Mekong River Commission
Flood Management and Mitigation Programme

Final

Seasonal Flood Situation Report for the Lower Mekong River Basin

Covering period from 1st June to 31st December 2012

Prepared by
Regional Flood Management and Mitigation Centre

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1. Flood season 2012

1.1 Rainfall situation

The critical rainfall situation in the Lower Mekong Basin, as previous year, was concentrated in July and August, a period of Southwest Monsoon activity, low pressure troughs, storm and typhoon's appearances in the South China Sea. In terms of total seasonal rainfall, the general picture was one of the average years (see Figure 1-1). It can be seen that the total rainfall in the flood season 2012 at all stations in LMB (except Luang Prabang, Chiang Khan, Kratie, Kompong Cham and Phnom Penh Bassac) is lower than the long-term average and all is lower than those of the previous flood season 2011.

The spatial variation of rainfall is high indicating that the intensity of heavy rain situations along the Lower Mekong Basin from upstream to downstream took place as a function of time (Annex A: 1. Graphs and Tables for monthly observed rainfall distribution during flood season 2012):

- The wet season started in early June; the heavy rain mostly occurred in upper reach of the LMB.
- During July - August, the intensive and continued rain covered the most of upper and middle reaches of LMB and appeared more frequently in August.
- From September to October was the time of intensive rainfall in lower reach, especially from Kratie to Kompong Cham.

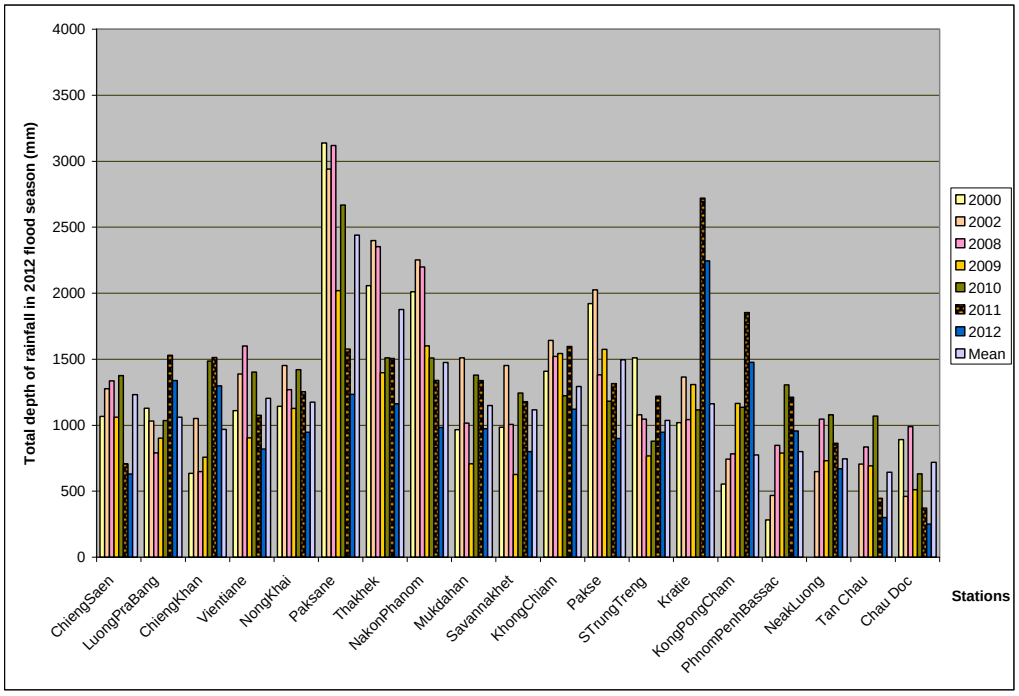

Figure 1-1 Total depth of rainfall in the flood season of the years 2000, 2002, 2008, 2009, 2010, 2011, 2012 and the long-term average flood seasonal rainfall

In 2012, three main weather patterns caused heavy rains, which are presented below:

- Southwest monsoon: influenced the Mekong River basin from early June to mid-October; the critical activity mostly occurred from the end of July to the end of August and from the mid-September to mid-October. As a common phenomenon, there was after mid-October that a moderate to weak SW monsoon prevailed over lower parts of Thailand, Myanmar, Cambodia and Viet Nam. Figure 1-2 shows an illustration of weather map for Southwest Monsoon in the end of July.

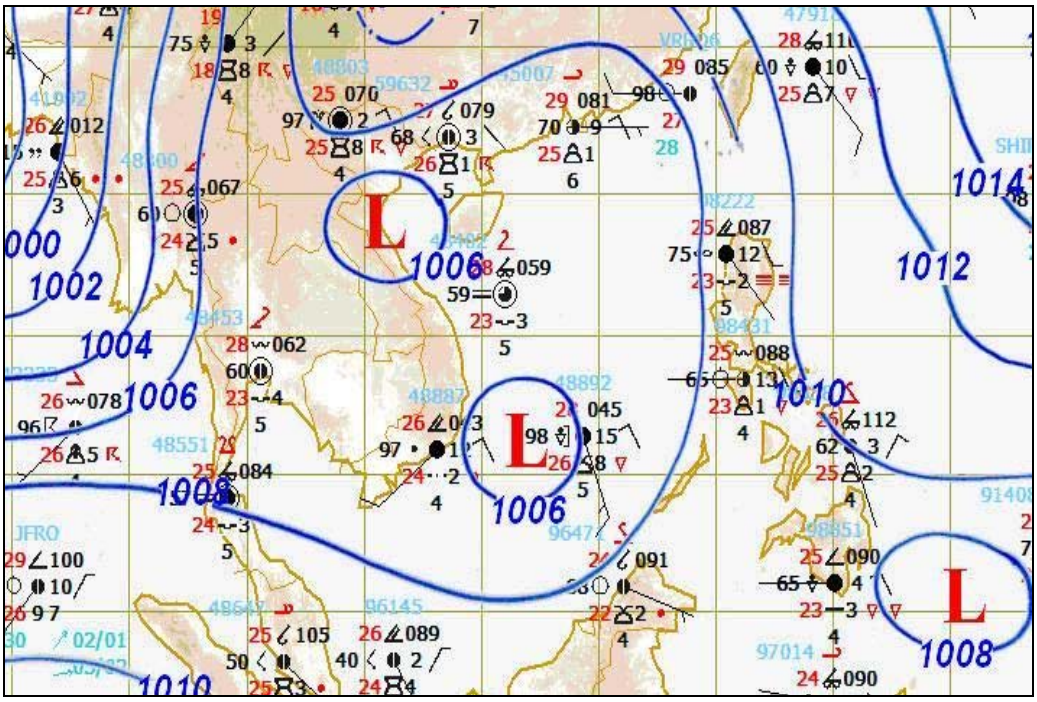

Figure 1-2 Weather map for Southwest Monsoon in the end of July.

- Tropical Low Pressure (TLP) and Inter Tropical Convergence Zone (ITCZ): these periodically appeared from early June to the mid of October with on average 3 to 7 days duration. In the flood season 2012, the frequent appearances of TLP and ITCZ during almost the entire flood season were one of the main phenomena which caused continuous heavy rain and rising water along the Mekong River. In August, TLP and ITCZ were observed and had significant influence on the upper and middle reaches of the LMB while the influence on the lower reach took place mostly in October. Figure 1-3 shows an illustration of the appearances and influences of TLP and ITCZ to the LMB in August and October.
- Tropical depressions (TD), tropical storms (TS) or typhoons (TY): Same as previous year, there were about 8 tropical depressions, storms and typhoons which came to South China Sea and affected the Mekong River basin with different levels. Of these, the five storms *DOKSURI, VICENTE*, *TEMBIN, BOLAVEN, and GAEMI* were the most noticeable.
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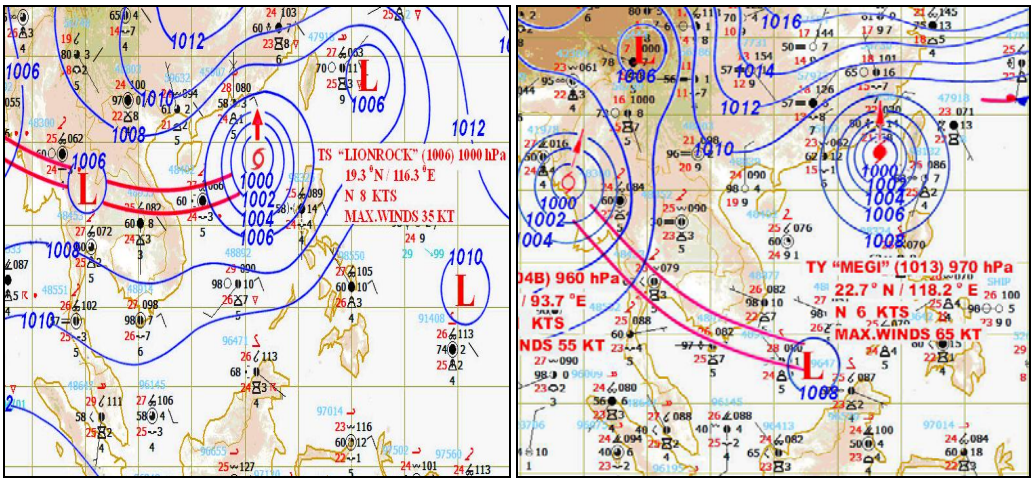


Figure 1-3 Weather maps for ITCZ in the end of August and mid-October.

1. *DOKSURI* was formed in the Philippines on 27th June, located in the South China Sea at latitude 22° N and longitude 112.8° E with maximum sustained wind about 65 kilometres per hour and moved West North-west ward and landed over China territory on 30th June.

2. *VICENTE* was formed in the South China Sea on the 22nd July, upgraded to the Typhoon on 23rd July afternoon when moving north-west ward close to South China coastline and made landfall on 24th July. It was downgraded into a tropical depression on 25th July and became a low pressure after moving deep into the mainland of China. Figure 1-4 presents the recorded track of Typhoon VICENTE and weather maps before and after landing were shown in Figure 1-5 and Figure 1-6, respectively.

3. *TY-TEMBIN and TY-BOLAVEN* were formed in the East of the Philippines on 19th and 20th August 2012, respectively. TEMBIN moved westward to the South of Taiwan while BOLAVEN moved northward to China, Korea and Japan. Figure 1-7 and 8 show a Storm Track and weather chart of TAMBIN and BOLAVEN Typhoons, respectively.

4. *GAEMI* was formed on 30th September 2012 on the South China Sea, upgraded to severe Tropical Storm named GAEMI on 4th October and made landfall over Binh Dinh and Phu Yen provinces in the Central of Viet Nam in the afternoon 6th October. After moving deep into Viet Nam territory, the tropical storm GAEMI downgraded into tropical depression in the evening 06th October and became a low pressure later. Figure 1-9 presents the recording storm track of GAEMI and weather maps of the GAEMI before and after landing over the northern part of Central Viet Nam are showed in Figure 1-10 and Figure 1-11, respectively.

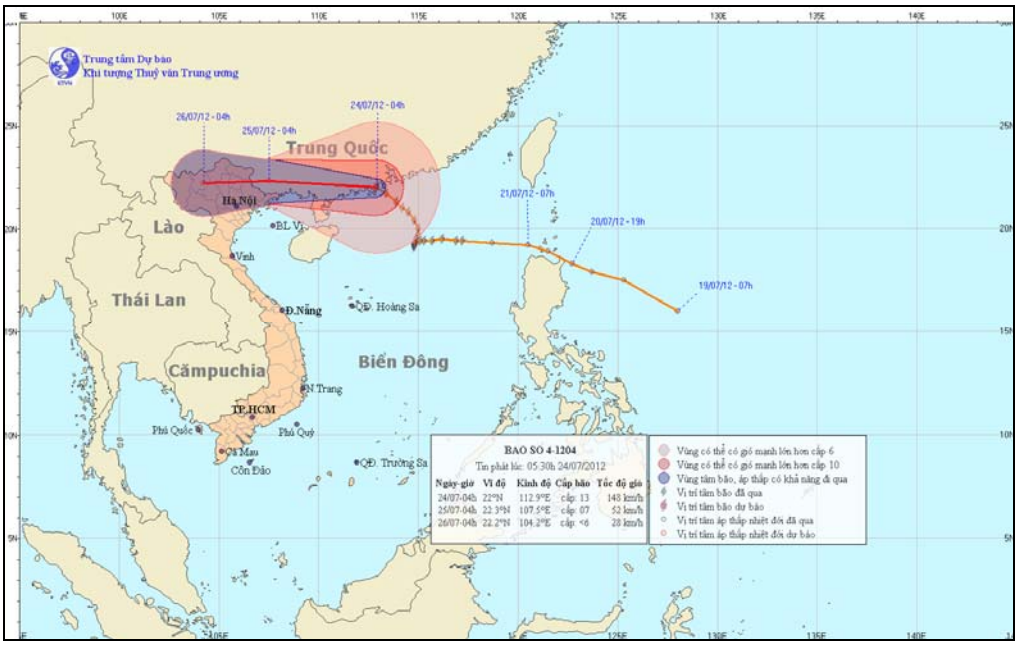


Figure 1-4 VICENTE Storm Track.

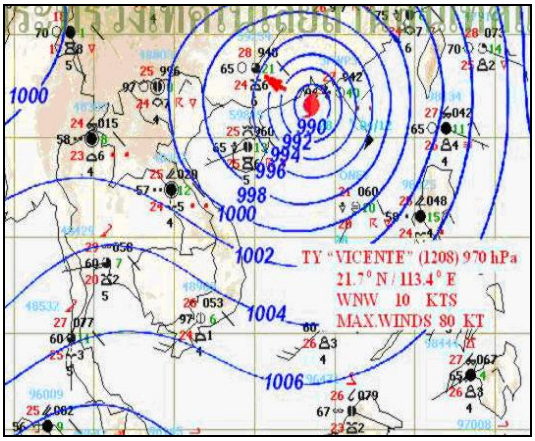


Figure 1-5 Weather map for VICENTE Typhoon on 24th July 2012, before landing.

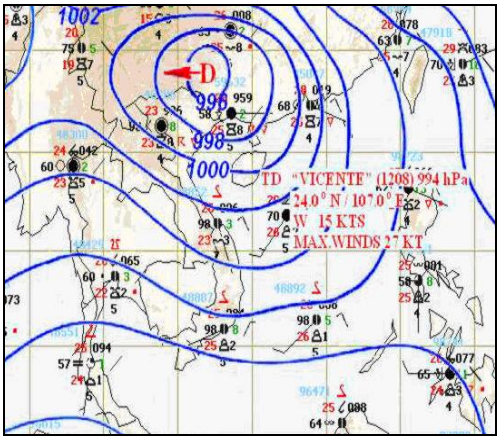


Figure 1-6 Weather map for VICENTE Tropical Depression on 25th July 2012, after landing.

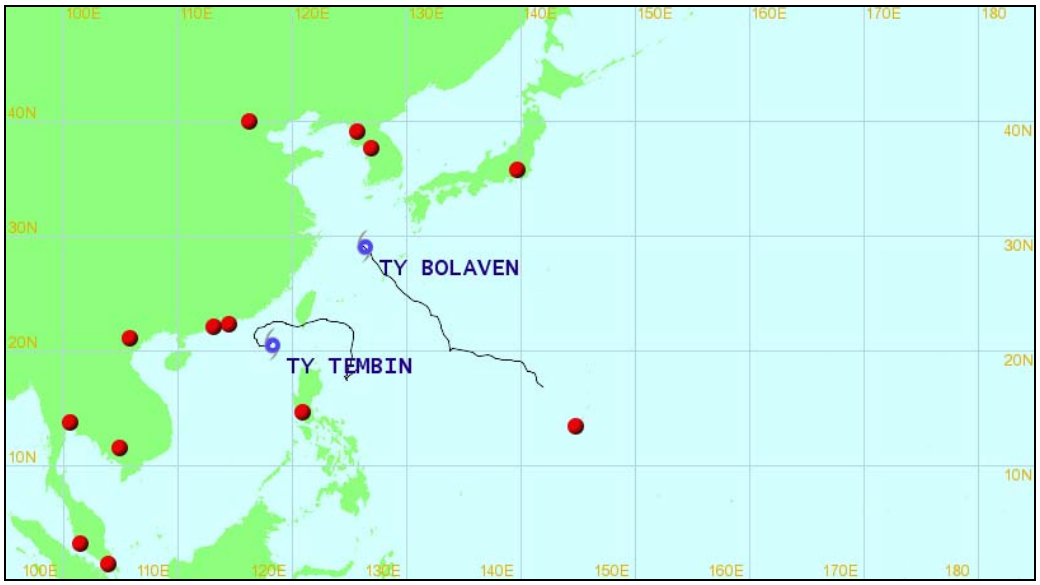


Figure 1-7 TEMBIN and BOLAVEN Storm Tracks.

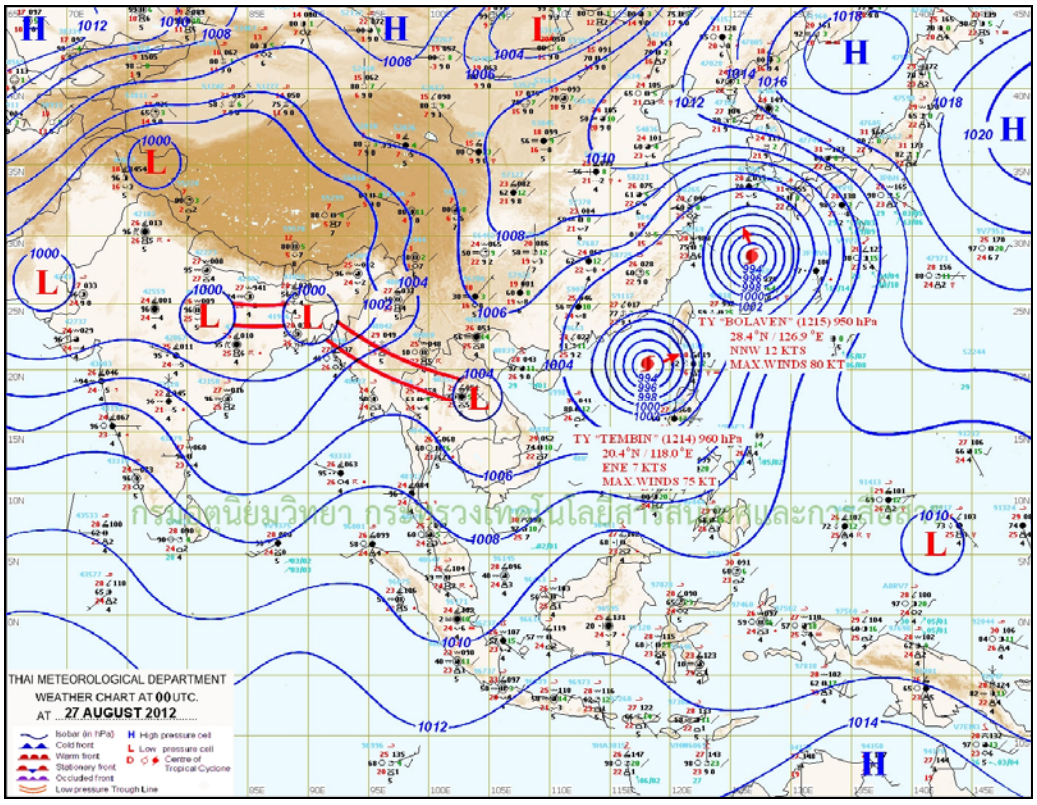


Figure 1-8 TEMBIN and BOLAVEN weather chart.

