Mekong River Commission

Flood Management and Mitigation Programme

Final

Seasonal Flood Situation Report for the Lower Mekong River Basin

Covering a period from 1st June to 31rd October 2013

Prepared by:
Regional Flood Management and Mitigation Centre

December 2013

Certification of Approval
of Internal FMMP Technical Document

Seasonal Flood Situation Report for the Lower Mekong River Basin
Covering period from 1 June to 31 October 2013

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1. Flood season 2013

1.1 Rainfall situation

During the five months of the flood season 2013, the critical rainfall situation in the Lower Mekong Basin occurred during the end of June, the month of July, the beginning of August, and the middle of September, as a result 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 higher than the average years (see Figure 1-1). The total of rainfall in the flood season 2013 at stations of the LMB was higher than the long-term average (LTA) and higher than in the previous flood season 2012.

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

- The wet season started at the end of June; the heavy rain mostly occurred in the middle reaches (from Paksane to Pakse) of the LMB.
- During July - August, the intensive and continued rain covered the entire LMB and appeared more frequently during this period.
- As is usual, from September to October intensive rainfall occurred in lower reach. However this year it covered the entire LMB as a result of many Tropical Storms and Typhoons related activities.

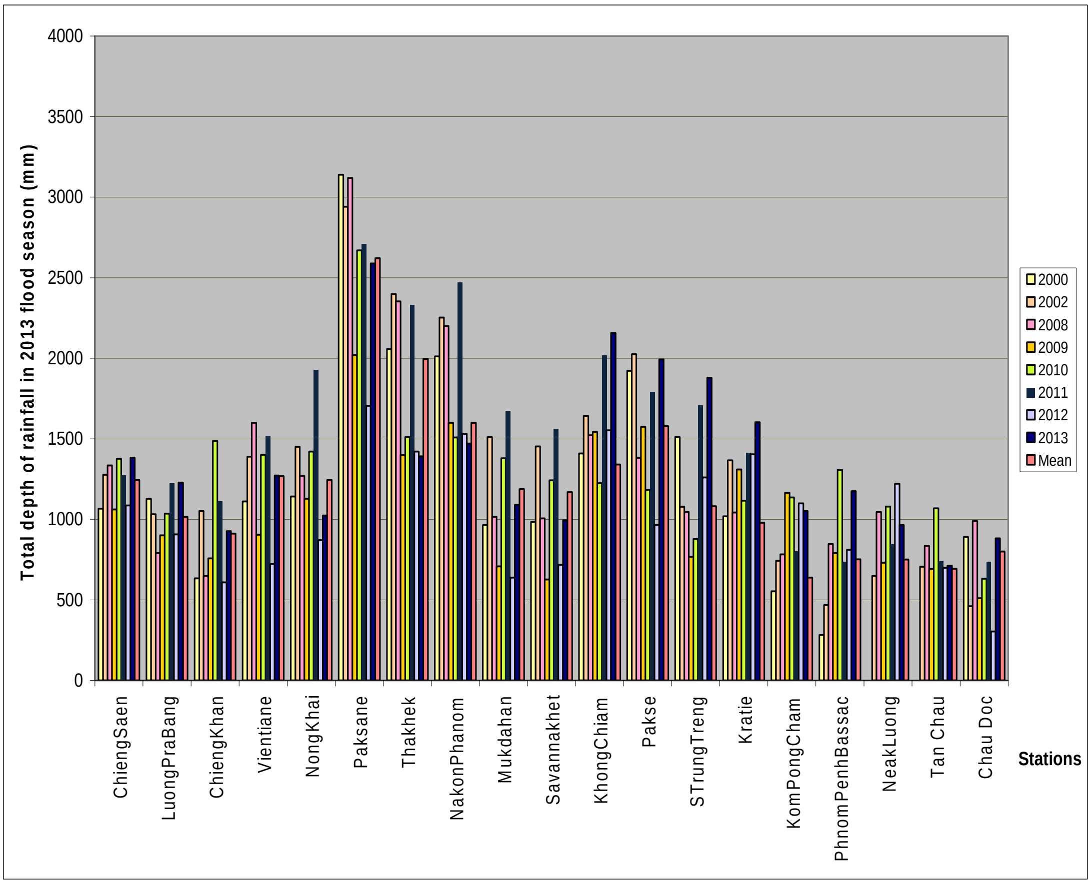


Figure 1-1 Total depth of rainfall in the flood season of the years 2000, 2002, 2008, 2009, 2010, 2011, 2012, 2013 and the long-term average flood seasonal rainfall.

