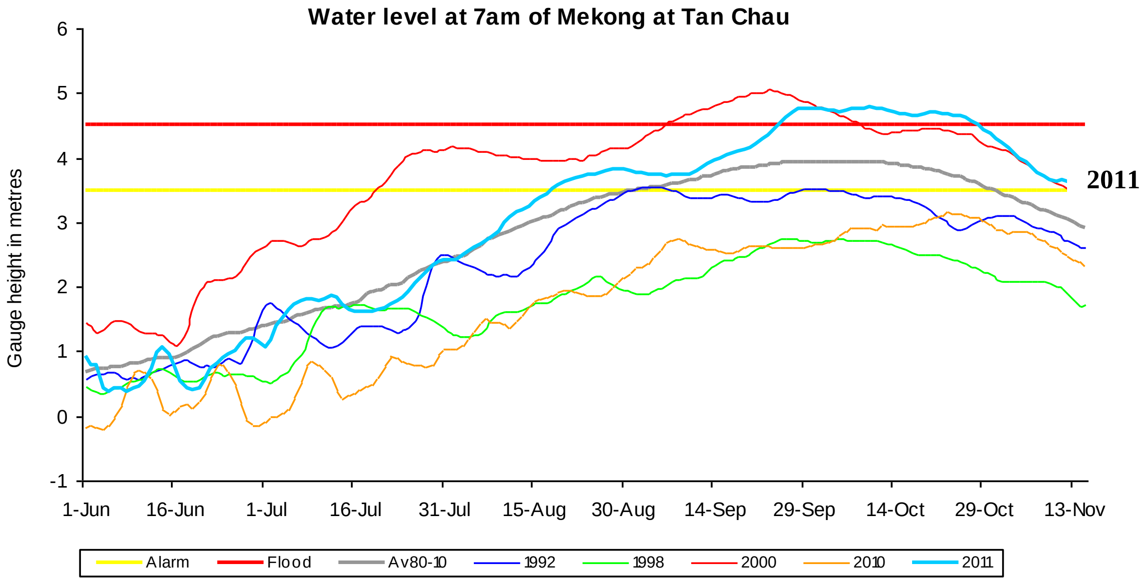


Figure 4.6 Water levels at Tan Chau from 1 June to 14 November, 2011

Only the water levels in Kampong Cham and Kratie exceeded the maximum levels in 2000. An overview of historic flood levels in 1978, 1996, 2000 and 2011 is presented for the major gauge stations in the Cambodian floodplain and the Mekong Delta in Table 4.2.

Table 4.2 Comparative maximum historical flood water levels at Stung Treng, Kratie, Phnom Penh, Neak Luong, Tan Chau and Chau Doc ("orange/brown" = flood level reached or overtopped; "yellow" alarm level reached or crossed).

Comparative maximum historical flood water levels in the Cambodian floodplain and Mekong delta area							
Gauge station / flood level	**Stung Treng FL=12.00m**	**Kratie FL=23.00m**	**Kampong Cham FL=16.20m**	**Phnom Penh Chaktomuk FL=12.00m**	**Neak Luong FL=8.00m**	**Tan Chau FL=4.50m**	**Chau Doc FL=4.00m**
1978[5]	17.08.1978 12.10m	19.08.1978 22.13m	17.08.1978 **16.83m**	No record available	20.08.1978 7.87m	03.10.1978 4.78m	10.10.1978 4.44
1996	24.09.1996 **12.19m**	28.09.1998 **23.02m**	29.09.1996 16.11	02.10.1996 10.9m	02.10.1996 8.00m	05.10.1996 4.86m	07.10.1996 4.54m
2000	16.09.2000 11.48m	17.09.2000 22.6m	18.09.2000 15.91m	19.09.2000 **11.20m**	20.09.2000 **8.12m**	23.09.2000 **5.05m**	23.09.2000 **4.89m**
2011	23.09.2011 11.25m	24.09.2011 22.88m	25.09.2011 16.02m	28.09.2011 10.85m	29.09.2011 8.06m	09.10.2011 4.77m	03.10.2011 4.18m

Water levels in Nakhon Panhom, Thakhek, Savannaket, Mukdahan and Pakse peaked twice, reflecting the impact of Tropical Storm Nock-Ten in mid-August and the combined impact of the Southwest Monsoon and the ITCZ in late September.

The maximum water level in Kratie in 2010 was 19.6m and was reached on 16 September. In 2011, the higher peak of 22.9m was a week later on 24 September.

While water levels at Stung Treng, Kratie and Kampong Cham fell after reaching their peaks, those at Phnom Penh, Koh Khel, Tan Chau and Chau Doc persisted and were very slow to recede. This may have been caused by additional rainfall over the catchments of the Tonle Sap Lake in October, which would have contributed to higher discharges of the Tonle Sap River (around 10,000 cumecs) into the Mekong mainstream. Another factor may have been the reduced storage and discharge capacity of the Cambodian floodplain and Mekong Delta in Viet Nam, arising from land-use changes, infrastructure development and urbanization since 2000. It is recommended to investigate this phenomenon, which is transboundary in nature, taking into account the potential impacts of climate change and rising sea levels.

[5] During the Khmer Rouge regime the hydrological station in Cambodia did not function. Water levels have been estimated through DSF gap-filling (reference is made to Working Paper 01 of the Water Utilization Programme – A).

5. Flood discharges

With the exception of the benchmark station at Kratie, the final flood discharge data at the various gauge stations in 2011 are not yet available since further evaluation and verification of the rating curves are required. The maximum discharge at Kratie[6], estimated at 63,250 cumecs, was reached on 24 September compared with 57,000 cumecs in 2000. The mean annual flood peak discharge in 2011 is 52,000 cumecs. The 2011maximum discharge therefore ranks among the most extreme discharges.

[6] The rating curve 2006 has been used for the discharge calculations. IKMP and FMMP are in the process of updating the rating curves in the Mekong FFS. Consolidated figures will be presented in the Annual Mekong Flood Report 2011.

6. Flood volumes

Flood volume is the best indicator of the potential duration of the inundation and the severity of flooding in the Cambodian floodplain and the Mekong Delta in Viet Nam.

Flood volumes in 2011 were considerably below average in Jinghong in China. While volumes between Chiang Sean and Luang Prabang were average, they were significantly above average from Chiang Khan to Tan Chau. Detailed figures for 2011 will be presented in the Annual Flood Report.