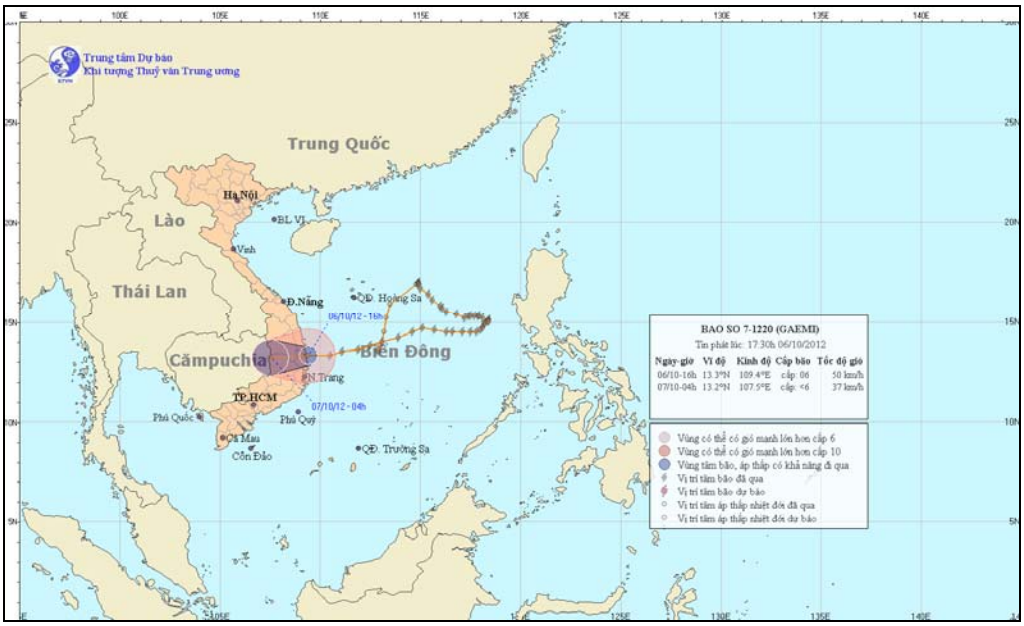


Figure 1-9 GAEMI Storm Track.

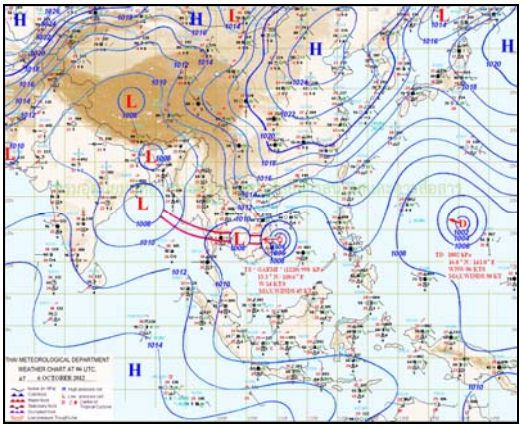


Figure 1-10 Weather map for GAEMI in the afternoon 06th Oct, before landing.

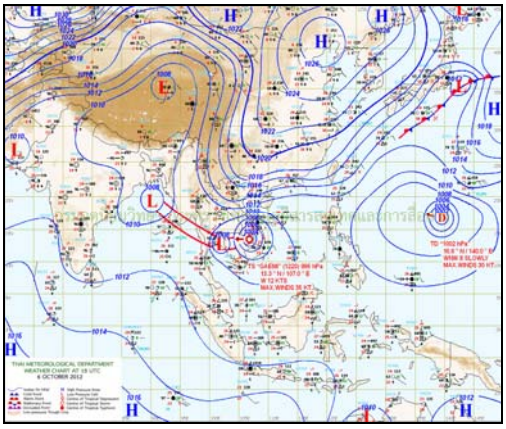


Figure 1-11 Weather map for GAEMI in the evening 06th Oct, after landing.

1.2 General Behaviour of the Mekong River and Seasonal Flood Situation

The terms “flood” and “flooding” may world-wide have different meanings. Therefore the definitions as used in this report are basically adopted from the Mekong Annual Mekong Flood Forums:

- ***Flood:*** *natural abundance of water in response to storm, rainfall, snowmelt, etc ... ergo the flood season on the Mekong ..... however, this does not necessarily lead to flooding;*

- ***Flooding:*** *the inundation of areas, which usually are not submerged.*

The 2012 flood season started later than previous flood years. The first flood event occurred on the fourth-week of July with the appearances and influences of South-West Monsoon and two tropical storms: *DOKSURI* and *VICENTE*.

In general, the water levels at upper reach of LMB started below the long-term average (LTA) while stations in middle and lower reaches of LMB were about or above the LTA. After the influences of VICENTE in July; TEMBIN and BOLAVEN in August, water levels of all stations rose up and were about or above the LTA except those in lower reach still below the LTA, in which only water level at Nong Khai was above alarm level of 11.4m (as defined by the national agencies) on 4th August (see Table 1-1).

From September to the end of flood season, water levels recessed below LTA in many stations; except those in lower reach of LMB with the arrival flood water from the upper and middle reaches, water levels rose up steadily below LTA with average intensity of 0.10-0.20m/day.

Regarding the downstream stations at Tan Chau and Chau Doc, the water levels were most of the time below the long-term average. The water levels at Tan Chau was above alarm level of 3.0m on 3rd October, Chau Doc was above alarm level of 2.5m on 3rd October (see Table 1-1 for detail and Annex C presents the hydrographs of 22 main hydrological stations along the Mekong River).

In 2012, although there were about the same numbers of tropical depressions, storms and typhoons, their influences were less than last flood season year.

Table 1-1 shows the flood peaks of main locations along the Mekong mainstream during 2012 flood season.

Table 1-1 The flood peaks of main locations along the Mekong mainstream during 2012 flood season

ID	Station	Alarm level	Flood Level	Day/Month of Peak	Hmax (m)	Comment
010501	Chiang Saen	11.50	11.80	29-Jul	7.91	Below alarm level
011201	Luang Prabang	17.50	18.00	23-Aug	15.25	Below alarm level
011903	Chiang Khan	17.32	17.40	02-Aug	13.28	Below alarm level
011901	Vientiane	11.50	12.50	25-Aug	10.28	Below alarm level
012001	Nong Khai	11.40	12.20	04-Aug	11.66	Above alarm level
012703	Paksane	13.50	14.50	12-Aug	12.42	Below alarm level
013101	Nakhon Phanom	12.60	12.70	13-Aug	10.22	Below alarm level
013102	Thakhek	13.00	14.00	13-Aug	11.31	Below alarm level
013402	Mukdahan	12.50	12.60	13-Aug	9.99	Below alarm level
013401	Savanakhet	12.00	13.00	13-Aug	8.85	Below alarm level
013801	Khong Chiam	16.00	16.20	04-Sep	11.17	Below alarm level
013901	Pakse	11.00	12.00	04-Sep	9.4	Below alarm level
014501	Stung Treng	10.70	12.00	05-Sep	9	Below alarm level
014901	Kratie	22.00	23.00	06-Sep	19.55	Below alarm level
019803	Kompong Cham	15.20	16.20	07-Sep	13.46	Below alarm level
020101	Phnom Penh Port	9.50	11.00	29-Sep	7.7	Below alarm level
033401	Phnom Penh Bassac	10.50	12.00	29-Sep	8.56	Below alarm level
033402	Koh Khel	7.40	7.90	17-Sep	6.94	Below alarm level
019806	Neak Luong	7.50	8.00	01-Oct	6.12	Below alarm level
020102	Prek Dam	9.50	10.00	01-Oct	7.76	Below alarm level
019803	Tan Chau	3.50	4.50	13-Oct	3.19	Below alarm level
039801	Chau Doc	3.00	4.00	13-Oct	2.86	Below alarm level

(Alarm level, flood level are defined by the national line agency)

The main hydrological situations along the Mekong River are presented in more detail below:

For stations from Chiang Saen to Vientiane/Nong Khai

During the 2012 flood season, water levels at stations Chiang Sean, Luang Prabang, Chiang Khan, Vientiane/Nong Khai were most of the time below the long-term average (LTA), except for some periods in July and August that rose up above LTA. There were two flood events with amplitudes over 2 meters which occurred at those stations (see more detail in Annex A, Part 3, Table A2).

Influences of VICENTE in July and later TEMBIN and BOLAVEN in August, resulted in moderate to heavy rainfall in this upper reach of LMB. Some recorded of two-month rainfalls (July and August) were over 300mm, such as at Cheang Saen (568.7mm), at Luang

prabang (498mm), at Vientiane (371.1mm) and Nong Khai (405.4mm). Therefore during mid-July to August, the rising water level occurred at all stations from Chiang Saen to Vientiane/ Nong Khai and reached the 2012 flood peak during this period (see Table 1-1 for details). It should be noted that flood amplitudes for the stations Chiang Sean to Vientiane/Nong Khai were over 4m (Annex A, Part 3, Table A2).

Figure 1-12 shows quick rising of water levels at stations: Xieng Kok and Chiang Saen during 26th – 29th July 2012 with amplitudes of 4.67m and 7.38m, respectively. Xieng Kok is an upstream station of Chiang Saen, located on the mainstream of Mekong river at the border of Lao PDR and Myanmar.

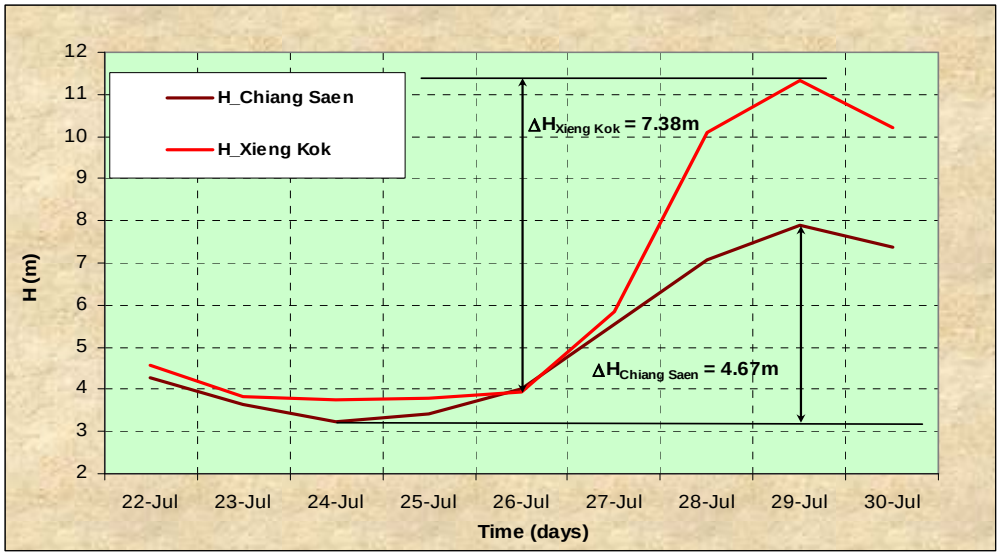


Figure 1-12 Quick rising of water levels at stations: Xieng Kok and Chiang Saen during 26th – 29th July 2012.

Water levels at Luang Prabang rose 4.62m during 26th – 29th July 2012 and other upstream stations such as Chiang Khong, Pak Beng were also rose sharply; particularly at Pak Beng with the amplitude of 11.86m during 26th – 29th July 2012. The hydrograph at those stations was shown in Figure 1-13.

From September to the end of season, influence of low pressures as well as ITCZ across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar did not affect much in this region, no flood amplitudes over 2m had happened (Annex A, Part 3, Table A2).

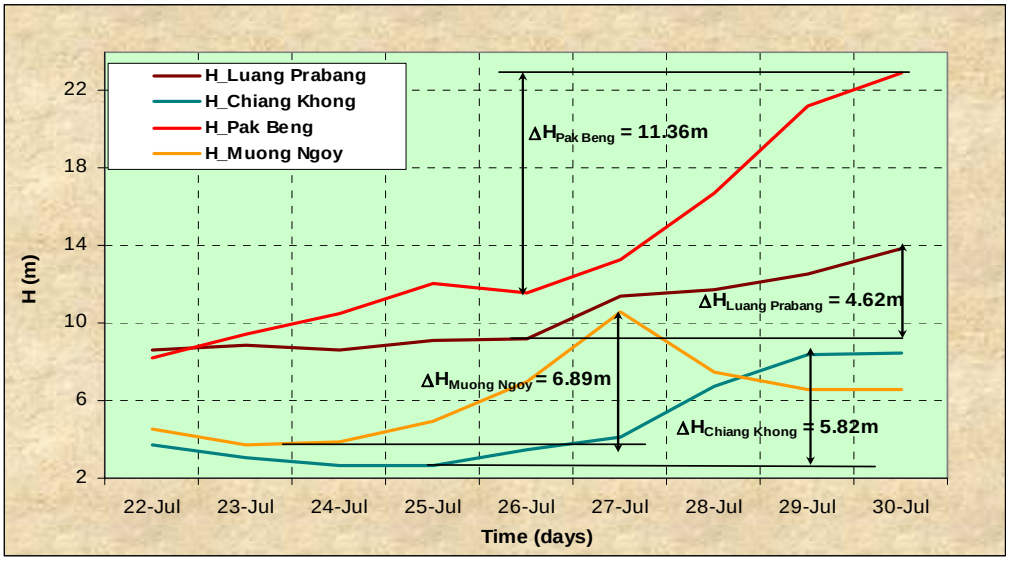


Figure 1-13 Water level rising at stations: Pak Beng, Chiang Khong, Muong Ngoy and Luang Prabang during 26th – 29th July 2012.

For stations from Paksane to Pakse

During the 2012 flood season, water levels from Paksane to Pakse were most of the time below the long-term average (LTA), except for some periods in July and August that rose up above or about LTA. There was one flood event with amplitudes over 2.5 meters which occurred at those stations (see more detail in Annex A, Part 3, Table A3).

The same influences of VICENTE in July and later TEMBIN and BOLAVEN in August, resulted in moderate to heavy rainfall in this middle reach of LMB. Some recorded of two-month rainfalls were over 300mm, such as at Paksane (1109.7mm), at Nakhon Phnom (967.5mm), at Thakhek (856.2mm), at Mukdahan (342mm), at Savannakhet (418.2mm), at Khong Chiam (801.3mm) and at Pakse (505.7mm). Therefore during mid-July to August, the rising water level occurred at all stations from Paksane to Savannakhet and reached the 2012 flood peak during August; only Khong Chiam and Pakse had reached flood peak a bit later at the beginning of September (see Table 1-1). It should be noted that flood amplitudes for the stations Paksane to Pakse were over 2.5m (Annex A, Part 3, Table A3). Figure 1-14 shown waters level rising at stations: Vientiane, Nong Khai and Paksane during 26th – 29th July 2012.

From September to the end of season, influence of low pressures as well as ITCZ across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar did not affect much in this reach, no flood amplitudes over 2m had happened (Annex A, Part 3, Table A3).

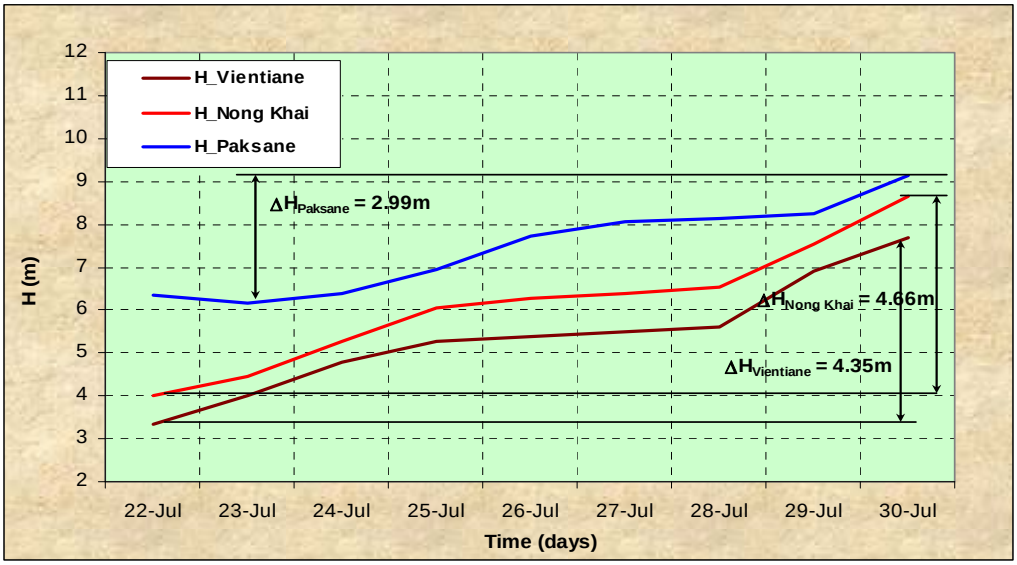


Figure 1-14 Water levels rising at stations: Vientiane, Nong Khai and Paksane during 26th – 29th July 2012.

For stations from Stung Treng to Kompong Cham

During the 2012 flood season, water levels from Stung Treng to Kompong Cham started above the long-term average (LTA) and continue to rise up above LTA till end of September, then fall below LTA.

The same influences of VICENTE in July and later TEMBIN and BOLAVEN in August, resulted in moderate to heavy rainfall in this lower reach of LMB. Some recorded of two-month rainfalls were over 500mm, such as at Stung treng (733mm), at Kratie (715.8mm) and at Kompong Cham (502.1mm).

As a result of flood water from the upper and middle reaches of LMB together with heavy rainfall, the rising water level occurred at all stations from Stung Treng to Kompong Cham and reached the 2012 flood peak in early September and their flood amplitudes were over 2 meters at Stung Treng and over 3 meters at Kratie and Kompong Cham (see more detail in Annex A, Part 3, Table A4). .