In 2013, three main weather patterns caused heavy rains, which are presented below:

- **Southwest monsoon**: influenced the Mekong River Basin from the end of June to October; the critical activity mostly occurred in July. Typically, heavy rain event from 21st - 31st July in the upper and middle reaches of LMB, which caused rapid rise in water level. From mid-September, there was moderate to weak SW monsoon, which prevailed over Indochina Peninsula as a common phenomenon.

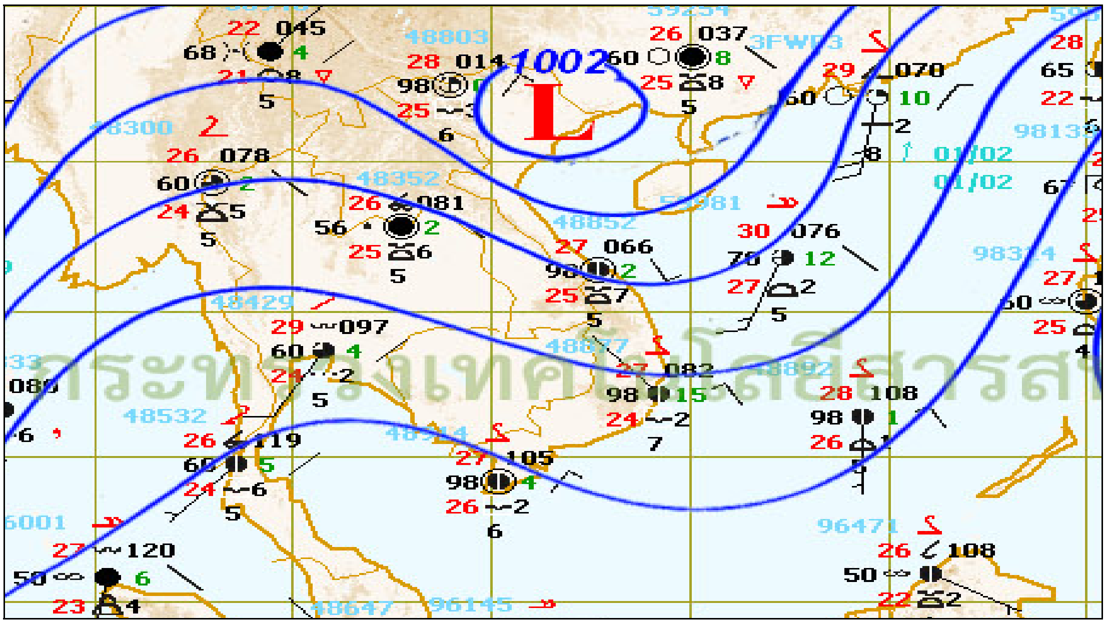


Figure 1-2 Weather map for Southwest Monsoon on June (22nd June 2013).

- **<u>Tropical Low Pressure (TLP) and Inter Tropical Convergence Zone (ITCZ)</u>**: these periodically appeared from early June to the mid of October with on average 3 to 7 days duration. In the flood season 2013, 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 September and October. Figure 1-3 shows an illustration of the appearances and influences of TLP and ITCZ to the LMB in August and September.