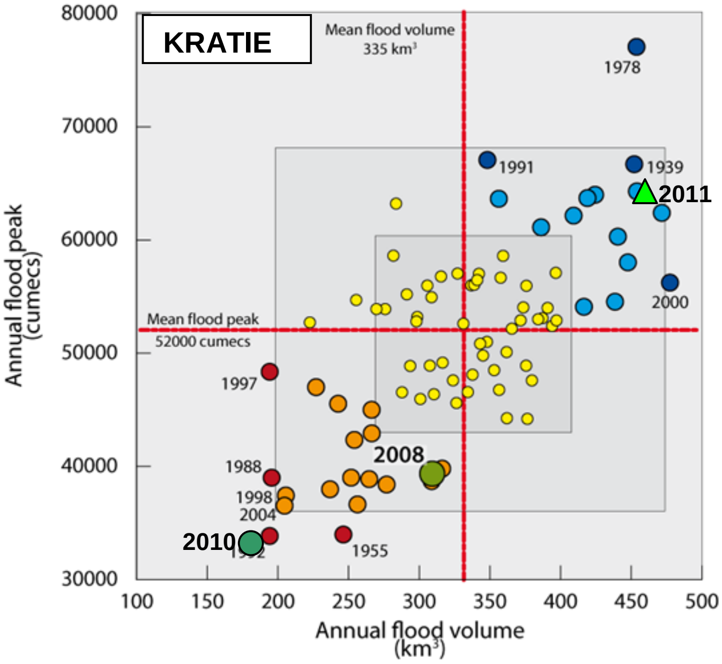


Figure 6.1 Scatterplot of the joint distribution of the annual maximum flood discharge (cumecs) and the volume of the annual flood hydrograph (km^3) at Kratie on the Mekong mainstream. The 'boxes' indicate one (1δ) and two (2δ) standard deviations for each variable above and below their respective means. Events outside of the 1δ box might be defined as *significant* flood years and those outside of the 2δ box as historically *extreme* flood years.

In 2000, the flood volume at Kratie was roughly 475 km^3 between 16 June and 8 November. In the 2010 season, the volume of 193.1 km^3 was less than that of 1992, which was regarded as the most severe drought on record. Based on an approximation of the end of the 2011 flood season, the calculated volume was 460 km^3 which is 37% higher than the long-term average for Kratie of 335 km^3. See the "green" triangular 2011 plot in Figure 6.1. This plot brings the 2011 flood at the "benchmark" station Kratie in terms of flood peak and flood volume close to the recorded *extreme* flood years on record.

7. Risk of occurrence

Runoff from China in 2011 was much lower than average during the entire flood season, indicating that rainfall throughout the Lower Mekong Basin was responsible for both the flood and flooding. For the purpose of this Flood Situation Report the risk of occurrence is estimated for the benchmark station Kratie only.

The peak discharge at Kratie has been estimated in 63,250 cumecs and the flood volume at roughly 460 km^3. Both values rank among the higher values recorded.

Table 7.1 Recurrence intervals annual flood peak for Kratie (1924-2006)[7].

	Recurrence Interval (years)					
Annual flood peak (cumecs)	2	5	10	20	50	100
	52,000	58,000	63,000	68,000	74,000	78,500

Table 7.2 Recurrence intervals annual flood volume for Kratie (1924-2006)[8].

	Recurrence Interval (years)					
Annual flood volume (km^3)	2	5	10	20	50	100
	333.7	394.2	424.6	447.5	470.6	483.4

The return period for the combination of peak discharge and flood volume at the benchmark station of Kratie is estimated in once every 10-20 years (see Tables 7.1 and 7.2).

[7] Yet to be adjusted to period 1924-2011
[8] Yet to be adjusted to period 1924-2011

8. Prospects for the rest of the 2011 flood season

By the end of October, water levels were falling at all gauge stations along the Mekong River. The water levels on the Cambodian floodplain and the Mekong Delta in Viet Nam were remarkably slower retreating than in 2000. Moreover, the end of the season was expected to be rather late compared to both 2000 and 2010. At Kratie, the season ended on 2 November in 2010 (5 days early). The end of the 2011 season was expected to be delayed until after 7 November, the historical average for Kratie.

The spring tide of the South China Sea was forecast to have temporarily impounded discharges from the Cambodia floodplain and the Mekong Delta in Viet Nam by the end of October. This was expected to have created a few days of higher water levels in the delta, the highest at along the coast and gradually reducing towards Phnom Penh.

9. Damage

All MRC Member Countries were badly affected by the tropical depressions related to the Tropical Storms Haima and Nock-Ten in June and July, low-pressure occurrences due to the Inter-Tropical Convergence Zone in September and October, and more rainfall from Typhoon Nalgae and Tropical Storm Haitang in October. Flash floods triggered landslides while tributary and mainstream floods caused widespread inundation, devastating Mekong communities and resulting in substantial loss of life and damages to property, infrastructure and rice fields.

The following is a first impression of the damages and losses caused by floods and flooding in the latest season. A more complete and accurate overview will be presented in the Annual Flood Report 2011 for which MRC Member Countries will be consulted.

Cambodia

The flood in 2011 will be recorded as the worst since 2000. As the Flood Situation Report was being prepared in October, the water levels in the Cambodian floodplain and the Mekong Delta were slowly falling, making the presentation of comprehensive damage assessments premature. In late October, the *Cambodia Daily* mentioned a death toll of 247. The National Committee for Disaster Management of Cambodia estimated the cost of destruction at $521 million with 220,000 ha of rice fields destroyed.

The damage assessment in 2000 was considered a “best guess” by national, provincial and district governments, national and international organizations and NGO’s. Since 2000, the guidelines for damage assessment have been improved, standards upgraded and the first signs are that the assessments in 2011 will have a substantially higher real value.

Lao PDR

In a 12 July report, the National Disaster Management Office (NDMO) of Lao PDR, with the support of the UN Resident Coordinator, described the losses and damages due to flooding caused by Tropical Storm Haima. The provinces of Xayabury, Vientiane, Xiangkhouang, Bolikhamxay and Khammouane were hardest hit. The report mentioned at least ten confirmed casualties and four children missing. The value of losses and damages was estimated at LAK 513 billion at least (roughly $65 million).