From September to the end of season, water levels were more or less stable and finally recessed at the end. No flood amplitudes over 2m had happened (Annex A, Part 3, Table A4).

For stations from Phnom Penh to Koh Khel/Neak Luong

During the 2012 flood season, water levels from Phnom Penh to Koh Khel/Neak Luong were most of the time below the long-term average (LTA), except for some periods in July and August that rose up about LTA.

The same influences of VICENTE in July and later TEMBIN and BOLAVEN in August, resulted in moderate rainfall in this reach of LMB. Some recorded of two-month rainfalls were over 100mm, such as at Phnom Penh (Bassac Chaktomuk) (279.5mm), at Koh Khel (226.7mm), at Neak Luong (406.9mm) and at Prek Kdam (165.9mm). As a result of flood water from the

upper and middle reaches of LMB together with local rainfall, the rising water level occurred at all stations from Phnom Penh to Koh Khel/Neak Luong and reached the 2012 flood peak in end of September and early October (see Table 1-1). It should be noted that flood amplitudes for the stations Phnom Penh to Koh Khel/Neak Luong were over 1m in August (Annex A, Part 3, Table A5).

From September to the end of season, water levels were more or less stable and finally recessed at the end. No flood amplitudes over 1m had happened (Annex A, Part 3, Table A5).

Tan Chau and Chau Doc

During the flood season 2012 stations recorded water levels that most of the time remained below the long-term average, except in the first half of July when flood water from the upper and middle reaches of LMB had arrived together with local rainfall that water levels of these two stations rose above LTA. From August to the end of flood season, water levels of these stations rose steadily with average intensity of 0.10 - 0.15m/day levels and then recessed at the end. No flood amplitudes over 1m had happened (see more detail in Annex A, Part 3, **Table A6**).

2. Flood Forecast in 2012

2.1 Data collection for models and flood forecast bulletin dissemination

Daily data collection consisted of hydrological and meteorological data (observed water level and rainfall) by HydMet from Line Agencies, Satellite Rainfall Estimate (SRE) and Numerical Weather Prediction (NWP) obtained from NOAA which served as inputs for the Mekong Flood Forecasting System (FFS). The performance indicators are shown in the Tables and graphs of the forecast achievement, Annex B (Table B3, Figure B2 to Figure B4).

The results of the evaluation show that the data from most of LAs normally arrived before 9 AM (Annex B, Table B3 and Figure B2). The manual data collected by HydMet was checked by LAs; hence, the quality of data is in general terms fairly good. However, there are a number of unavoidable problems in data transmission such as the late transfer of data, errors and especially missing data during five months of this flood season (see more detail in Table B3 and graphs in Performance, Annex B).

Satellite Rainfall Estimation and Numerical Weather Prediction inputs for the URBS/FEWS, were the most important factors to determine forecast results. Following the investigations and comments of the forecaster-in-charge in the weekly reports throughout the 2012 flood season, it is found that the high variability in both SRE and NWP was one of the main reasons which lead to large errors of forecast results, especially when the weather patterns caused heavy rain as tropical storms, south west monsoon and ITCZ.

Performance indicators of bulletin delivery (Annex B, Table B3 and Figure B4) shows that the flood bulletins containing flood situation information were disseminated timely to the registered national Line Agencies, MRC website, and other interested users around 10h30 AM, which is a prescribed time in the Operational Manual. It can be seen that the time of flood forecasting bulletin delivery in the first three months of the flood season was a bit later than 10h30. This was due to two main factors:

- The late transfer and incomplete of data from LA's usually occurred during flood season.
- The low water level together with significant tidal effect in the downstream of the LMB, which resulted in difficulties for forecaster-in-charge in analysing and adjusting forecast results and which consequently lead to the late bulletin dissemination.

During the 2012 flood season, the data of some stations was sometimes not updated by national Line Agency for 2 to 3 continuing days, and in case data were missing over 2-3 days it was not possible to provide a forecast at those stations. Figure B5 in Annex B shows that during the 2012 flood season there was one station without forecasts in July.

2.2 Accuracy and limitations in forecasting

During the 2012 flood season, the degree of accuracy varies from station to station. The shorter the lead time, the more accurate of the forecast (see Annex B, Table B1). The

evaluation of forecast achievement is presented in Table B2 by indicating the % of days "successful" against a respective benchmark. In general, the forecast errors for all lead time show decreasing trend from upper to lower reaches, except Luang Prabang, those stations in middle reach and Kratie where the accuracy for 2-3 day forecasts lead time was less than expected, if following the benchmarks of success. Based on the weekly flood situation reports, the large errors on 2-3 day forecasts at three those stations mainly occur during the first two months of flood season when tropical storms were active in the areas.

Through forecast performances at other stations in the lower reach of Mekong River, it can be seen that the use of a regression model is quite promising. Downstream stations start from Phnom Penh Bassac to Chau Doc, show average errors for 1-day and 2-day forecasts smaller than 0.03m and 0.10m respectively; while average errors for 3-day to 5-day forecasts are smaller than 0.2m at stations from Koh Khel to Tan Chau.

Based on investigations and forecasting experiences of the RFMMC, the main factors that influenced forecast accuracy can be summarized as below:

1. *Internal model functionality in forecasting at tidal affected stations in downstream:* The forecast performances by mean absolute error in using original forecast results from both regression and ISIS models were presented in Figure 2-1 and Figure 2-2 respectively. It is easily realized that the average error results by URBS and Regression for 3-day to 4-day forecasts at Tan Chau and Chau Doc were over 0.1m; and for 5-day were around 0.25m. It didn't achieve the benchmarks of success at those two stations for 3-day to 4-day forecasts, as is shown in Table B2, Annex B.

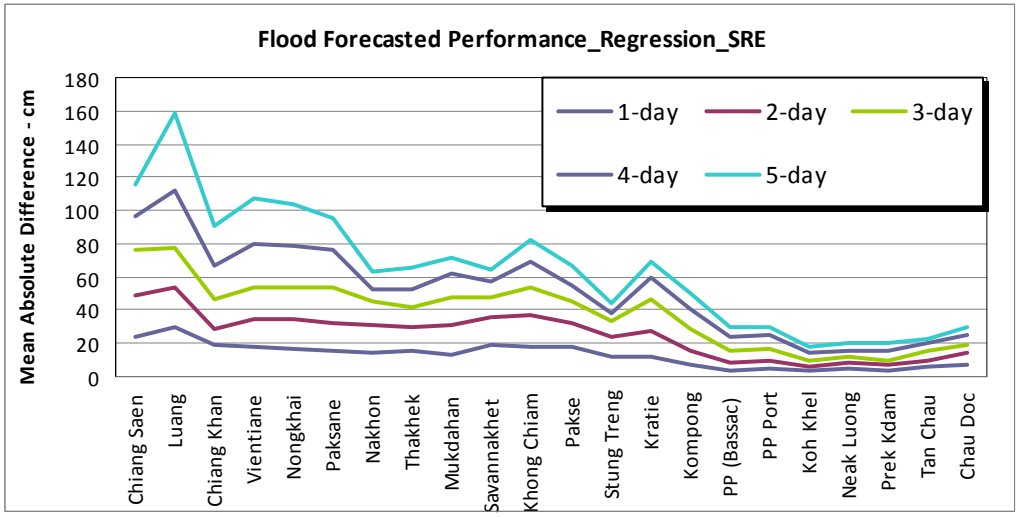


Figure 2-1 Forecast performance based on original results by URBS and Regression.

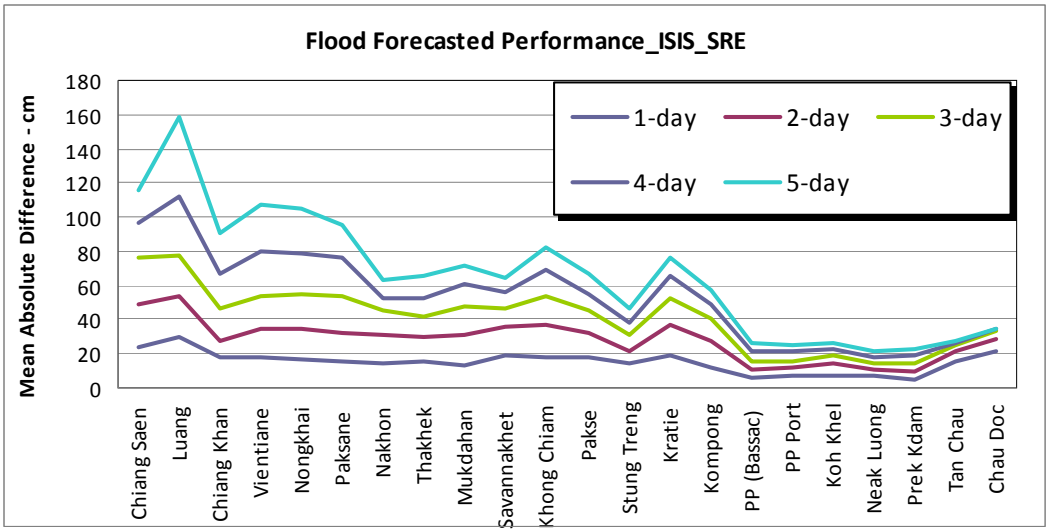


Figure 2-2 Forecast performance based on original results by URBS and ISIS.

2. *The high variability of satellite rainfall estimate (SRE) and Numerical Weather Prediction (MWP):* SRE rainfall is used, as the NWP model provided a 7-day GFS rainfall forecast. Throughout the 2012 flood season, the output for the URBS model, as can be seen from the results of daily forecast, is really sensitive to both SRE and NWP. SRE can be either under- or overestimated if compared with the observed rainfall. NWP can provide high variable rainfall forecast leading to high variation of forecast results, especially at stations in the upper and middle reaches when critical weather patterns occur such as tropical storms DOKSURI and VICENTE. Based on weekly investigation of the forecasting team, the original forecast results calculated from the model caused relatively large errors compared with observations. This is a practical difficulty for forecaster-in-charge in forecast adjustment.
3. *The quality and accuracy of forecast is also determined by the quality of forecast adjustment, which is usually performed by forecaster-in-charge so their knowledge, expertise and experiences are also the prominent determinant of the final forecast result*.

2.3 Lesson learned and actions to be taken

The following lessons have been drawn from the 2012 flood season, which can serve as the main factors that need to be taken into account by the flood forecasting team of the RFMMC in improving the forecast results:

1. The availability and quality of both hydrological and meteorological (rainfall) data as inputs for models are always the highest priority because these are the deciding factors for forecast results and accuracy. The corrected SRE had been used in the forecast but its quality depended very much on observed rainfall data that contained lots of missing data (see Annex B; Table B3)
2. The data from stations in the upstream of the Mekong River system in China is very important for analysing and forecasting in the LMB, not only during the flood season but also during the dry season. Hydrological and meteorological data from

stations belonging to China need as much and as often as possible to be shared during dry season of 2012-2013.

3. Strengthening the relationship and cooperation with Line Agencies in exchanging and collecting observed water level and rainfall data at stations on the Mekong mainstream in order to collect daily data on time and to minimize the missing and incorrect data.
4. Improving model calibration by updating the rating curves and other parameters at stations in the MRC's member countries to be supported by LAs.
5. The forecaster-in-charge needs to have more understanding of sub-basin characteristics, flow regime of left bank tributaries in the middle part of the LMB where frequently intensive rainfall and flooding occurs as well as more understanding of influences of tidal regime to the downstream of the LMB.

Aside from above-mentioned lessons in order to improve the accuracy of flood forecasting for next flood season 2012, a number of additional actions need to be undertaken as follows:

6. Performance of the ISIS model in the Cambodian Floodplain and the Mekong Delta should be compared with that of the Regression Model during the 2012 flood season. It is found that the discharges generated in ISIS are not consistent with the observed water levels. It is recommended to replace the old version in the MRC Mekong Flood Forecast System with the latest version of ISIS.
7. Continue to efficiently use water level and rainfall of the existing two stations: Jinhong and Manan of China. Analyse the impact of water release from dams to the water levels at Jinhong and to water level changes at stations in the upper part, such as at Chiang Saen and Luang Prabang, especially during transitional period between dry and wet season.
8. Watch closely situations of the sudden increasing water levels of left bank tributaries in the middle part of the LMB, such as Sre Pok River at Lumphat, Se Kong River at Vuen Khen, Se Bang Fai River at Mahaxai, when the weather patterns would inflict intensive rainfall such as Typhoon or Tropical Depression occurrences in South China Sea, the creations of low pressure trough line and Inter Tropical Convergence Zone (ITCZ) and sometimes the critical activity of South West monsoon.
9. Through the 2012 flood season, forecast results of water levels at stations in downstream of the LMB by using Regression model were evaluated as fairly good, however the error for 2-day to 3-day forecasts at hydrological stations affected by tidal from Neak Luong to Tan Chau/Chau Doc are quite high, based on benchmarks of success (Annex B, Table B2). Therefore, additional reference of tidal regime forecast documentation in 2012 provided by National Centre for Hydro-meteorology of Viet Nam can be referred to in improving the accuracy at those stations.
10. Learn more about the weather products of rainfall forecast published on the websites of the World Meteorological Organization and their practical applications.
11. Study the possibility of having 2nd run of daily flood forecast and medium-term forecast (6-10 days) – data availability and other requirements of the system by having further evaluation of the system's performance by using historically similar rainfall patterns.

For more details see the following Annex:

Annex A;

- Graphs and Tables for monthly observed rainfall distribution during flood season 2012
- Graphs for monthly rainfall in flood season from 2000 to 2012 and long-term average along the Mekong River
- Tables of flood event characteristics along the Mekong River during flood season 2012

Annex B:

- Graph for accuracy
- Table of forecast achievement
- Tables and graphs for performance

Annex C:

- Seasonal Water Level Graphs

Annex A Graphics and Tables

1. Graphs and Tables for monthly observed rainfall distribution during flood season 2012

Table A1 Monthly observed rainfall in flood season 2012

Unit in mm

2012	Jinghong	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nong Khai	Paksane	Thakhek	Nakhon Phanom	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	Phnom Penh Port	Bassac Chaktomuk	Neak Luong	Tan Chau	Chau Doc
June	17.0	64.9	147.5	157.6	69.8	87.7	164.4	173.7	136.3	145.6	107.8	164.6	128.0	137.4	333.3	184.0	No Data	100.5	67.1	20.8	16.8
July	318.0	115.3	238.0	223.9	120.1	141.4	209.8	218.2	181.0	183.5	150.0	207.5	166.4	178.3	426.1	265.9		157.4	106.5	41.4	33.5
August	265.8	182.6	398.8	367.2	272.4	308.7	359.4	328.8	295.5	287.0	250.8	315.2	259.3	241.5	534.5	358.1		216.2	150.3	64.5	50.0
Septebe	194.0	142.8	304.9	299.8	210.7	240.6	292.2	267.0	233.2	226.0	193.2	274.2	225.9	230.9	540.4	378.6		248.6	176.4	86.0	70.6
October	4.0	124.7	249.8	248.6	146.5	167.9	207.6	175.0	137.7	132.0	97.9	159.3	119.8	158.3	411.0	289.9		233.6	169.6	88.8	80.0
Season	798.8	630.2	1,338.9	1,297.2	819.5	946.2	1,233.4	1,162.7	983.7	974.1	799.7	1,120.7	899.4	946.4	2,245.2	1,476.5		956.3	669.9	301.6	250.9

(*) Observed data for Jinhong from 15th June to 15th October

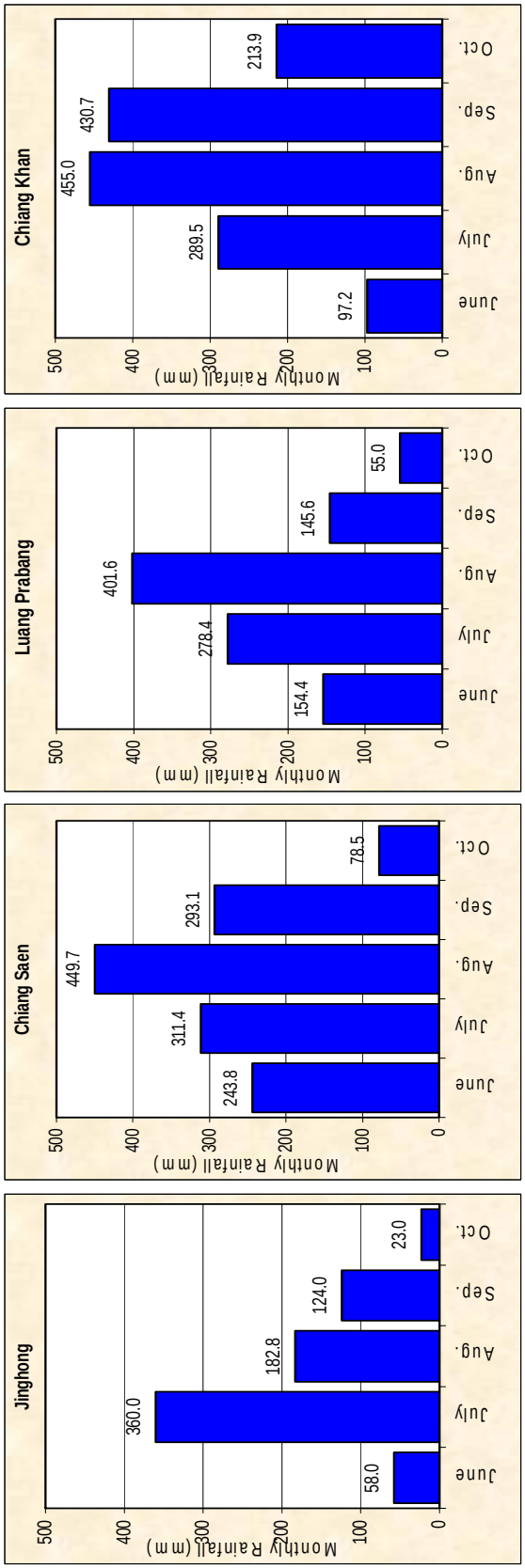


Figure A1 Monthly rainfall distribution for Jinghong, Chiang Saen, Luang Prabang and Chiang Khan.