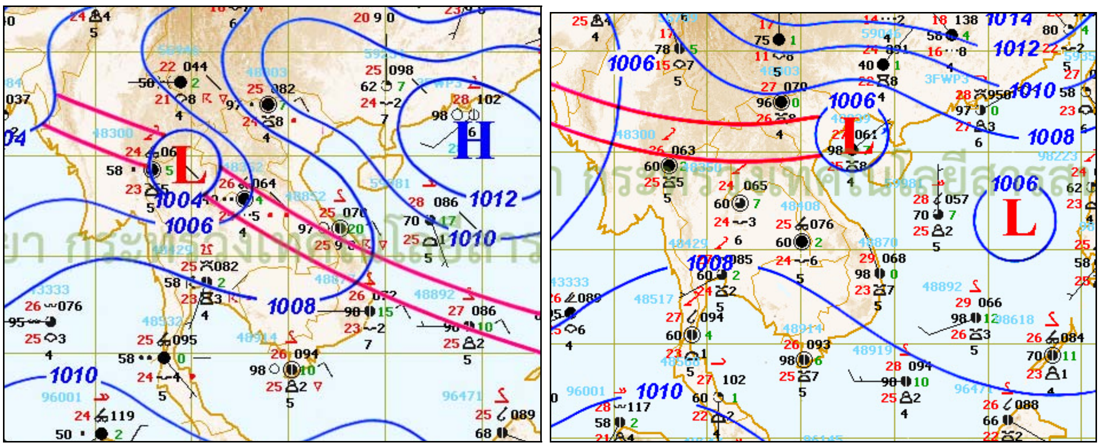


Figure 1-3 Weather maps for ITCZ in the begging of August and in the end of September.

- **<u>Tropical depressions (TD), tropical storms (TS) or typhoons (TY):</u>** The flood season 2013 presented more than 15 tropical depressions, storms and typhoons, which came to East Sea (see Figure 1-4), but only some of them affected the

Mekong River Basin. Of these, the four storms BEBINCA, MANGKHUT, JEBI, WUTIP, UTOR and NARI were the most noticeable.

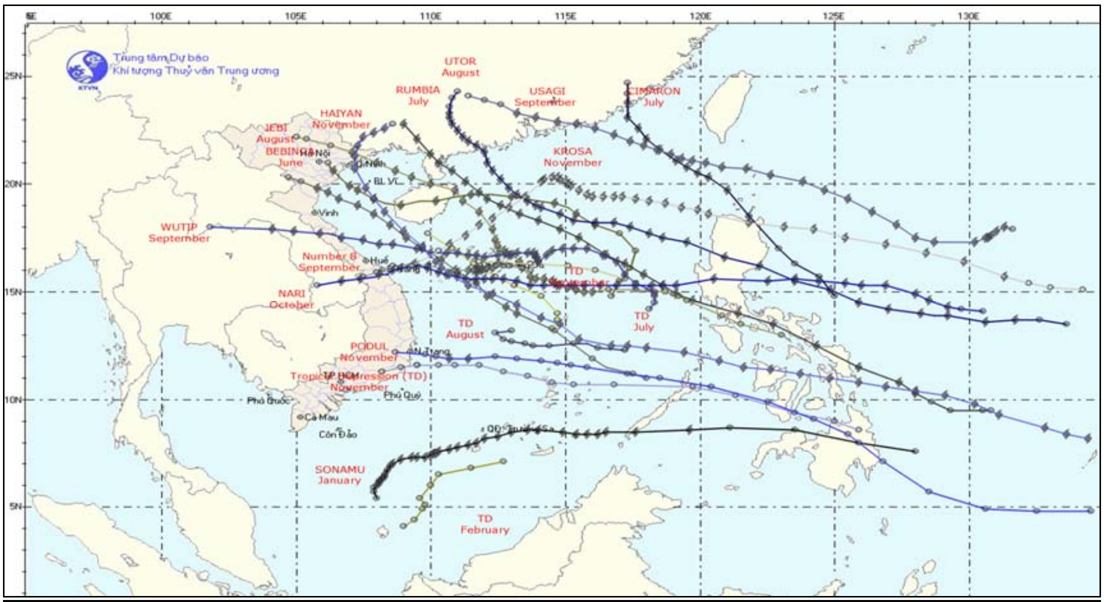


Figure 1-4 All the Typhoon/Tropical Storms and Tropical Depressions in 2013 from East Sea (Source: NCHMF).