Thailand

The flooding in Thailand has been ranked as being among the worst ever. Northern and Central Thailand suffered many casualties and massive losses and damages due to heavy rainfall flooding, caused by remnants of Tropical Storm Nock-Ten, and heavy monsoonal rains which extended over a long period, affected by La Niña. Flooding was triggered in northern Thailand in late July and early August and floodwaters overflowed the Yom and Nan rivers. Affected were the northern provinces of Bung Kan, Chiang Mai, Lampang, Lamphun, Mae Hong Son, Nan, Phrae, Uttaradit, and the northeastern provinces of Nakhon Phanom, Nong Khai, Sakon Nakhon and Udon Thani, the latter being part of the Lower Mekong Basin.

Floodwaters moved downstream and inundated the upper central provinces of Phichit, Phisanulok and Sokhothai. By September, floodwaters were continuing to flow downstream, reaching the outskirts of Bangkok in October. The three months of flooding reportedly resulted in more than 500 deaths. Around 800,000 homes across the country were destroyed or damaged, forcing several huge industrial estates in central regions to close. Sixty-one of Thailand’s 77 provinces were reportedly affected.

Around Bangkok, the provinces of Ayutthaya, Pathum Thani and Nakhon Sawan to the north were particularly badly hit. A third of the country was underwater at one stage. Officials estimated the floods affected more than 8 million people and caused economic damage of up to $5 billion. The floods were also expected to impact reinsurers, with the Office of Insurance Commission (OIC) giving a preliminary loss estimate of around $650 million for damages at major industrial estates in Ayutthaya province alone.

Viet Nam

On 20 October, the UN presented its Situation Report No. 10 for flooding in the Mekong Delta and Central Viet Nam. The reports covered casualties, damages and losses jointly for both regions, without disclosing separately the impacts for the Mekong Delta.

By mid-October, according to Vietnam News Agency (VNA), the National Steering Committee for Flood and Storm Prevention and Control was estimating that flooding in the Mekong Delta had killed at least 43 people of whom 38 were children. Dong Thap province was the hardest hit, with 15 victims, followed by An Giang, Can Tho, Long An and Kien Giang. Floods had inundated nearly 70,000 houses, over 18,000 ha of rice fields and nearly 3,700ha of subsidiary crops. Losses were estimated at more than $52.8 million.

10. Performance of the Regional Flood Management and Mitigation Centre flood forecasting

MRC forecasts during the 2011 flood season have generally been satisfactory, although not always up to the desired standards as there is insufficient knowledge and experience in using the MRC's Mekong Flood Forecasting System (Mekong FFS). Since not all forecasters are at the same level, the Flood Management and Mitigation Programme has organised training by international experts to bridge the gap.

The forecasts in the crucial period from 21 to 24 September from MRC and the Department of Hydrology and River Works (DHRW) of MOWRAM are presented in Figures 10.1 - 10.5 for the gauge stations Stung Treng, Kratie, Kampong Cham, Phnom Penh Chaktomuk and Neak Luong. Benchmark values, which have been recommended to MRC/RFMMC, are presented around the observed water levels. The forecast water levels for 1 to 3 days of MOWRAM and for 1 to 5 days of MRC can be compared.

Rising water levels and the peak of 11.25m in Stung Treng were not well captured by MRC forecasts, nor the DHRW forecast on 21 September. Estimates were too low. The adjusted value by DHRW for the 1-day forecast on 22 September was accurate while MRC's adjustment was heavily overestimated.

The water level rise and peak in Kratie of 22.88m was best forecast by MRC for the 1 3, 4 and 5-day forecasts on 21 September. The 2-day forecast was not close enough. Adjustments by MRC and DHRW on 22 September did not capture well the water levels for the 1 and 2-day forecasts.

MRC forecasts for all five days were outside the set benchmark values. The 3-day DHRW forecast was, however, within the benchmark range.

The water level rise and peak at 16.02m in Kampong Cham were properly forecast by DHRW for 1, 2 and 3 days on 21 September. MRC missed the 1, 3, 4 and 5-day benchmark boundaries; only the 2-day forecast was acceptable. The rise and peak for Phnom Penh Chaktomuk and Neak Luong on 21, 22 and 23 September was satisfactory for MRC and DHRW alike.

The DHWR forecasts were much closer to the recorded values for the 1, 2 and 3-day forecasts for Stung Treng and Kratie. The MRC forecasts were off as they did not capture the downward trend of the water level, especially at Stung Treng and Kratie for the 1, 2, 3, 4 and 5 days, due to the use of iSIS model values instead of Regression values.

At Kampong Cham, forecasts provided good results on 21 September, although the results of MRC and DHRW forecasts on September 22, 23 and 24 did not capture the downward trend of the water level. Accurate forecasting of critical flood situations remains a challenge; this goes especially for the flood peak build-up and flood peak passage for Stung Treng and Kratie. Bank overflows upstream or downstream of the gauge station locations may have contributed to fluctuations of water levels.

The occurrence of peak levels at Phnom Penh Chaktomuk and Neak Luong seem to have been delayed by one to two days, with the high flood levels slow to recede. This is most likely the result of relatively high inflows from the Tonle Sap Lake into the mainstream. It could also point to a reduction of downstream storage and discharge capacity in the Cambodian floodplain and Mekong Delta. Such a potential reduction should be further investigated for present and for future conditions.

The RFMMC has carried out an in-depth analysis internally. The Mekong FFS also provided Regression with corrected SRE values with remarkably good results during the critical period. However, these were not used for the forecast.

How good could have been the MRC forecasts?

Simulations have been carried out for the critical period 21-24 September for four reference stations in Cambodia. The total number of forecast points (1-5 days) during the period 21-24 September for the 4 stations of reference is 100.