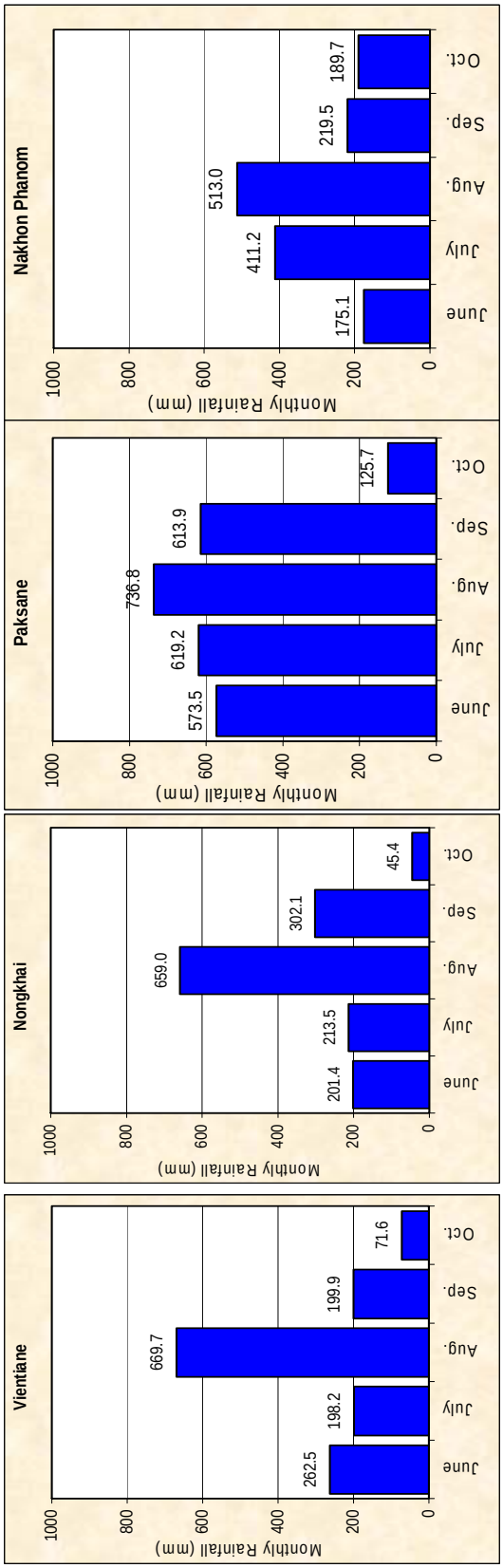


Figure A2 Monthly rainfall distribution for Chiang Khan, Vientiane, Nong Khai , Paksane and Nakhon Phanom.

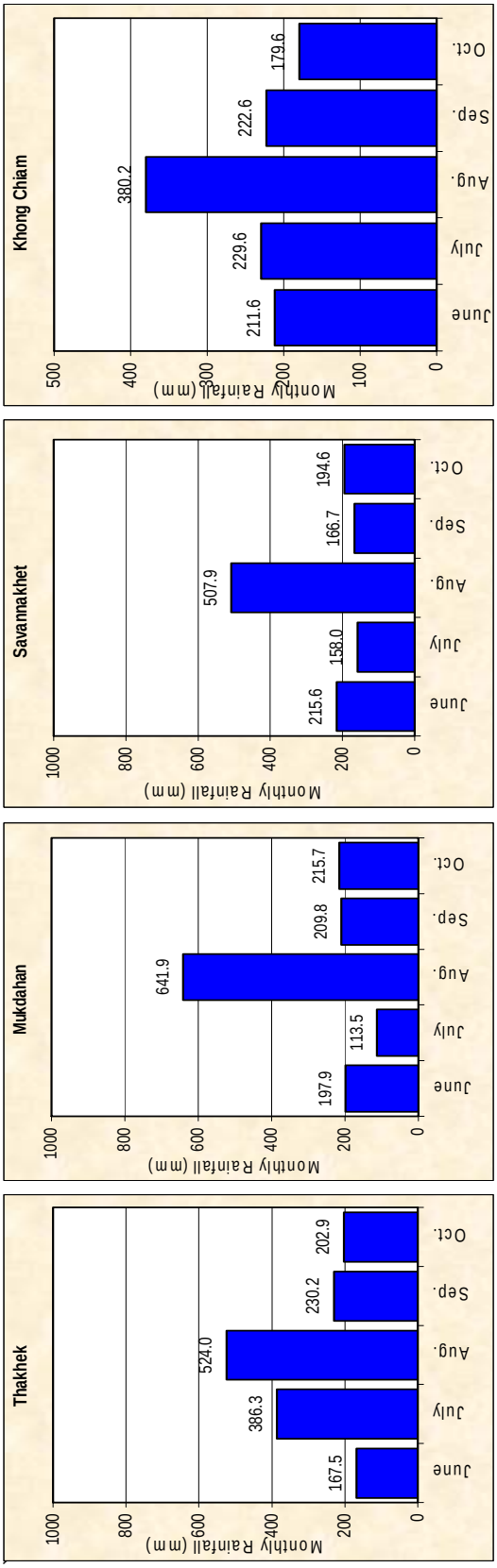


Figure A3 Monthly rainfall distribution for Thakhek, Mukdahan, Savannakhet and Khong Chiam.

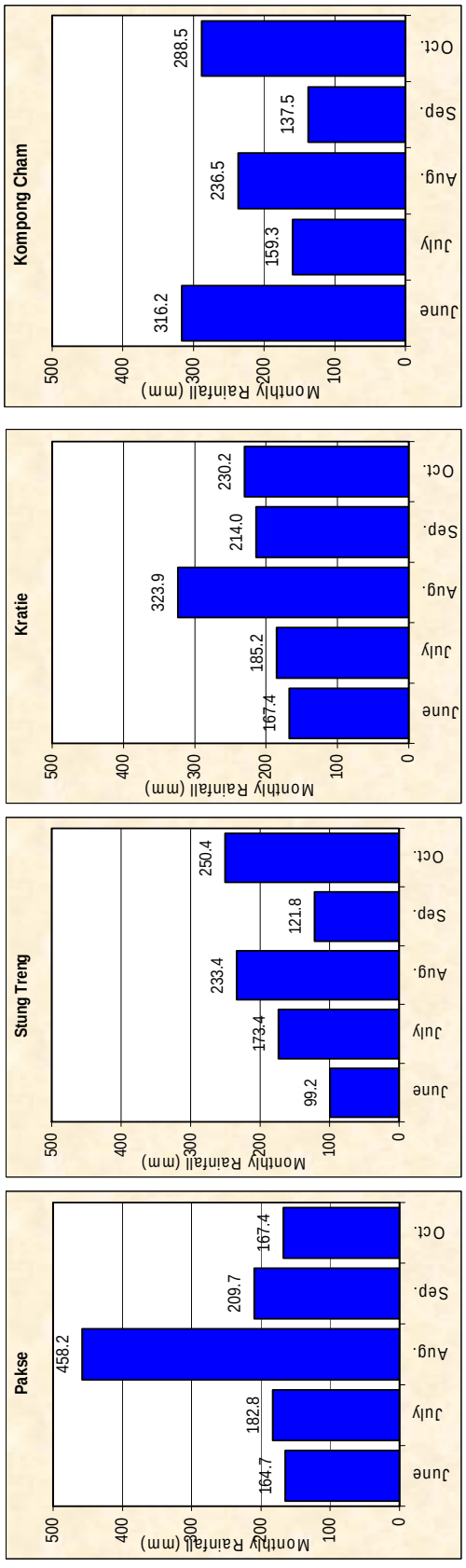


Figure A4 Monthly rainfall distribution for, Pakse, Stung Treng, Kratie and Kompong Chiam.

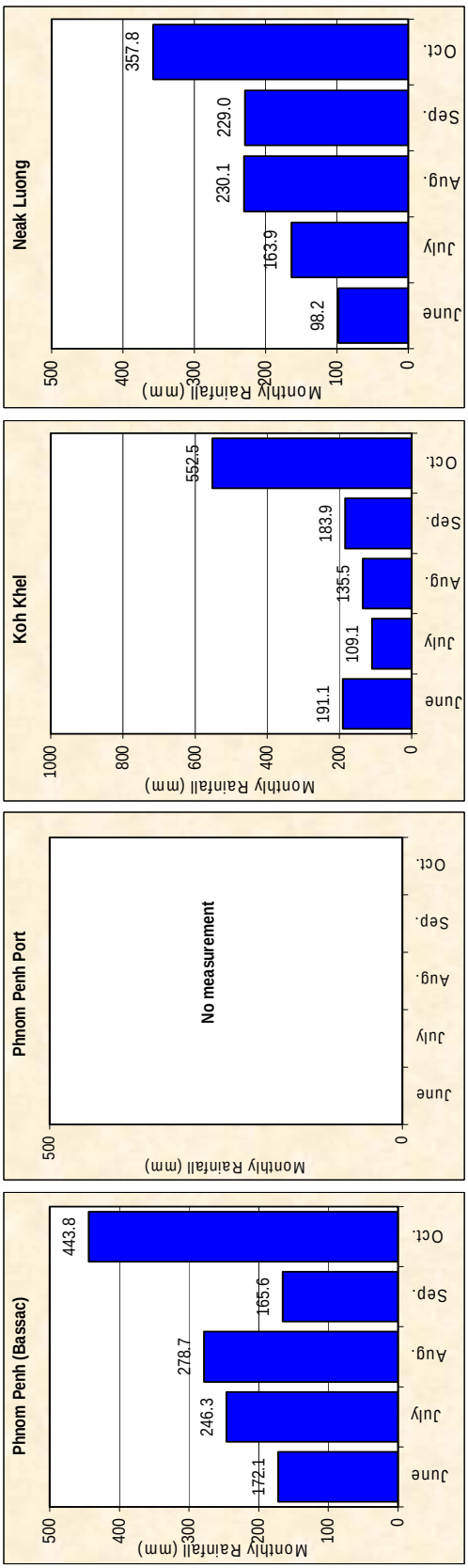


Figure A5 Monthly rainfall distribution for Phnom Penh (Bassac and Port), Koh Khel and Neak Luong.

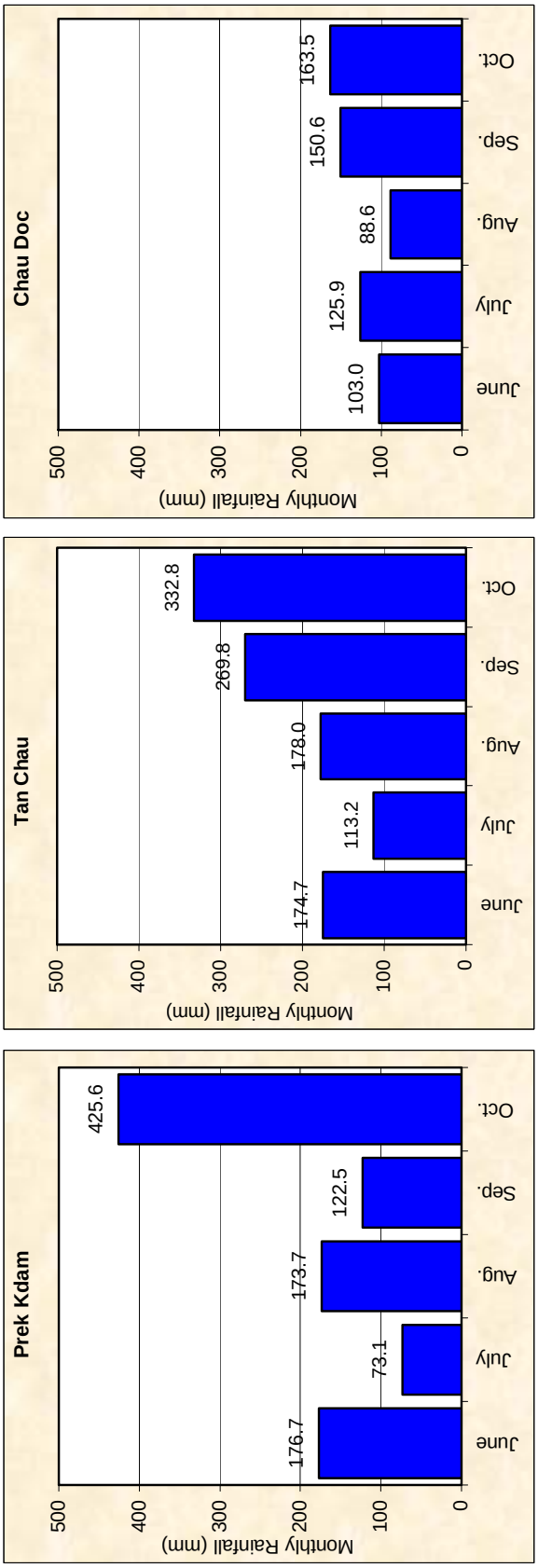


Figure A6 Monthly rainfall distribution for Prek Kdam, Tan Chau and Chau Doc.

2. Graphs for monthly rainfall in flood season from 2000 to 2012 and long-term average along the Mekong River

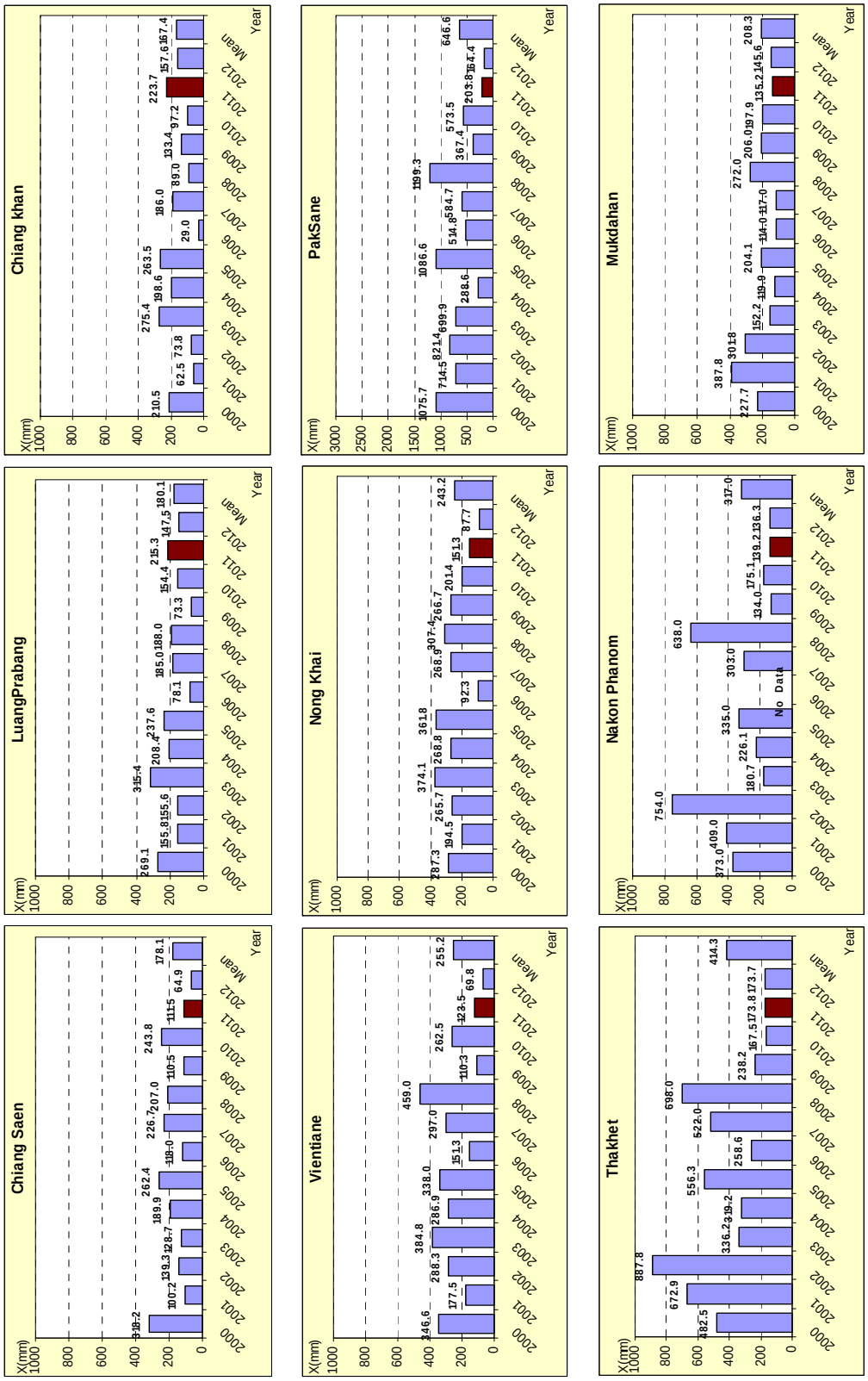


Figure A7 Monthly rainfall in June for main stations along the Mekong River.

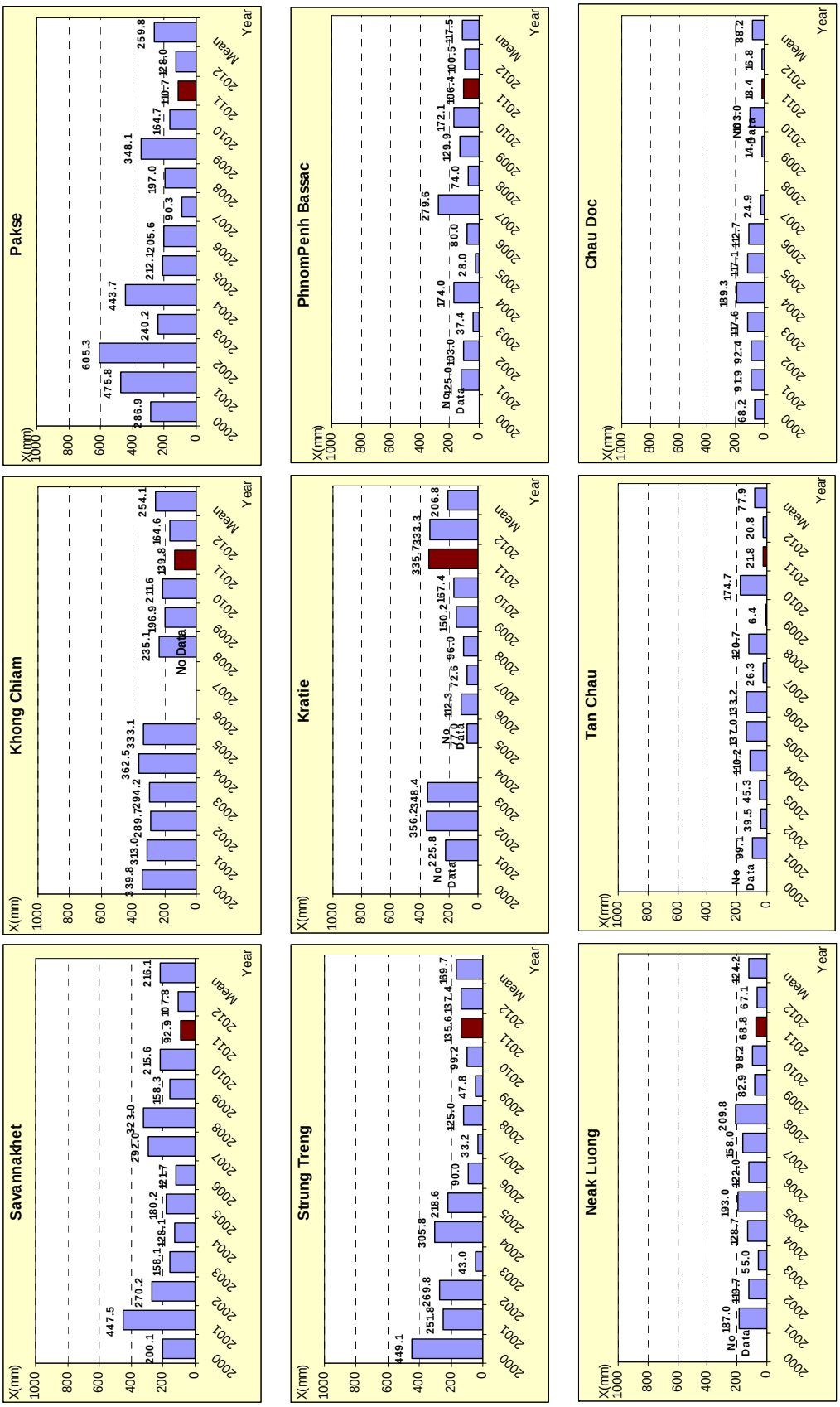


Figure A7 (cont.)