1. **BEBINCA** was formed as a Tropical Storm (TS) on the 21st June, moved from East Sea in north-westerly direction over the Bay of Tonkin, then entered into North-eastern provinces of Viet Nam on 23rd June. BEBINCA's Storm Track is shown in Figure 1-4. Weather maps for BEBINCA's situation are shown in Figure 1-5 and 6, respectively

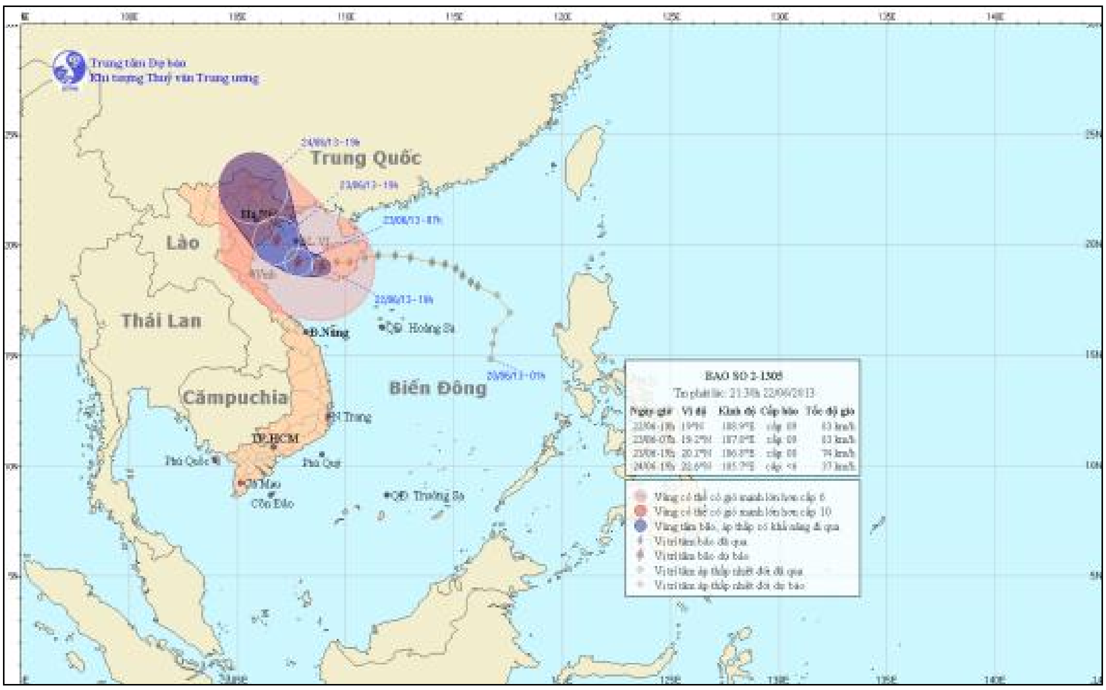


Figure 1-5 BEBINCA Storm Track (source: Website of NCHMF, Viet Nam).

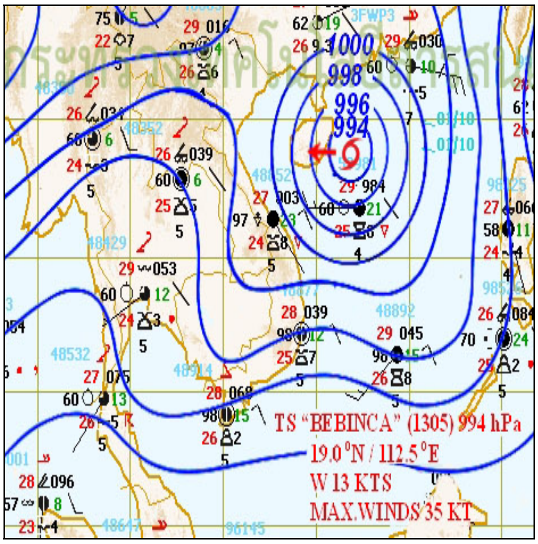


Figure 1-6 Weather map for BEBINCA Tropical Storm on 21st June 2013.