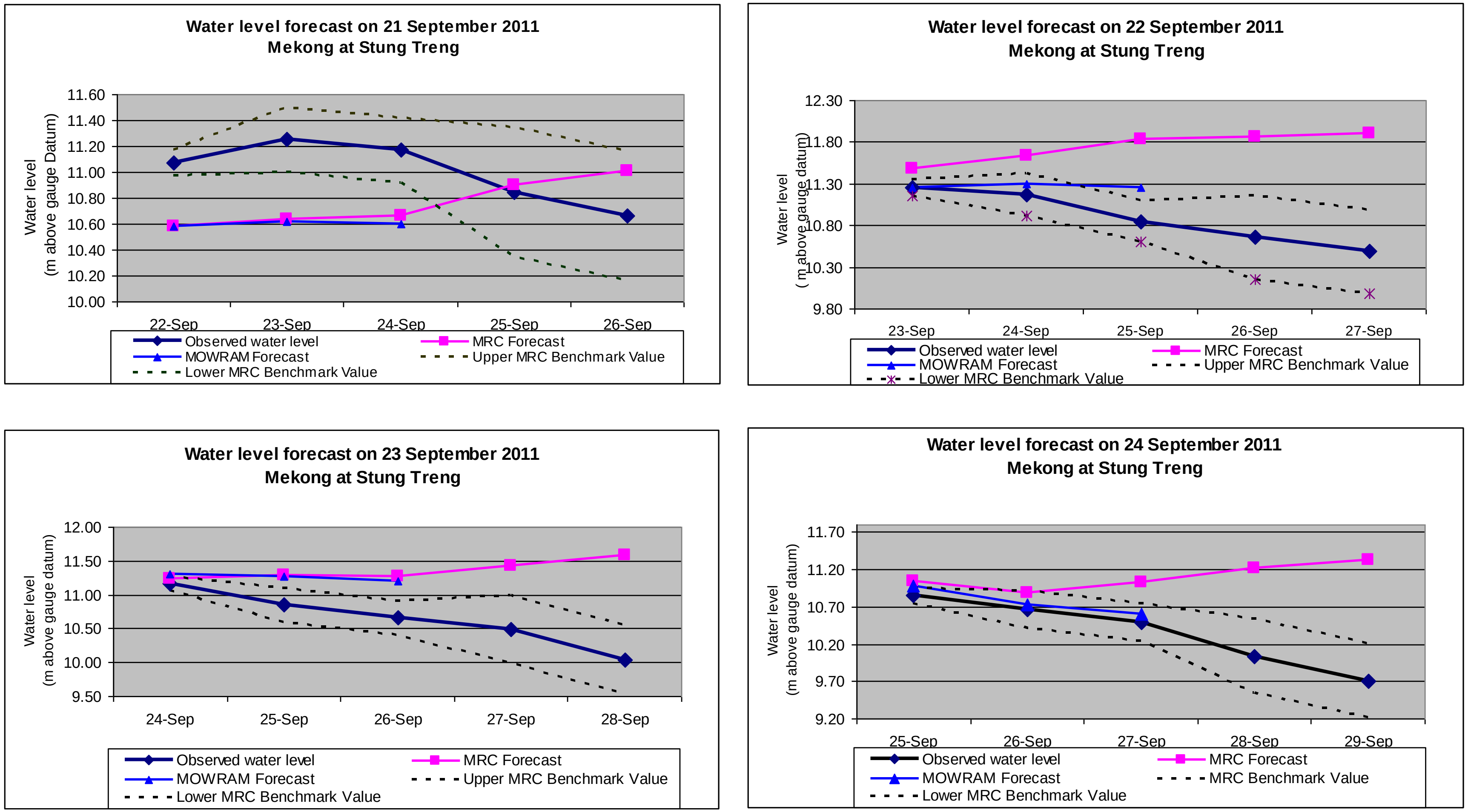


Figure 10.1 Stung Treng, 3-day MOWRAM forecast and 5-day MRC forecast on 21-24 September, 2011