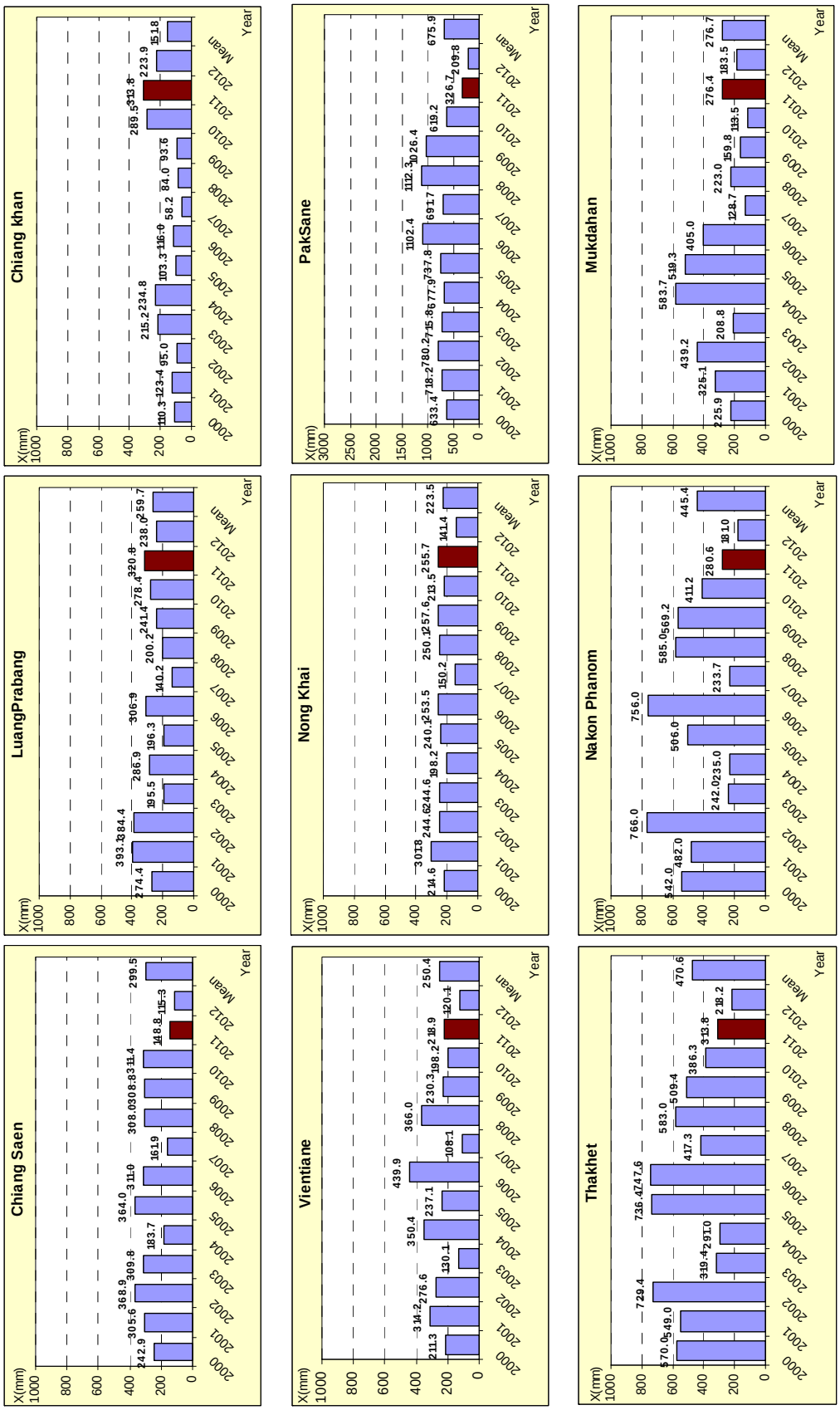


Figure A8 Monthly rainfall in July for main stations along the Mekong River.

Figure A8 (cont.)

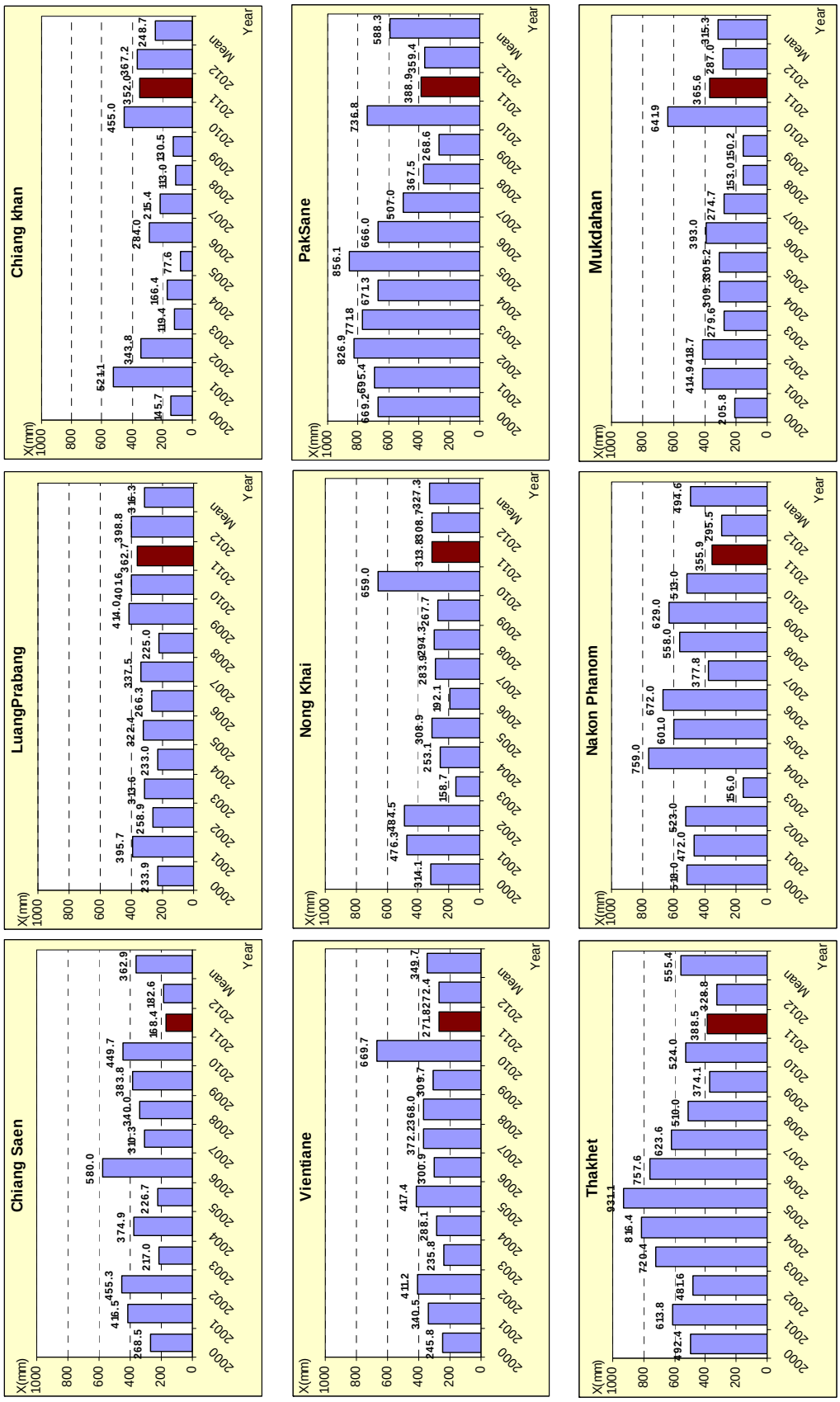


Figure A9 Monthly rainfall in August for main stations along the Mekong River.

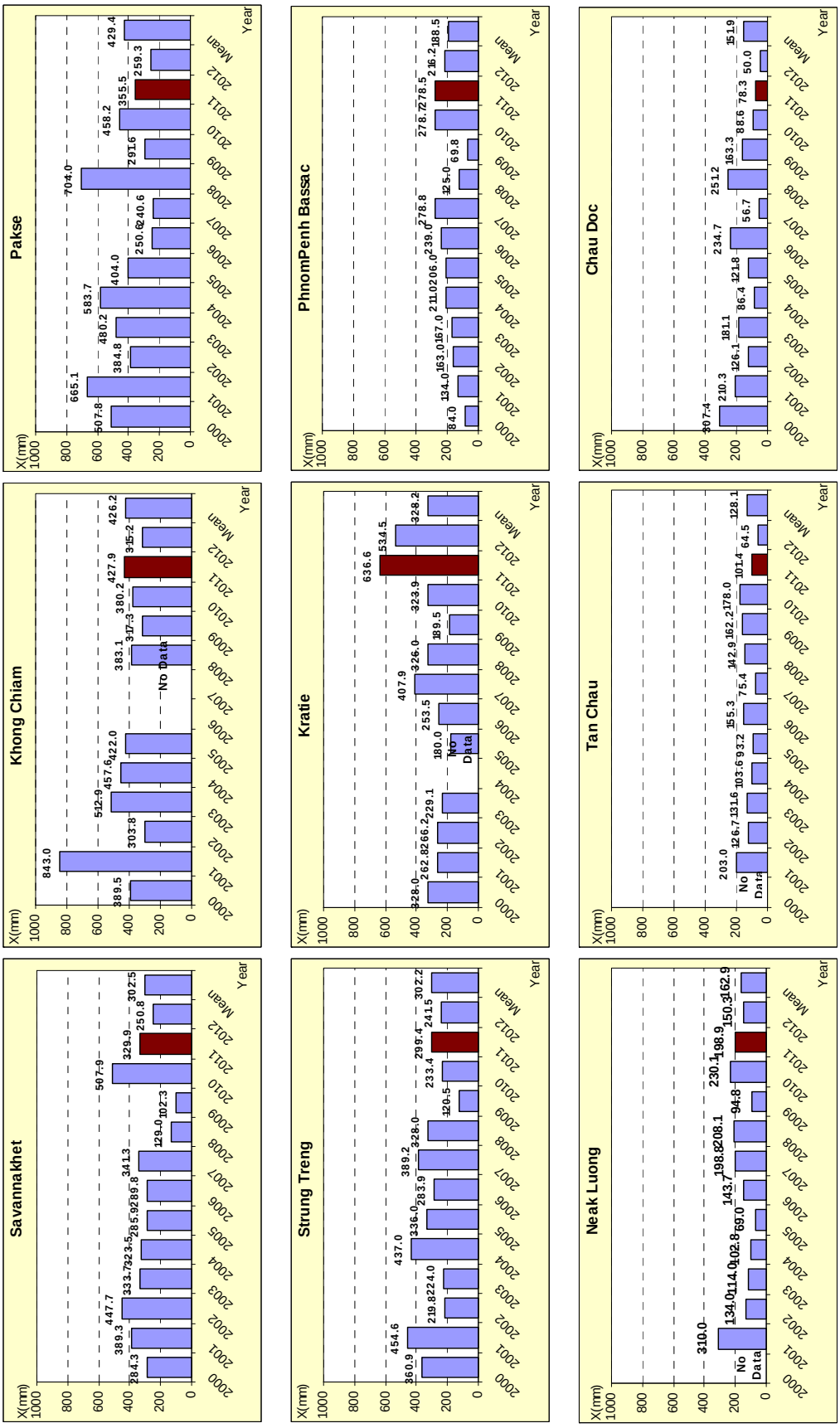


Figure A9 (cont.)

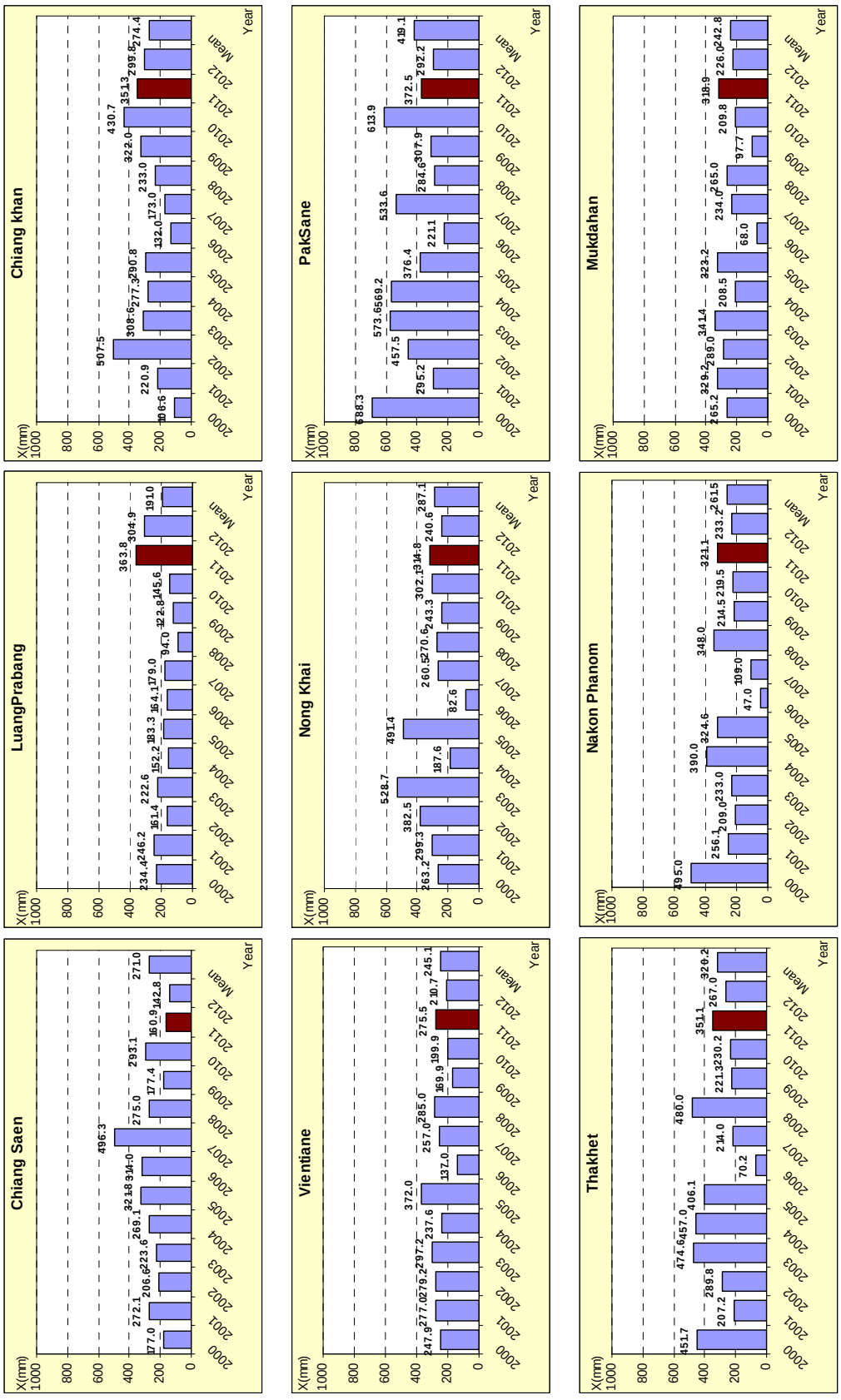


Figure A10 Monthly rainfall in September for main stations along the Mekong River.

Figure A10 (cont.)

Figure A11 Monthly rainfall in October for main stations along the Mekong River.

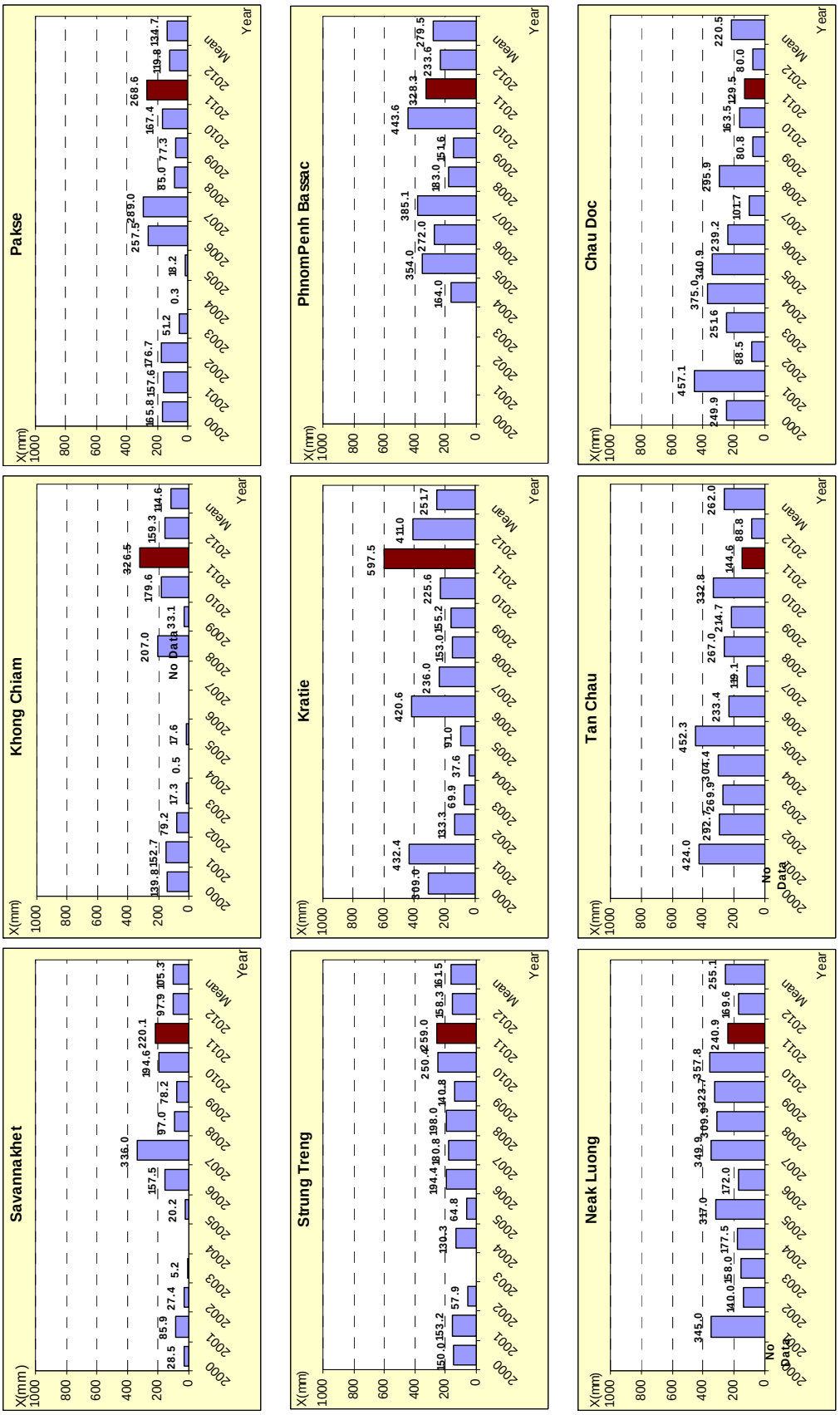


Figure A11 (cont.)