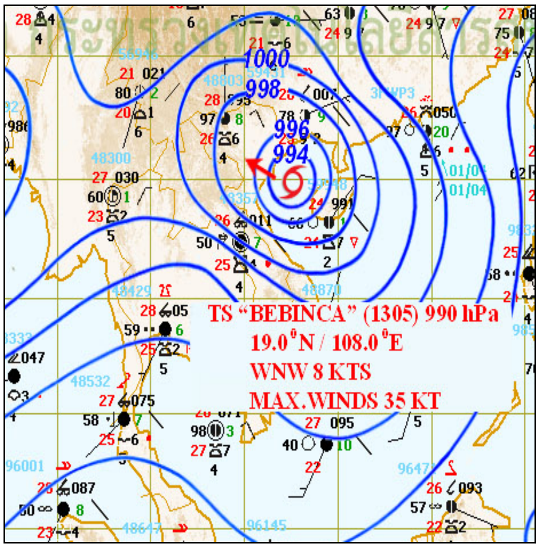


Figure 1-7 Weather map for BEBINCA Tropical Storm on 22nd June 2013.

2. Tropical storm **JEBI** was upgraded by Tropical Depression (TD) which was present over the East Sea areas at the end of July, and then the TD gained strength and became TS and moved in north-westerly direction and landed at Hai Phong Province of Viet Nam. On 04th August the TD was over the North of Viet Nam and was downgraded to a Tropical Depression. It brought moderate to heavy rainfall in these areas. **JEBI's** Storm Track and its weather maps with the situation of the TS are shown in Figure 1-8 and Figure 1-9, respectively.