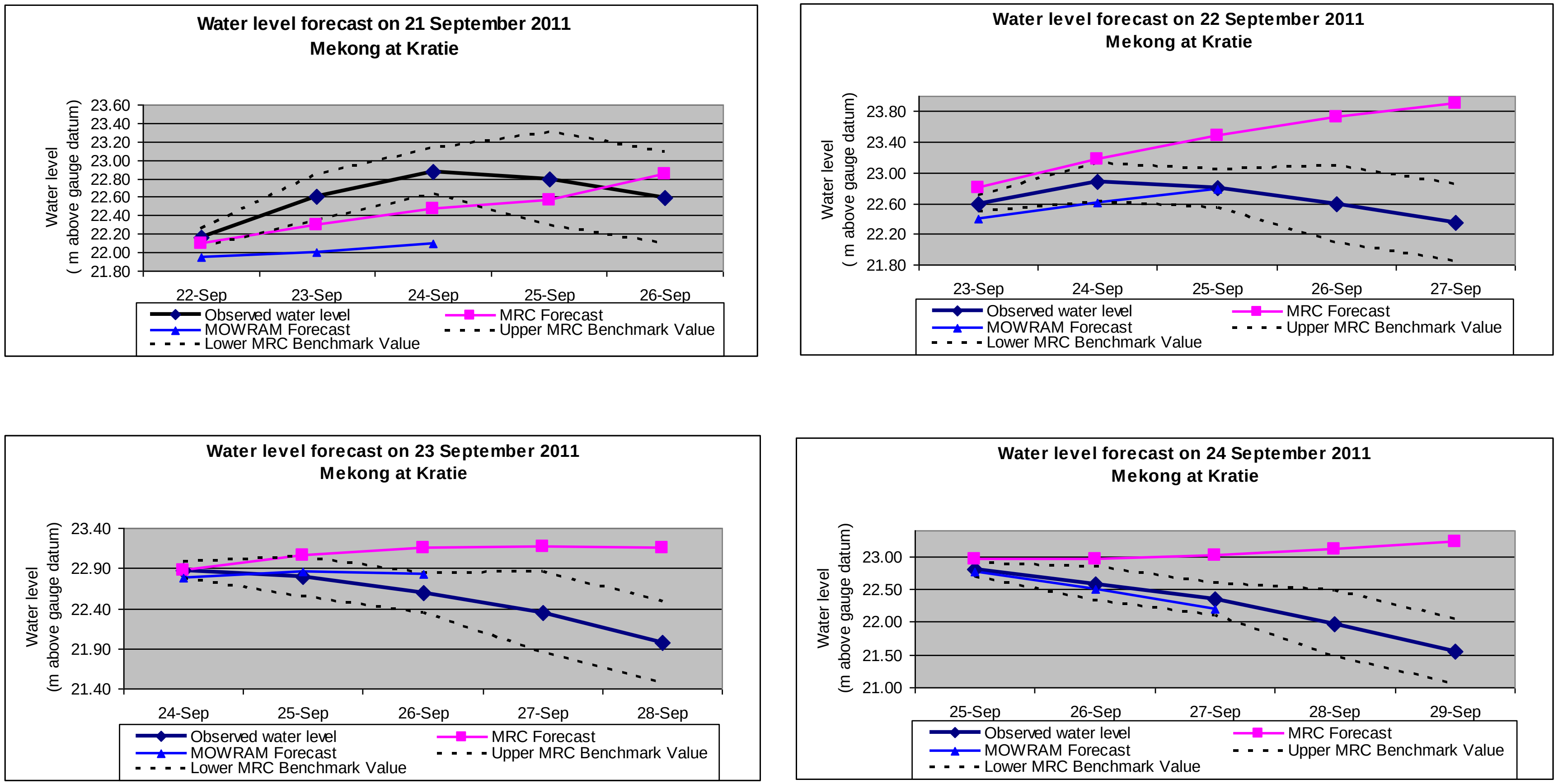


Figure 10.2 Kratie, 3-day MOWRAM forecast and 5-day MRC forecast on 21-24 September, 2011

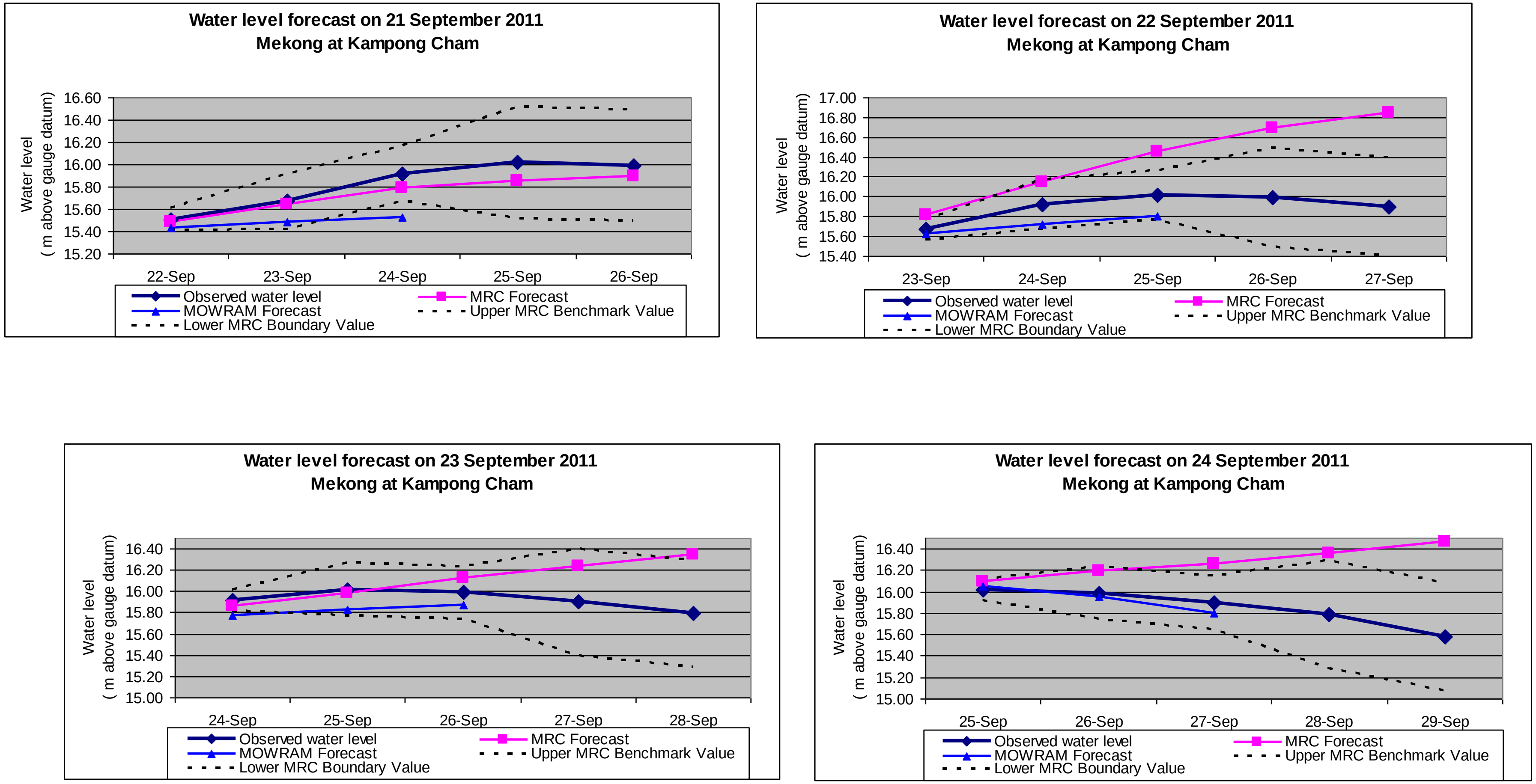
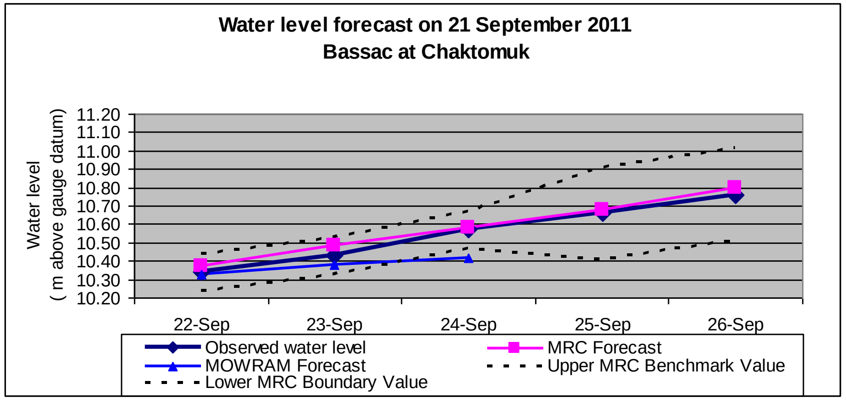
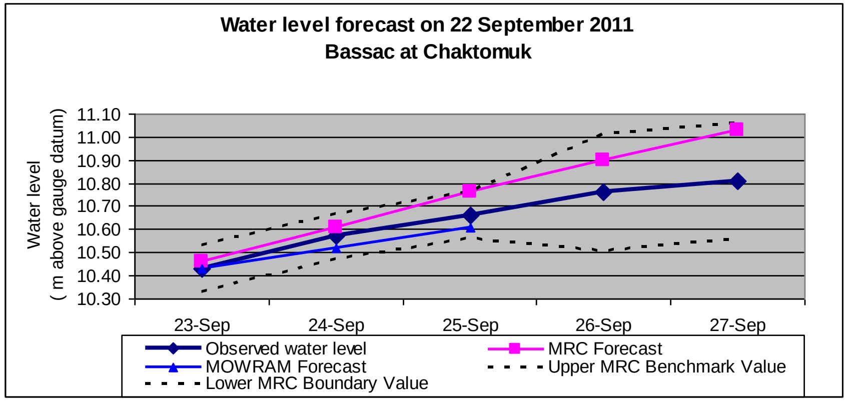
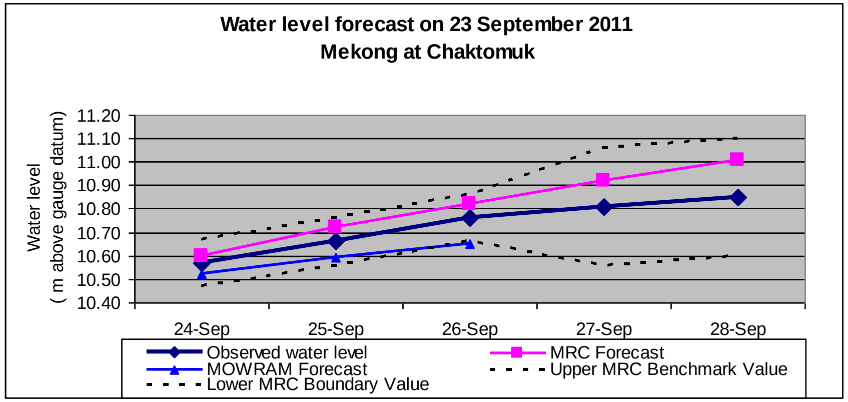