3. Tables of flood event characteristics along the Mekong River during flood season 2012

Table A2 The characteristics of flood events for station from Chiang Saen to Vientiane/Nong Khai

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	laverage (m/day)	
010501	Chiang Saen	24-Jul	3.24	29-Jul	7.91	5	4.67	26-Jul - 27-Jul	1.54	0.93	TS-VICENTE
		19-Aug	5.52	21-Aug	7.83	2	2.31	20-Aug - 21-Aug	1.21	1.16	TY-TEMBIN, TY-BOLAVEN
011201	Luang Prabang	26-Jul	9.23	01-Aug	15.22	6	5.99	26-Jul - 27-Jul	1.54	1.00	TS-VICENTE
		18-Aug	11.96	23-Aug	15.25	5	3.29	20-Aug - 21-Aug	1.21	0.66	TY-TEMBIN, TY-BOLAVEN
011903	Chiang Khan	21-Jul	6.62	02-Aug	13.28	12	6.66	28-Jul - 29-Jul	1.17	0.56	TS-VICENTE
		16-Aug	10.55	24-Aug	13.27	8	2.72	20-Aug - 21-Aug	0.65	0.34	TY-TEMBIN, TY-BOLAVEN
011901	Vientiane	28-Jul	5.60	03-Aug	9.97	6	4.37	28-Jul - 29-Jul	1.30	0.73	TS-VICENTE
		20-Aug	8.05	25-Aug	10.28	5	2.23	20-Aug - 21-Aug	0.81	0.45	TY-TEMBIN, TY-BOLAVEN
012001	Nong Khai	28-Jul	6.52	04-Aug	11.66	7	5.14	29-Jul - 30-Jul	1.12	0.73	TS-VICENTE
		20-Aug	9.14	25-Aug	11.24	5	2.10	20-Aug - 21-Aug	0.66	0.42	TY-TEMBIN, TY-BOLAVEN

Table A3 The characteristics of flood events for stations from Paksane to Pakse

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	laverage (m/day)	
012703	Paksane	29-Jul	8.25	03-Aug	12.04	5	3.79	30-Jul - 31-Jul	1.25	0.76	TS-VICENTE
		21-Aug	11.16	27-Aug	12.25	6	1.09	25-Aug - 26-Aug	0.30	0.18	TY-TEMBIN, TY-BOLAVEN
013101	Nakhon Phanom	30-Jul	6.34	04-Aug	9.78	5	3.44	31-Jul - 1-Aug	1.87	0.69	TS-VICENTE
		23-Aug	9.18	28-Aug	9.85	5	0.67	26-Aug - 27-Aug	0.29	0.13	TY-TEMBIN, TY-BOLAVEN
013102	Thakhek	30-Jul	7.50	04-Aug	10.90	5	3.40	31-Jul - 01-Aug	1.59	0.68	TS-VICENTE
		24-Aug	10.23	28-Aug	10.93	4	0.70	26-Aug - 27-Aug	0.26	0.18	TY-TEMBIN, TY-BOLAVEN
013402	Mukdahan	30-Jul	6.19	05-Aug	9.68	6	3.49	31-Jul - 01-Aug	1.45	0.58	TS-VICENTE
		24-Aug	8.82	28-Aug	9.56	4	0.74	26-Aug - 27-Aug	0.22	0.19	TY-TEMBIN, TY-BOLAVEN
013401	Savannakhet	01-Aug	5.60	05-Aug	8.56	4	2.96	01-Aug - 02-Aug	2.30	0.74	TS-VICENTE
		24-Aug	7.72	28-Aug	8.41	4	0.69	26-Aug - 27-Aug	0.21	0.17	TY-TEMBIN, TY-BOLAVEN
013801	Khong Chiam	31-Jul	7.20	05-Aug	10.85	5	3.65	01-Aug - 02-Aug	1.41	0.73	TS-VICENTE
		24-Aug	9.70	30-Aug	10.97	6	1.27	27-Aug - 28-Aug	0.40	0.21	TY-TEMBIN, TY-BOLAVEN
013901	Pakse	01-Aug	6.21	05-Aug	9.01	4	2.80	02-Aug - 03-Aug	1.29	0.70	TS-VICENTE
		25-Aug	7.95	30-Aug	9.16	5	1.21	27-Aug - 28-Aug	0.36	0.24	TY-TEMBIN, TY-BOLAVEN

Table A4 The characteristics of flood events for stations from Stung Treng to Kompong Cham

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	laverage (m/day)	
014501	Stung Treng	02-Aug	6.53	05-Aug	8.90	3	2.37	03-Aug - 04-Aug	1.19	0.79	TS-VICENTE
		02-Sep	8.08	05-Sep	9.00	3	0.92	03-Sep - 04-Sep	0.38	0.31	SW, ITCZ
014901	Kratie	03-Aug	15.27	06-Aug	18.64	3	3.37	03-Aug - 04-Aug	1.73	1.12	TS-VICENTE
		02-Sep	18.31	06-Sep	19.55	4	1.24	03-Sep - 04-Sep	0.55	0.31	SW, ITCZ
019802	Kompong Cham	02-Aug	9.43	06-Aug	12.53	4	3.10	04-Aug - 05-Aug	1.46	0.78	TS-VICENTE
		03-Sep	12.63	07-Sep	13.46	4	0.83	03-Sep - 04-Sep	0.30	0.21	SW, ITCZ

Table A5 The characteristics of flood events for stations from Phnom Penh Bassac/Phnom Penh Port, Koh Khel/Neak Luong to Prek Kdam

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	laverage (m/day)	
033401	Bassac Chaktomuk	03-Aug	5.73	07-Aug	7.39	4	1.66	04-Aug - 05-Aug	0.79	0.42	TS-VICENTE
		03-Sep	7.82	07-Sep	8.30	4	0.48	04-Sep - 05-Sep	0.18	0.12	SW, ITCZ
020101	Phnom Penh Port	03-Aug	4.91	06-Aug	6.47	3	1.56	04-Aug - 05-Aug	0.75	0.52	TS-VICENTE
		03-Sep	6.92	07-Sep	7.41	4	0.49	03-Sep - 04-Sep	0.14	0.12	SW, ITCZ
033402	Koh Khel	04-Aug	5.28	07-Aug	6.50	3	1.22	04-Aug - 05-Aug	0.64	0.41	TS-VICENTE
019806	Neak Luong	04-Aug	4.10	07-Aug	5.18	3	1.08	04-Aug - 05-Aug	0.62	0.36	TS-VICENTE
020102	Prek Kdam	03-Aug	4.71	07-Aug	6.09	4	1.38	04-Aug - 05-Aug	0.62	0.35	TS-VICENTE

Table A6 The characteristics of flood events for stations from Tan Chau and Chau Doc (**)

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	laverage (m/day)	
019803	Tan Chau	04-Aug	1.55	07-Aug	2.14	3	0.59	04-Aug - 05-Aug	0.27	0.20	TS-VICENTE
039801	Chau Doc	04-Aug	1.15	07-Aug	1.48	3	0.33	05-Aug - 06-Aug	0.20	0.11	TS-VICENTE

(**) Water levels at Tan Chau and Chau Doc are influenced by tidal effect; the WL in the Table A6 were recorded at 7AM during 2012 flood season.

Annex B Accuracy and performance

Accuracy

"Accuracy" describes the accuracy of the adjusted and published forecast, based on the results of the MRC Mekong Flood Forecasting System, which are then adjusted by the Flood Forecaster in Charge taking into consideration known biases in input data and his/her knowledge of the response of the model system and the hydrology of the Mekong River Basin.

The information is presented as a graph below, showing the average flood forecasting accuracy along the Mekong mainstream.

The graph of average difference between forecast and actual water levels for the whole flood season from the 1st June to the 31st October shows the normal pattern.

In general terms, the accuracy is good for all forecasts lead time at most stations along Mekong River, however the accuracy for 2-day to 3-day forecasts start from Chiang Saen to Neak luong. The detail analysis is presented in paragraph 2.2.

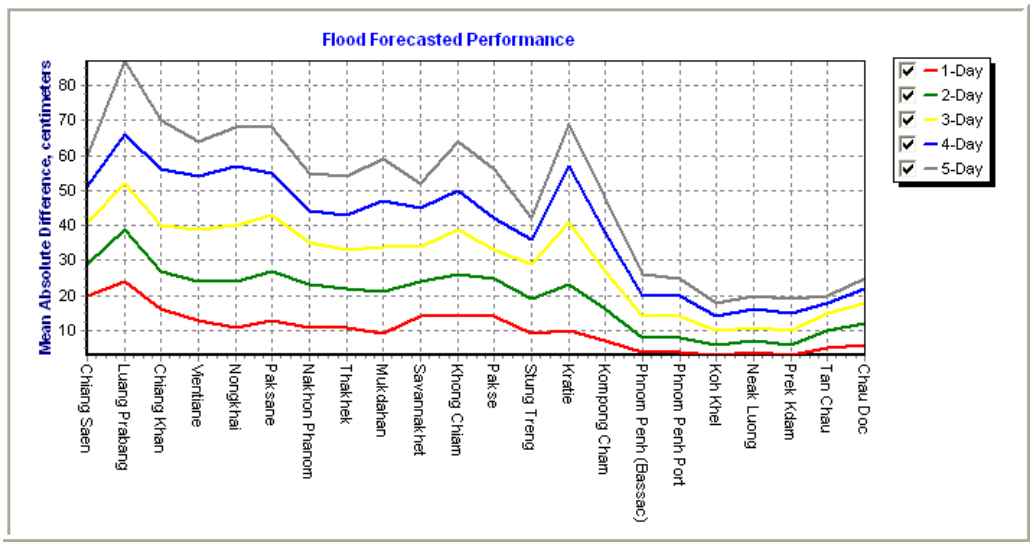


Figure B1 Average flood forecast accuracy along the Mekong mainstream.

Forecast Achievement

The forecast achievement indicates the % of days that the forecast at a particular station for a lead-time is successful against a respective benchmark (Table B2).

Table B1 Achievement of daily forecast against benchmarks

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nong Khai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	Phnom Penh (Bassac)	Phnom Penh Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average
1-day	75.0	70.4	79.6	57.2	60.5	53.9	65.1	63.8	70.4	60.5	59.2	50.0	70.4	69.1	86.2	94.7	91.4	96.7	94.7	97.4	86.8	82.9	74.4
2-day	15.9	3.3	48.3	14.6	20.5	13.9	9.3	4.0	3.3	8.6	13.9	14.6	26.5	16.6	28.5	5.3	49.7	19.9	27.8	55.6	36.4	35.1	21.4
3-day	69.3	62.0	70.7	41.3	42.0	38.0	50.7	52.0	55.3	50.0	50.7	58.7	57.3	45.3	66.7	49.3	50.0	73.3	67.3	66.7	51.3	48.7	55.3
4-day	75.2	65.8	55.0	51.7	51.0	57.0	67.1	67.8	64.4	67.8	62.4	67.8	72.5	61.7	74.5	34.9	79.2	55.0	81.2	86.6	45.0	34.2	62.6
5-day	68.9	56.1	49.3	46.6	41.9	41.9	56.8	58.8	52.0	60.8	54.1	56.1	64.9	52.7	62.8	60.8	58.1	81.8	75.7	79.7	76.4	65.5	60.1

Table B2 Benchmarks of success (Indicator of accuracy in mean absolute error)

Unit in cm

	Chiang Saen	Luang Prabang	Chiang Khan	Ventiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	Phnom Penh (Bassac)	Phnom Penh Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc
1-day	25	25	25	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2-day	50	50	50	25	25	25	25	25	25	25	25	25	25	25	25	10	10	10	10	10	10	10
3-day	50	50	50	25	25	25	25	25	25	25	25	25	25	25	25	10	10	10	10	10	10	10
4-day	75	75	50	50	50	50	50	50	50	50	50	50	50	50	50	10	25	10	25	25	10	10
5-day	75	75	50	50	50	50	50	50	50	50	50	50	50	50	50	25	25	25	25	25	25	25

Note: *An indication of the accuracy given in the Table B2 is based on the performance of the forecast made in 2008 from the new flood forecasting system and the configuration for the 2009 flood season and is published on the website of MRC (http://ffw.mrcmekong.org/accuracy.htm).*

A new set of performance indicators that is established by combining international standards and the specific circumstances in the Mekong River Basin, is applied officially for the flood season of 2011 onward.

Performance

Performance is assessed by evaluating a number of performance indicators, see Table and graphs below:

Table B3 Overview of performance indicators for flood season 2012 from June to October

	Flood Forecast: time sent			Arrival time of input data (average)								Missing data (number)							
2012	FF completed and sent (time)	stations without forecast	FF2 completed and sent (time)	Weather information available (number)	NOAA data	China	Cambodia - DHRW	Cambodia - DOM	Lao PDR - DMH	Thailand - DWR	Viet Nam - NCHMF	NOAA data	China	Cambodia - DHRW	Cambodia - DOM	Lao PDR - DMH	Thailand - DWR	Viet Nam - NCHMF	
June	10:42	0	-	19	07:12	08:12	07:29	06:16	08:56	07:34	07:19	1	0	69	497	579	3	414	
July	10:32	1	-	17	07:37	07:57	07:19	06:03	08:46	07:13	07:12	6	0	8	84	515	8	391	
August	10:32	0	-	16	08:12	08:12	07:14	06:13	08:45	07:24	07:35	3	1	8	77	508	5	446	
eptembe	10:24	0	-	26	08:12	08:12	07:19	06:15	08:45	07:26	07:03	0	2	37	125	567	13	558	
October	10:25	0	-	18	08:12	08:11	07:07	06:15	08:51	07:10	07:09	0	0	1	418	578	21	485	
season	10:31	1	-	96	07:52	08:08	07:17	06:12	08:49	07:22	07:16	10	3	123	1201	2747	50	2294	

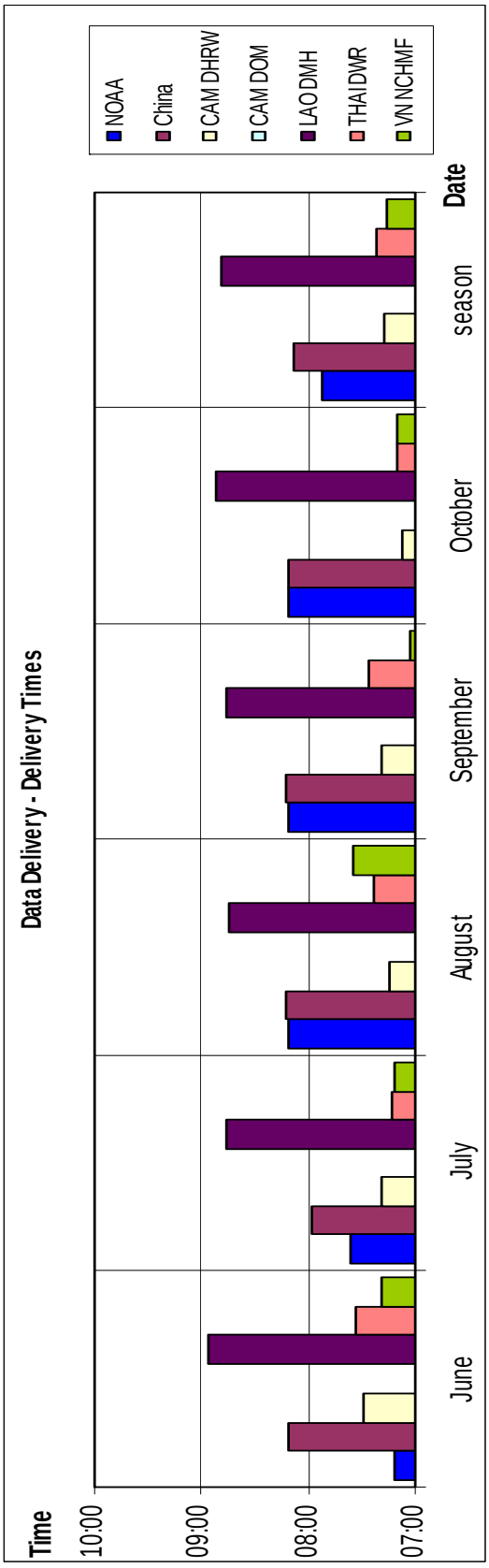


Figure B2 Data delivery times for flood season 2012 from June to October.