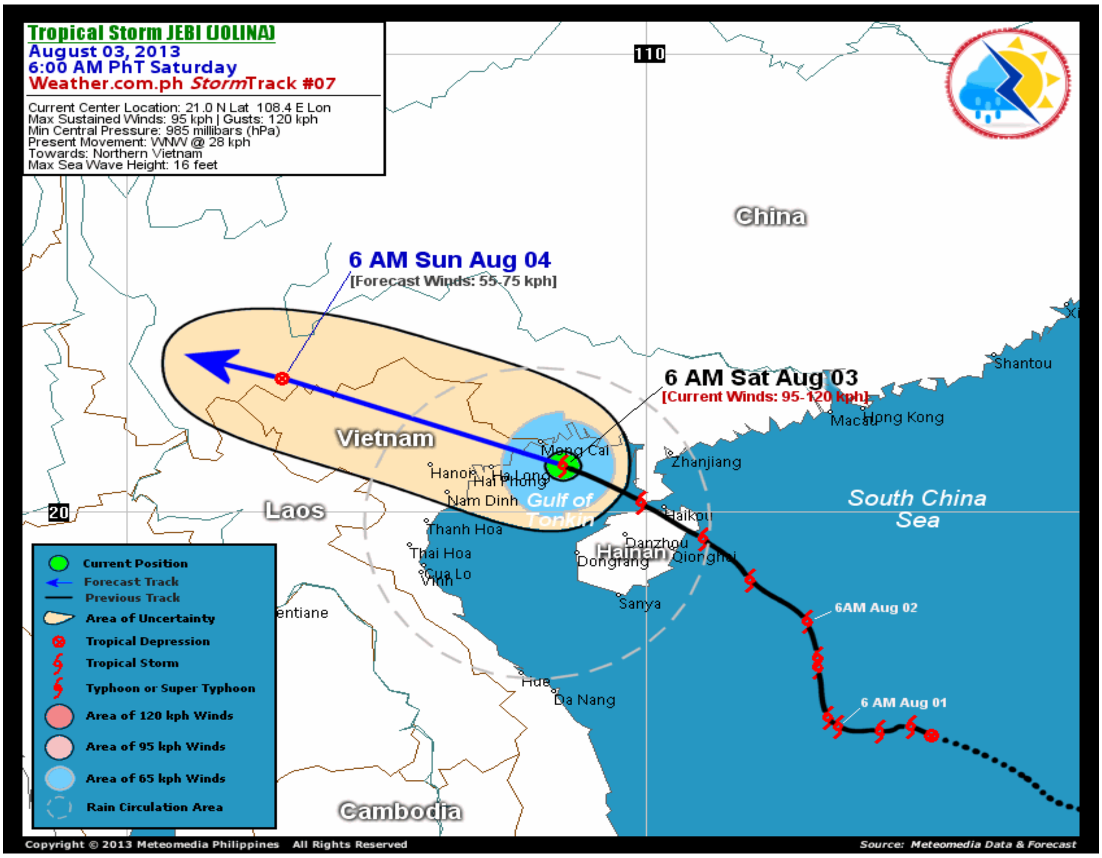


Figure 1-8 Tropical Storm JEBI's Track (Source: Website of Weather Philippines).

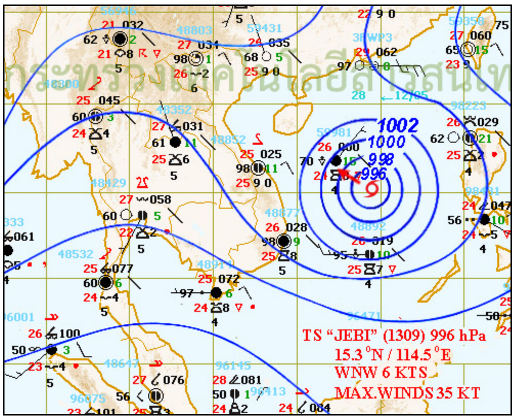


Figure 1-9 Weather map for JEBI Tropical Storm on 01st August 2013.

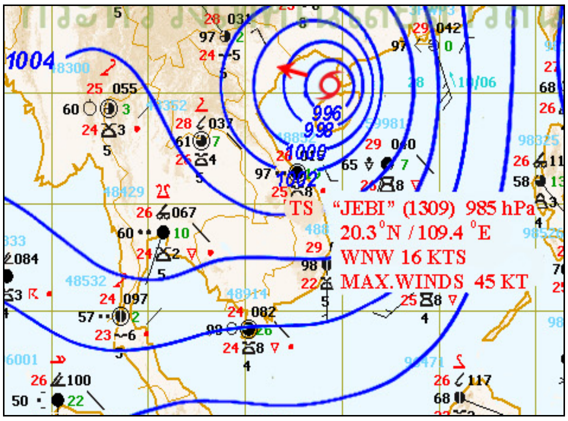


Figure 1-10 Weather map for BEBINCA Tropical Storm on 02nd August 2013.

3. Tropical storm **MANGKHUT** was upgraded by Tropical Depression (TD) which moved from the East Sea areas on 5th August quickly in north-westerly direction and landed at Thanh Hoa Province of Viet Nam. It brought moderate to heavy rain in these areas. MANGKHUT Storm Track is shown in Figure 1-7 and its weather maps with the situation of the TD are shown in Figure 1-8 and Figure 1-9, respectively.