Figure 10.3 Kampong Cham, 3-day MOWRAM forecast and 5-day MRC forecast on 21-24 September, 2011







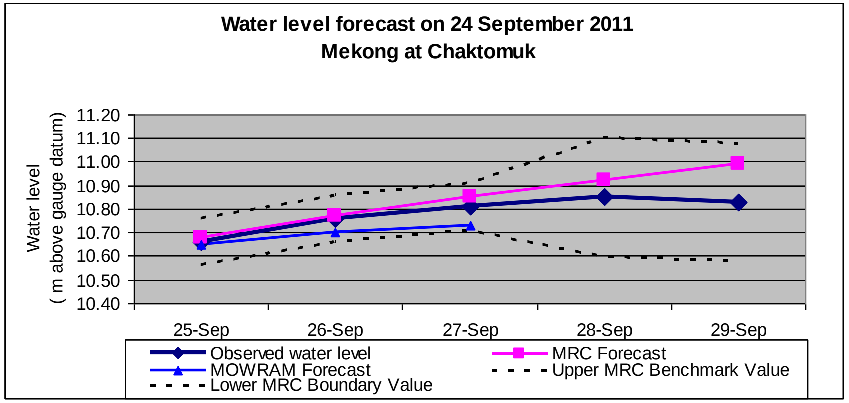
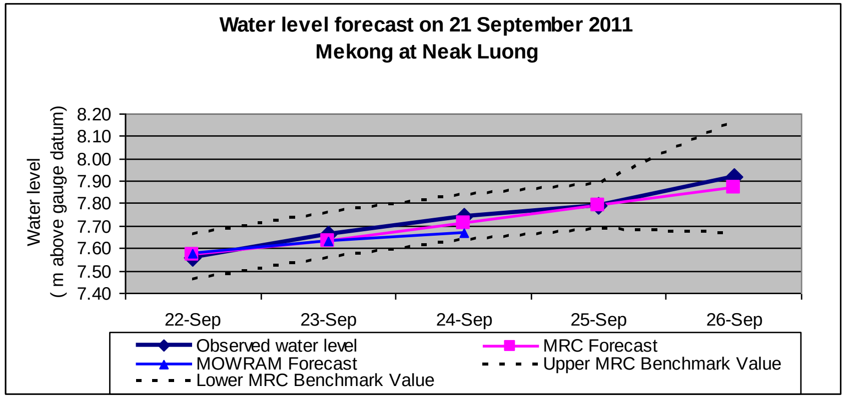
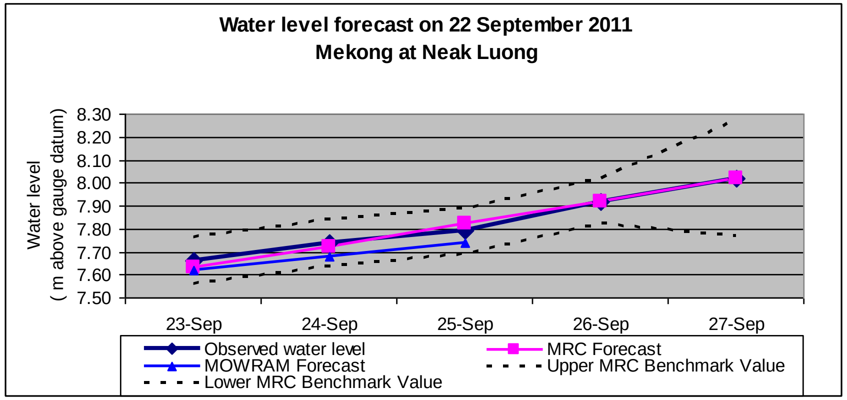
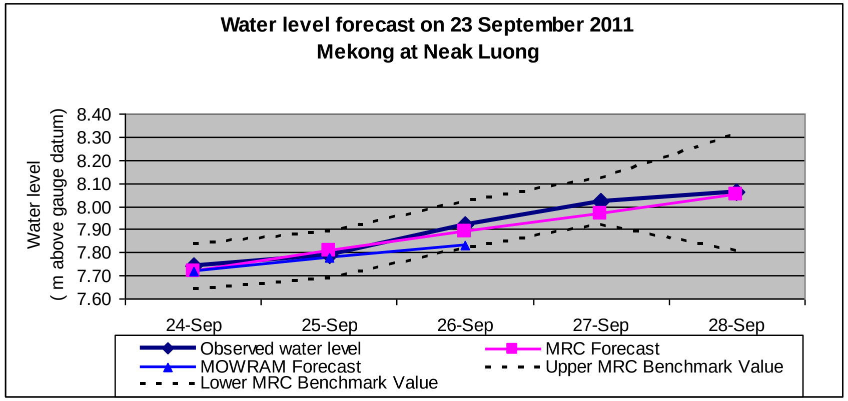