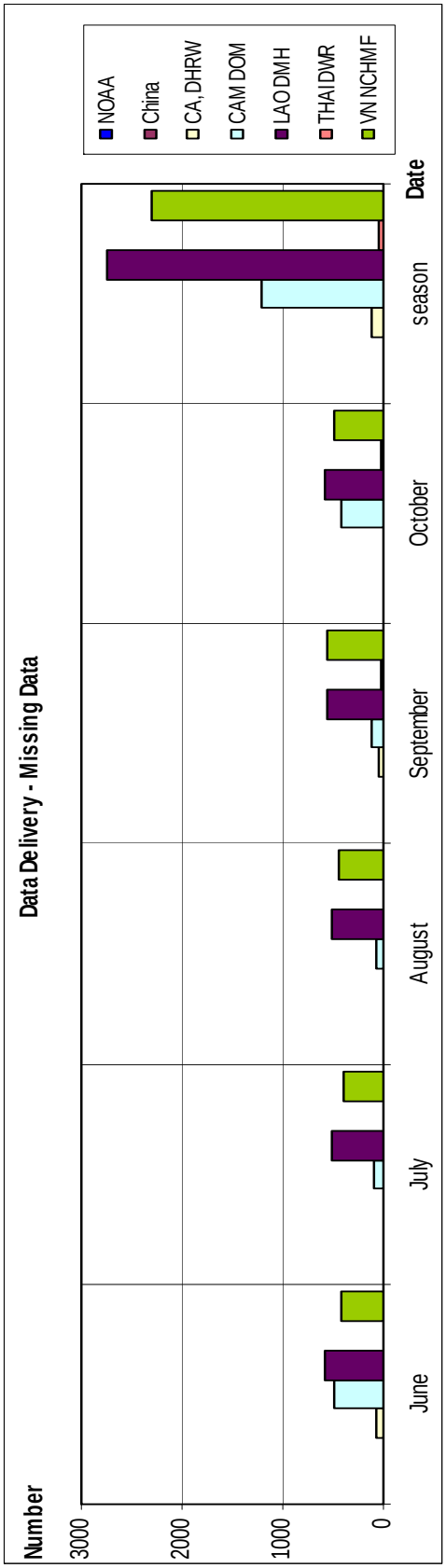


Figure B3 Missing data for flood season 2012 from June to October.

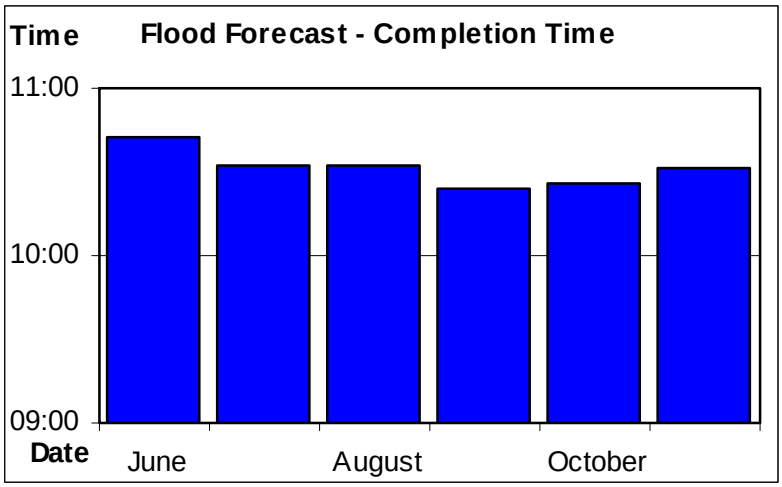


Figure B4 Flood forecast completion time.

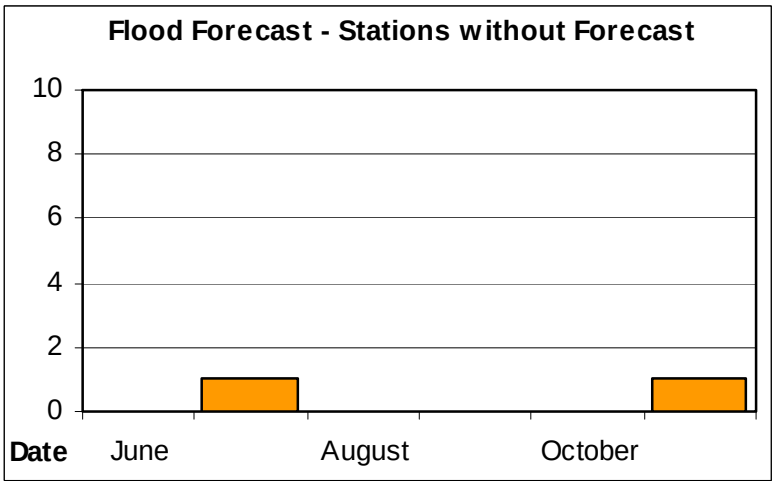


Figure B5 Flood forecast stations without forecast.

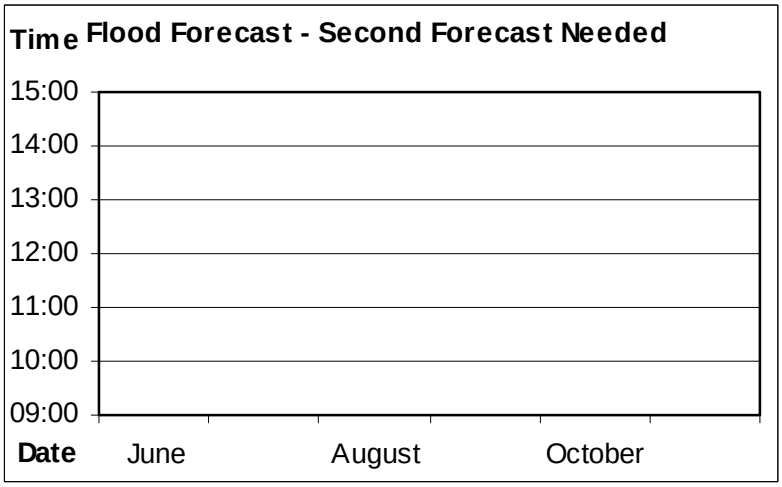


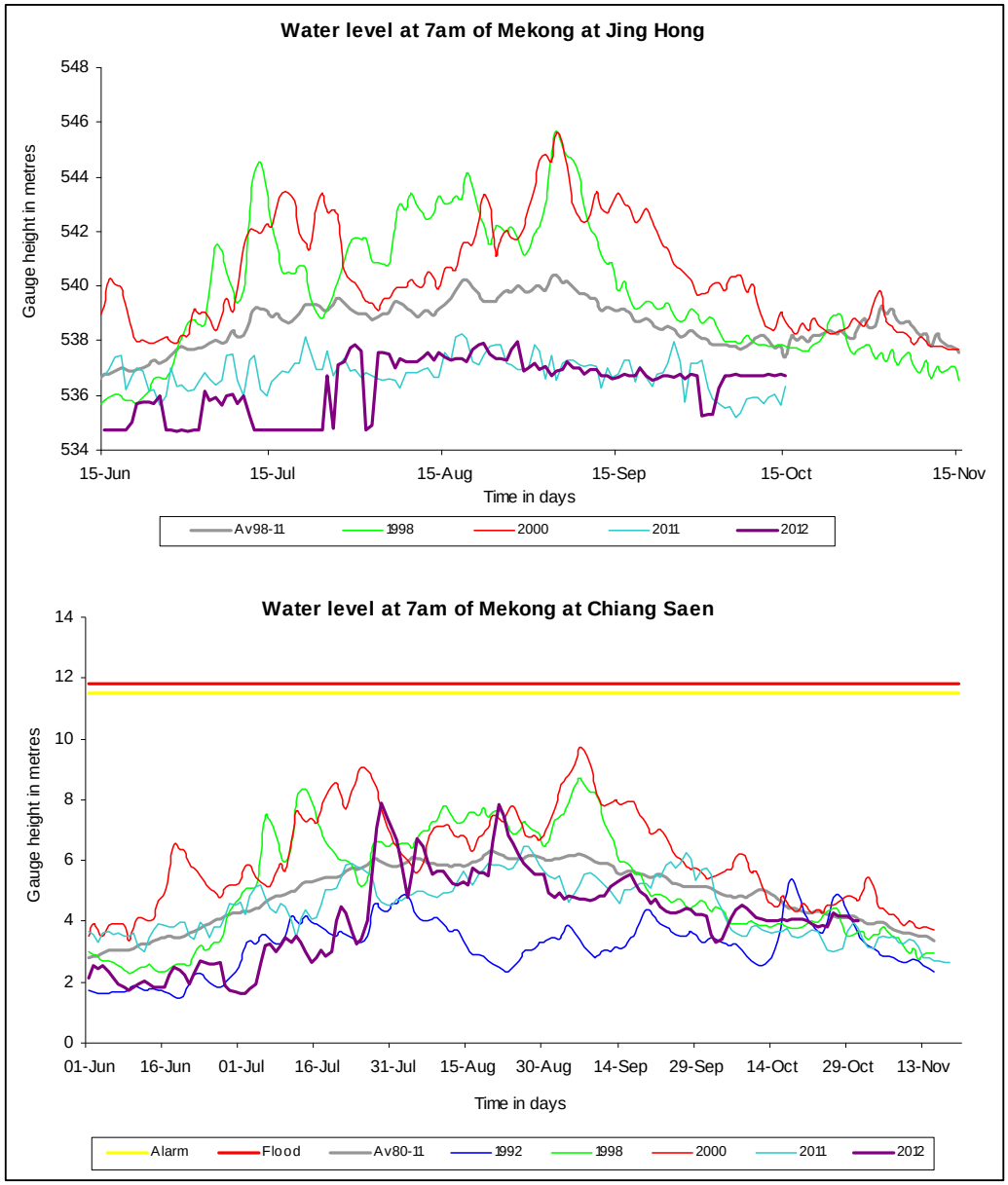
Figure B6 Second forecast needed.

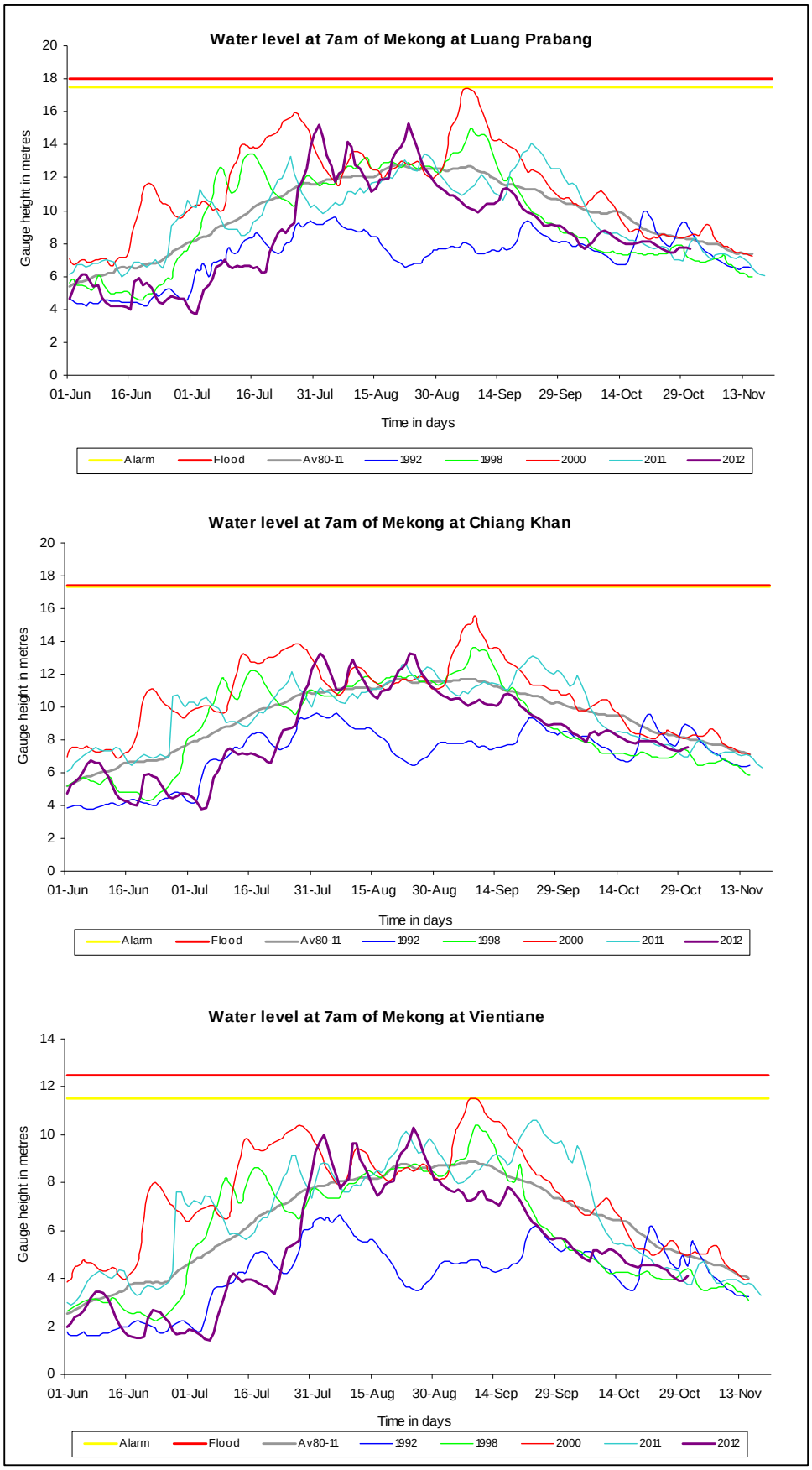
Annex C Season Water Level Graphs

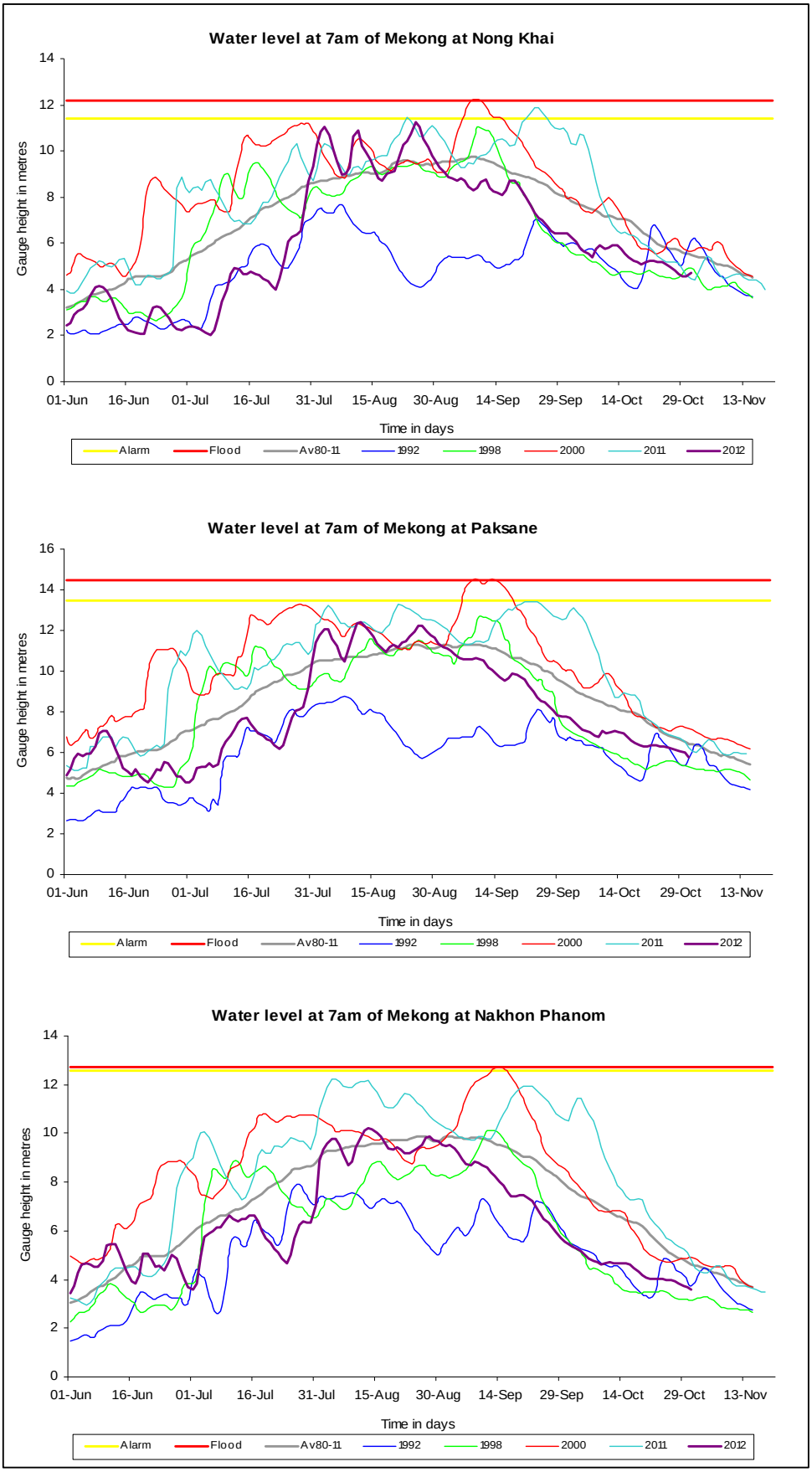
This Annex has the water level and rainfall graphs of the report date. These graphs are distributed daily by email together with the Flood Bulletins.