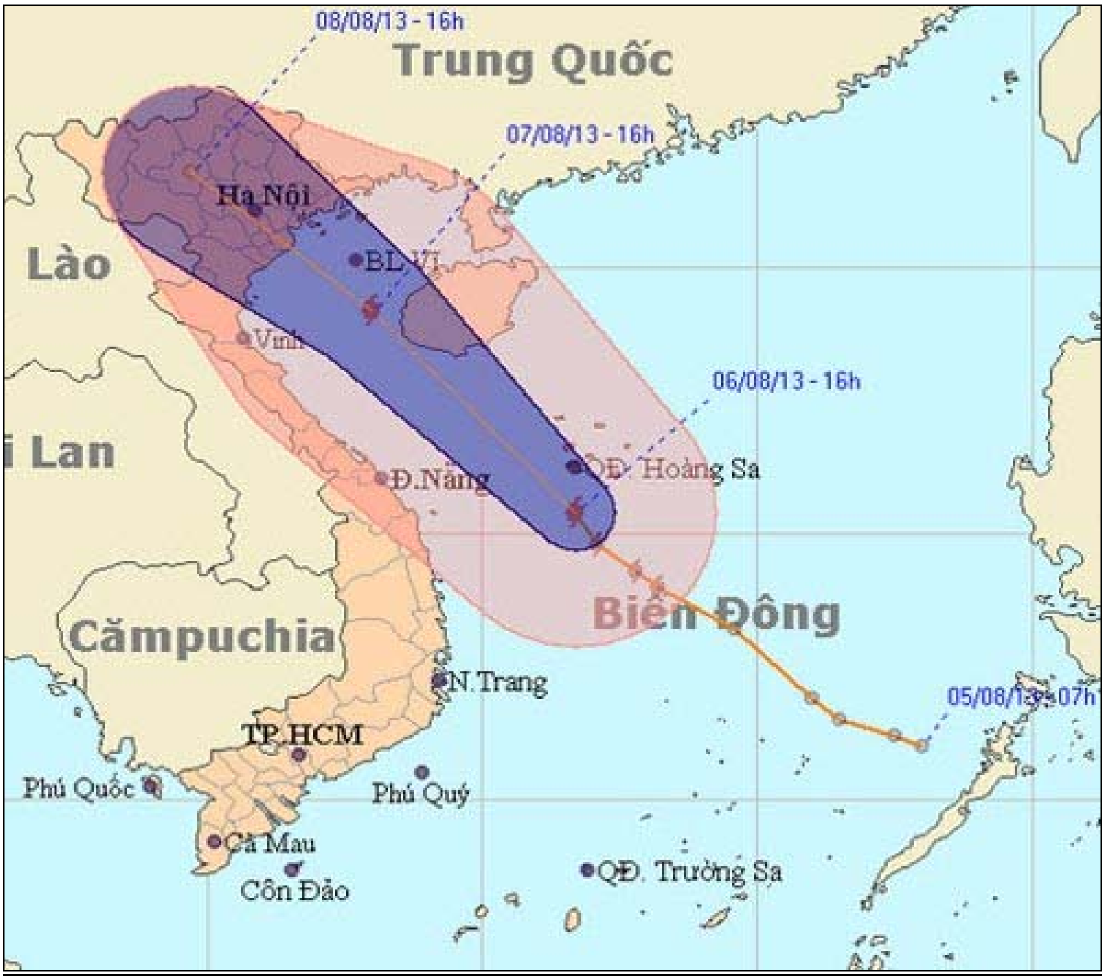


Figure 1-11 MANGKHUT Storm Track.

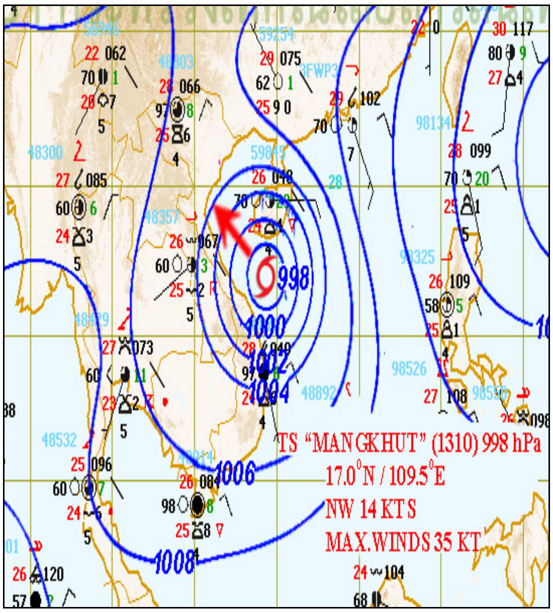


Figure 1-12 Weather Chart issued at 18:00 UTC on 06 August, 2013.