Figure 10.4 Phnom Penh - Chaktomuk, 3-day MOWRAM forecast and 5-day MRC forecast on 21-24 September, 2011







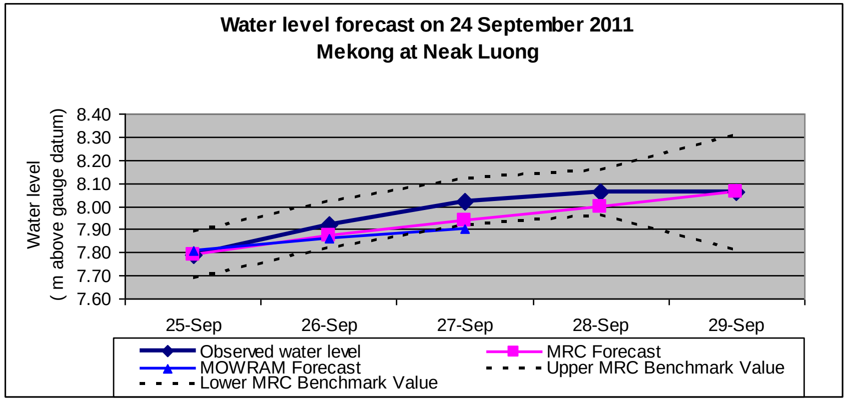


Figure 10.5 Neak Luong, 3-day MOWRAM forecast and 5-day MRC forecast on 21-24 September, 2011

The MRC forecast, using iSIS with Corrected SRE, adjusted, scores 58 points within the benchmark values. Applying the Regression with Corrected SRE, unadjusted, scores a high of 87. Such a high score for a critical flood situation could be considered very satisfactory.

However, the MRC forecast water levels for 3, 4 and 5 days on 22 September were over 11.80m for Stung Treng, and substantially over 23.00m for the 2, 3, 4 and 5-day forecasts for Kratie (0.30-1.30m higher than the peak in 2000). Similarly unrealistic values were forecast for Kampong Cham (1-day 15.81m to 5-day 16.85m) on 22 September. Obviously iSIS has shown that the current version in the Mekong FFS does not provide realistic results during critical situations. The Flood Management and Mitigation Programme needs to replace it with the updated iSIS version, which was substantially improved by FMMP and IKMP during the implementation of FMMP Component 2 “Structural Measures and Flood Proofing”. Tests will have to be carried out; with satisfactory results, this updated version can be put into operation in the Mekong FFS.

It is concluded that Mekong FFS, based on simulation of the 2011 flood season as well as simulations of specific flood events during the year, provided generally satisfactory results. Nevertheless, there were periods during which the Mekong FFS did not meet the desired standards. The MRC forecasting results for the Cambodian gauge locations during the 2011 critical flood situation were far from satisfactory. During the critical situation in Cambodia from 21 to 24 September, Mekong FFS provided both highly reliable as well as extremely weak forecasting results. The forecasts put on the MRC website during the critical flood period in Cambodia was unfortunately based on the weak Mekong FFS forecasting result.

The RFMMC is equipped with state-of-the-art models and systems. Considering the geographical extent of the Lower Mekong Basin, however, the daily input of rainfall and water level data remains limited. The provision of satisfactory levels of accuracy, lead times and the reliability of the Mekong FFS remain a constant challenge for the programme. The recent situation demonstrates that the full understanding of the models and systems is needed in order to minimize or prevent human errors. To make the right choices in interpreting model and system results, this person also needs ample experience with and solid understanding of the characteristics of the Lower Mekong Basin and its sub-basins that value meteorological, hydrological and historical data and information[9].

Increasingly accurate data transfer is anticipated from member countries. At the same time, the RFMMC is making noticeable progress in coming to grips with on rainfall run-off in remote areas of the basin. Better representation of tributary inflows into the mainstream will directly improve the accuracy and extension of the lead-time of the Mekong FFS.

Regarding the level of forecast accuracy, benchmark values were evaluated and revised at the end of 2009 to align with worldwide comparative standards based on recommendations by an international expert. From the 2011 flood season onwards, the RFMMC has incorporated more challenging performance benchmarks for mean absolute errors in meters for 1 to 5-day forecasts. This new standard, although more stringent and thus more challenging for the RFMMC, is more realistic and better suited to Mekong conditions.

To improve forecasting, especially at Stung Treng and Kratie, where conditions may serve as upstream boundaries for the iSIS hydrodynamic model, updating rating curves is important for the proper conversion of recorded water levels into discharges and vice versa. Further investigation of discharges, flow directions and water levels across the entire Cambodian floodplain (by reactivating previously established flood markers) is relevant to understand flood behavior properly. Simulation of the updated iSIS model for flood situations may be helpful.

[9] Recommendations regarding professional staff requirements for the development and operations of the RFMMC have been presented in the FMMP Concept Note, dated December 2009.

FMMP and IKMP jointly anticipated the 2011 flood situation and contracted six pairs of Radarsat-2 satellite images between 9 September and 27 October to monitor the flood peak propagation on the Cambodian floodplain. Results of this monitoring will contribute to the analysis and understanding of the flood behavior of the 2011 flood situation.

11. Lessons leant and recommendations

Based on the material presented in this *Flood Situation Report, November 2011* a number of lessons learnt, some of which have resulted in corrective steps[10] which have already been taken to minimize or prevent human errors and to maximize the flood forecasting performance of the RFMMC, and recommendations have been formulated with reference to the following issues:

Data and Information

- Forecast rainfall data and resulting tributary runoff in uphill areas with few rainfall stations is still causing substantial oscillations in the forecasted water levels.