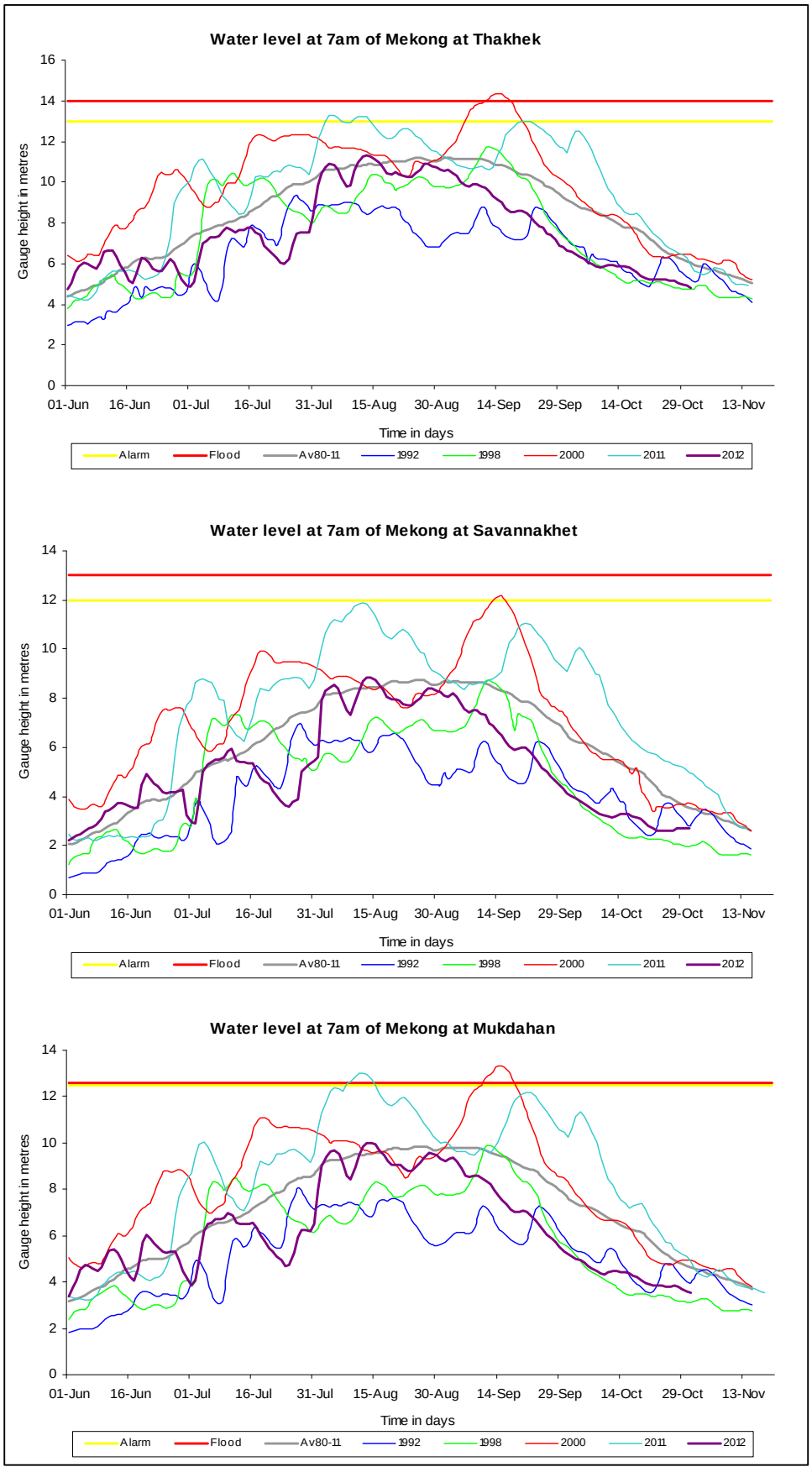
HYDROGRAPHS OF THE MEKONG AT MAINSTREAM STATIONS

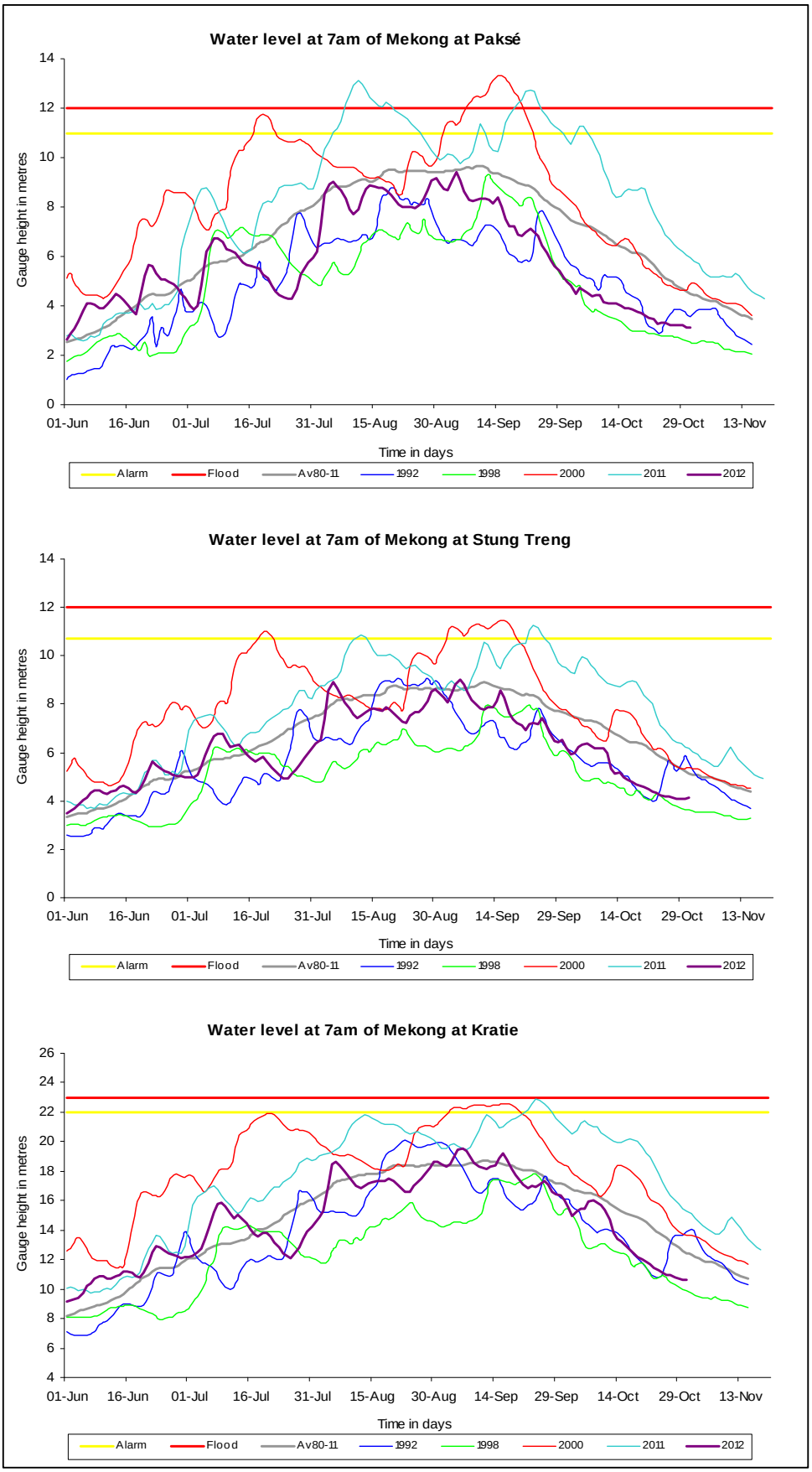
IN FLOOD SEASON FROM 1 JUNE TO 31 OCTOBER

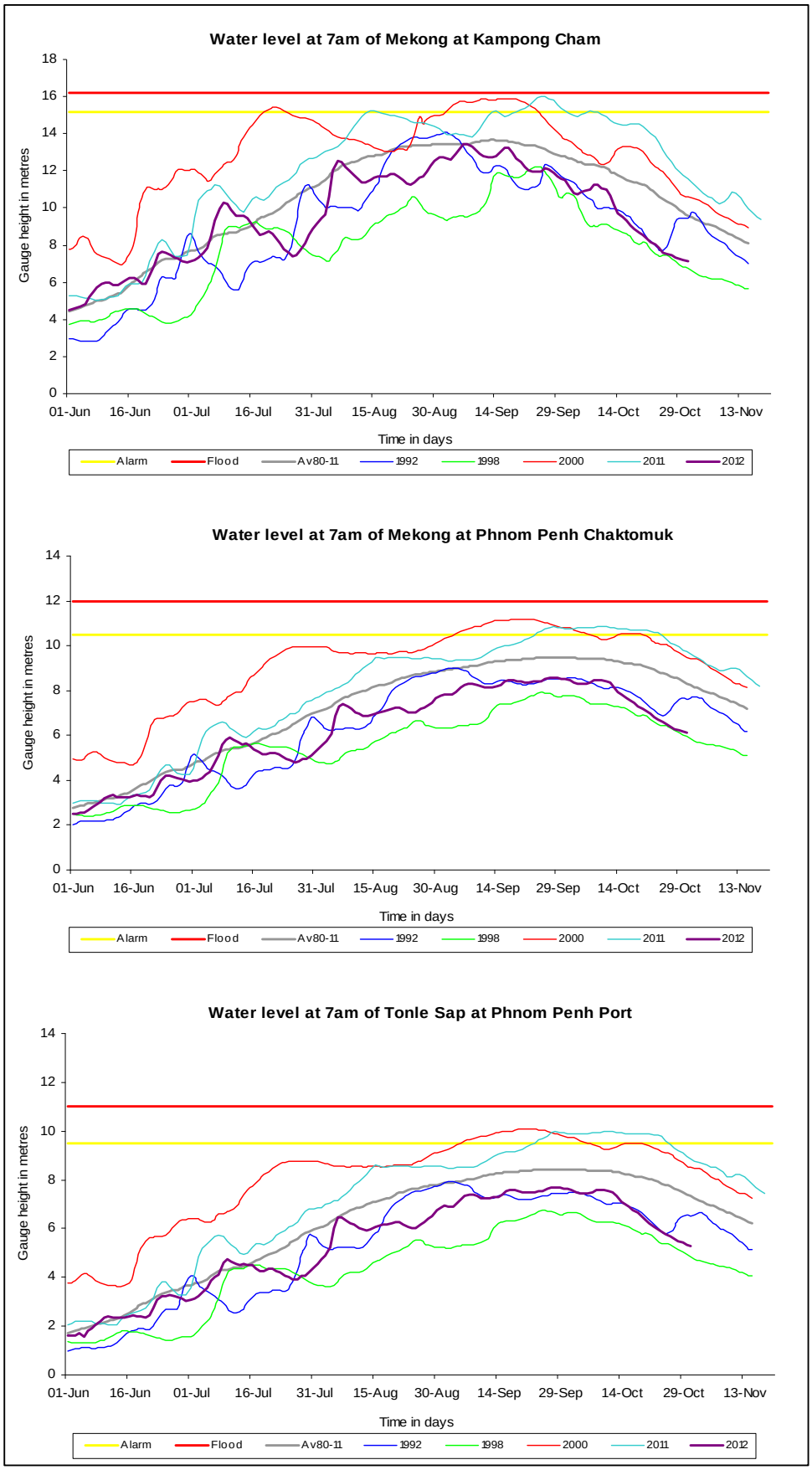


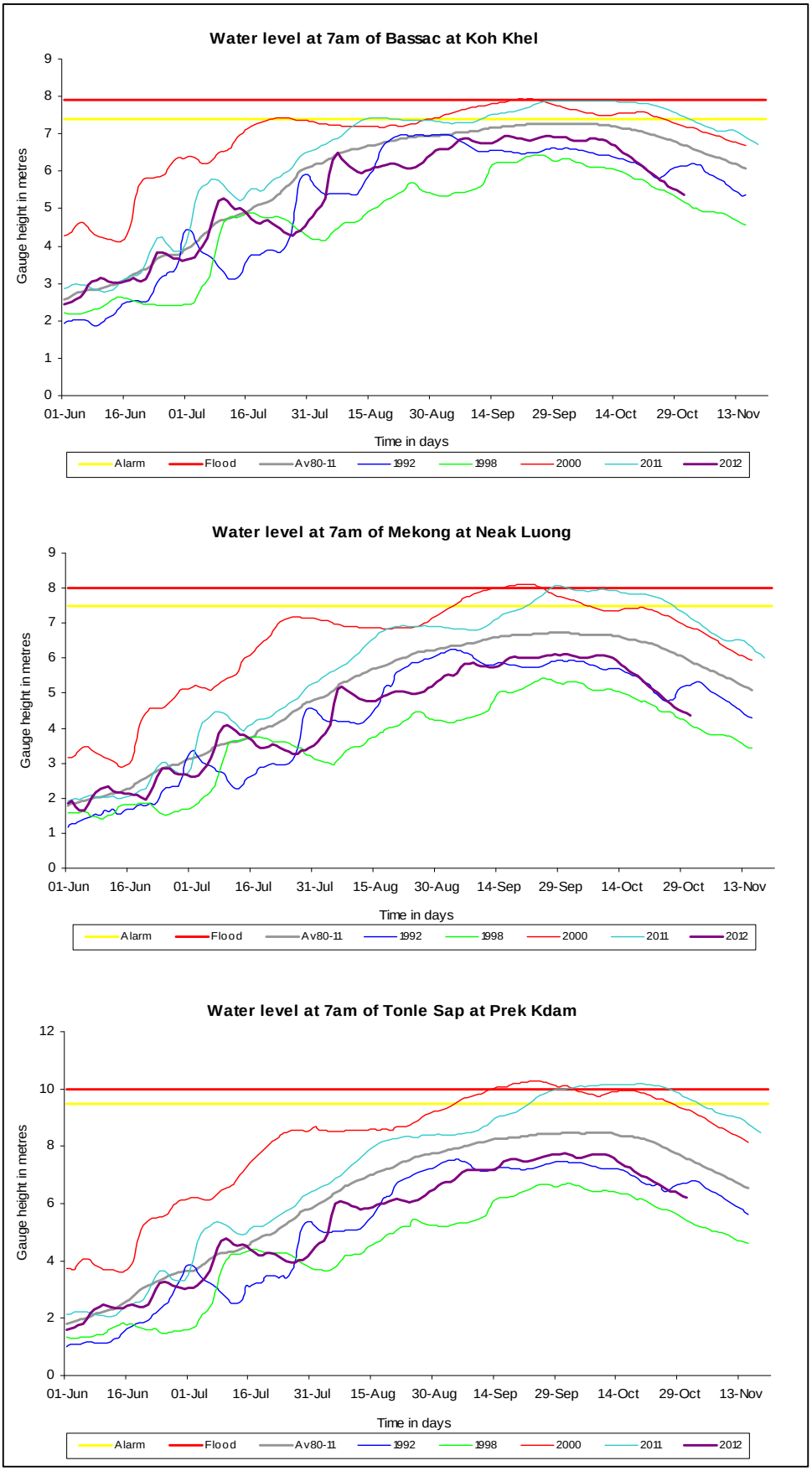

Water level at 7am of Mekong at Luang Prabang
Gauge height in metres
Time in days
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Chiang Khan
Gauge height in metres
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Vientiane
Gauge height in metres
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012

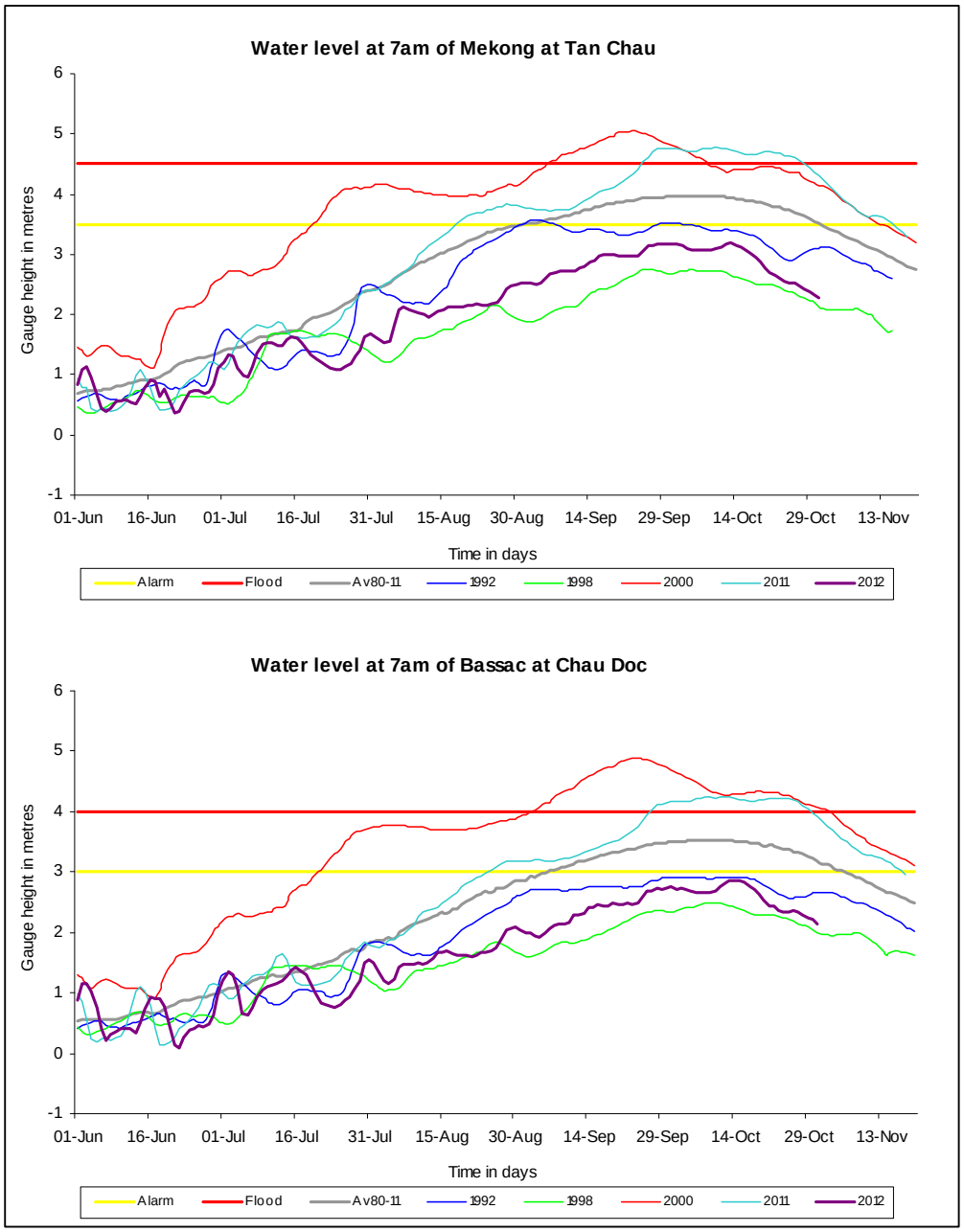

Water level at 7am of Mekong at Nong Khai
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Paksane
Gauge height in metres
0
2
4
6
8
10
12
14
16
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Nakhon Phanom
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012


Water level at 7am of Mekong at Thakhek
Gauge height in metres
Time in days
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Savannakhet
Gauge height in metres
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Mukdahan
Gauge height in metres
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012


Water level at 7am of Mekong at Paksé
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Stung Treng
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Kratie
Gauge height in metres
4
6
8
10
12
14
16
18
20
22
24
26
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012


Water level at 7am of Mekong at Kampong Cham
Gauge height in metres
0
2
4
6
8
10
12
14
16
18
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Phnom Penh Chaktomuk
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Tonle Sap at Phnom Penh Port
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012


Water level at 7am of Bassac at Koh Khel
Gauge height in metres
0
1
2
3
4
5
6
7
8
9
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Mekong at Neak Luong
Gauge height in metres
0
1
2
3
4
5
6
7
8
9
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Tonle Sap at Prek Kdam
Gauge height in metres
0
2
4
6
8
10
12
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012


Water level at 7am of Mekong at Tan Chau
Gauge height in metres
6
5
4
3
2
1
0
-1
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012
Water level at 7am of Bassac at Chau Doc
Gauge height in metres
6
5
4
3
2
1
0
-1
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-11
1992
1998
2000
2011
2012