- The real-time data transfer by the automatic stations of the MRC Hydrologic Network to the RFMMC flood forecasting system during the 2011 flood season still encountered a lack of reliability of the data transfer. Only since the last week of October did the Hydrologic Network of the telemetric stations feed the RFMMC's database system according to the set criteria. The data collection and transfer systems should be verified and consolidated.

- During flood situations, the RFMMC is equipped to operate on a 12-hourly-basis for which externally arrangements will have to be made internally with MRCS and externally with the MRC Member Countries, using the real-time data from the automatic stations of the MRC Hydrologic Network.

- The RFMMC has requested the NASA through the Hydrologic Research Center (HRC) in San Diego, USA, to provide sub-basin specific satellite rainfall estimates for the LMB, which is expected to improve the flood forecasting system results.

Flood modeling capability and forecast accuracy

- The performance of the forecasting is still affected by data deficiencies and the poor understanding of the flood hydrology of the major tributaries in Lao PDR and Cambodia. Improvements have been made, however, and further steps are being taken by the RFMMC to improve the forecast accuracy in the stretches Khong Chiam – Pakse and Kratie – Kampong Cham. The development of sub-daily simulations for major tributaries should be explored.

- Based on the flood forecasting experiences during the critical flood situation for 21-24 September 2011 FMMP has identified the need to enhance forecasting capabilities with the aim of minimizing or preventing human errors. The RFMMC has adopted monitoring and analyses of forecasting performances and simulations for all stations sudden steep rises and subsequent quick falling of water levels during flood seasons.

- The rather slow recession of the water level downstream from the Phnom Penh Chaktomuk area in Cambodia from end of September to end of October was due to the high inflows from the Tonle Sap River to the mainstream. As soon as the inflow reduced, the water levels in Chaktomuk and downstream receded quicker. However, there is a gradual reduction of storage area and discharge capacity of the Cambodian floodplain and the Mekong Delta of Viet Nam as a result of land-use changes, urbanization and

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[10] Corrective steps, which are ongoing or have been taken, are underlined in the text of Section 11.

infrastructure, which is increasing flood risks. These changes in combination with potential impacts from climate change and sea level rising should be investigated.

- The RFMMC is in the process of improving the Mekong FFS; the present iSIS model version is being replaced by an updated iSIS version, which will provide a substantially improved application of flood modeling simulations. Rating curves of gauge stations will be updated soon in the Mekong FFS for mainstream stations.
- The RFMMC has requested the Joint Research Centre of the European Commission in Italy to get access to Global Flood Awareness System, GloFAS, which may provide a longer range forecast (one-month) for the Mekong region. Further to this and based on the improved operational conditions in real-time data collection and transfer by the MRC Hydrologic Network, as well as on improved satellite rainfall estimates, the RFMMC is looking into the reduction of the time step in the Mekong FFS to better represent temporal effects in flood modeling simulations.

Dissemination of flood forecasts and early warning

- Institutional arrangements to disseminate MRC forecasts and early warnings have been validated after presentation of the Flood Situation Report August 2008 and adjustments have been made through implementation of the prevailing FMMP Action Plan.
- Although there has been regularly telephone and email contact between the RFMMC's forecasters on duty and staff at the National Centers for Flood Forecasting, the level of communication between the regional and national centers, especially during flood situations, should be substantially improved as the rationale for flood forecasts values should be clearly understood before publication on the respective websites. FMMP has taken measures to secure an effective level of communication between the RFMMC and the National Centers in case of critical flood situations.
- The recent update of the MRC website has not been followed yet by an update of the flood pages. The RFMMC should update the flood pages before flood season 2012 (regarding maps and especially flood extent maps).
- The interpretation of the alarm- and flood levels values should be clarified further on the MRC website, as flooding can occur already even though the flood level has not been reached in a particular gauge station. Adjacent crest levels can be lower or higher than the crest level of the embankment at the particular gauge stations location.

Flood preparedness

- The recent event also provides practical lessons and emphasizes the need to further strengthen flood preparedness in selected provinces and districts in Cambodia, Lao PDR, Thailand and Viet Nam. Given the overall encouraging effects of flood forecasting and flood preparedness in reducing the number of flood casualties and loss of livelihoods, continuation of these efforts and improvement of these systems by MRC seems to be recommendable. The Annual Mekong Flood Report 2011 will incorporate pay attention to the positive effect of flood preparedness during the 2011 flood situation.

Staffing the Regional Flood Management and Mitigation Centre

- Acknowledging the weakness in securing the flood forecasting expertise at the RFMMC annual refreshment courses by international experts have been organized to support the RFMMC's forecasters with detailed understanding and further improvement of the forecasting systems. Such courses will be repeated in 2012.

- The FMMP is presently reviewing and updating its operational procedures, thereby emphasizing the specific staff responsibilities for the application of the certified work process. The importance of the proper application of the operational procedures for carrying out verification and checks of the forecast products is still underestimated.

- There is an urgent need for quality management at the RFMMC in order to monitor the process of analysis and simulations of the flood season hydrograph for the various locations along the mainstream during the flood season; this with the aim to prevent or minimize human errors. The position of Operations Manager is still vacant. A third round of recruitment is soon initiated, as the previous recruitments were not successful.

- Given the fact that an assignment of 3-4 years for professional staff in the position of flood forecaster is no guarantee that in the beginning of the assignment there is sufficient knowledge and expertise to produce validated flood forecasts. This is partly due to the lack of knowledge and experience of the characteristics in the Lower Mekong Basin and partly due to the lack of experience with the RFMMC forecasting systems.

- In 2012, two professional staff positions will become vacant. The lack of continuity of flood forecasting knowledge and experience has been and remains a major challenge for the RFMMC. To secure knowledge and experience for the proper operations of the flood forecasting systems for the medium and longer run, recommendations have been provided in the Concept Note for the Development and Operations of the RFMMC. One of the suggestions is to allow maximum three renewals of a three year contract term-system, which provides a maximum of 12 year continuity of knowledge and experience for professional staff positions at the centre. Also other options may have to be considered within the framework of the ongoing decentralization exercise of the MRC Strategic Plan 2011-2015. Building-up a regional flood forecasting knowledge base through the application of RFMMC's systems at the National Centers at the one hand in combination with a number of longer term arrangements for expert staffs may provide a feasible option. However for the short term very practical internal measures have been taken in order to minimize the negative impact of these expert staff changes by applying internal knowledge sharing approaches, joint analysis and simulation exercises and stimulation of team-work.

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