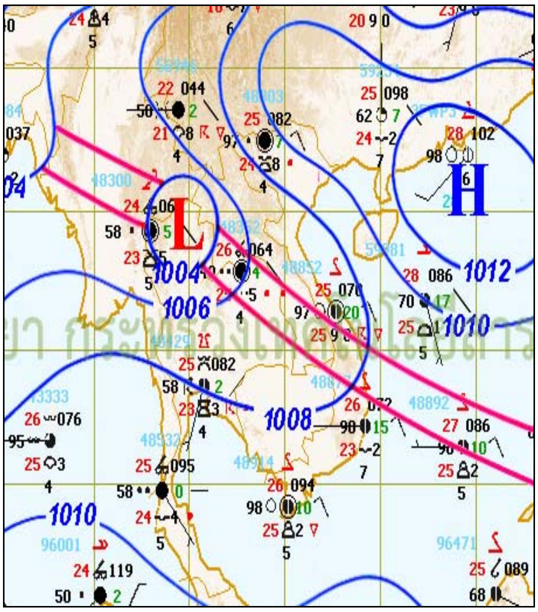


Figure 1-13 Weather Chart issued at 18:00 UTC on 08 August, 2013.

4. **UTOR** was formed as a Typhoon (TY) on 13th August over the East Sea, and was moving in north-westerly direction with a speed of about 24 km/h. On 15th August the TY was downgraded to Tropical Depression (TD) after it made landfall over Guangxi, South of China. UTOR's Storm Track is shown in Figure 1-7 and its weather maps with the situation of the TD are shown in Figure 1-8 and Figure 1-9, respectively

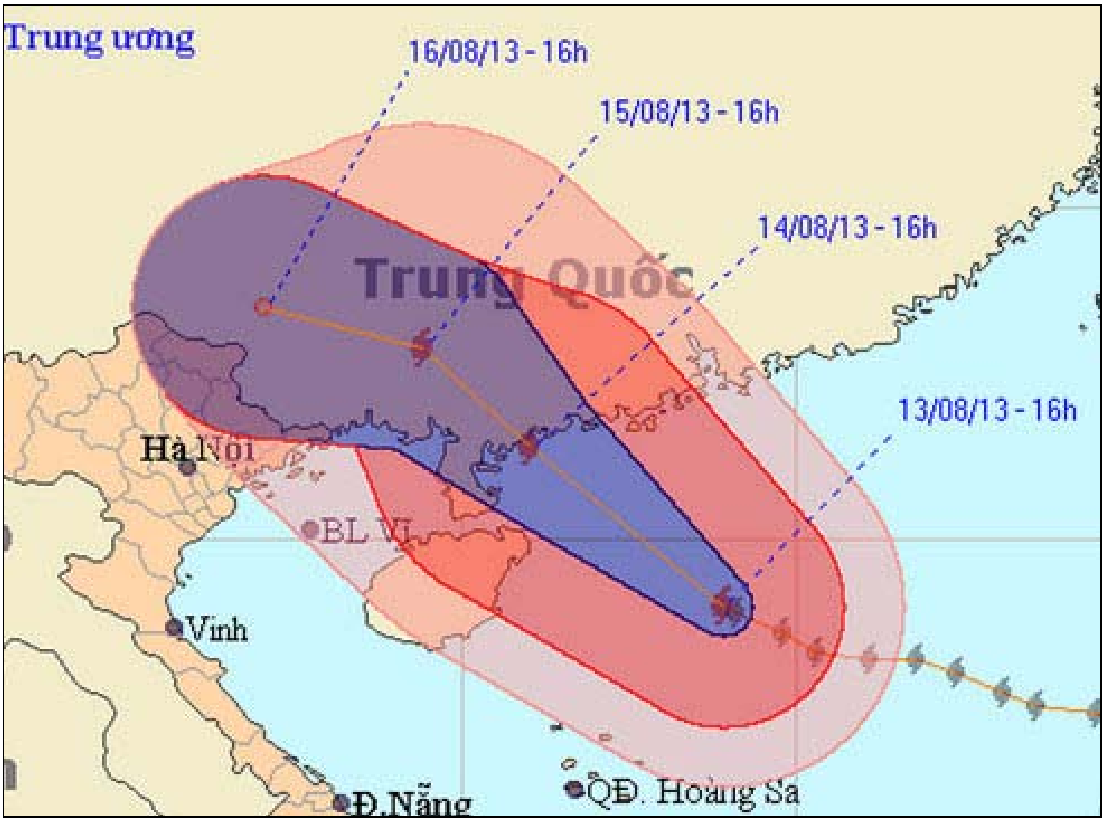


Figure 1-14 UTOR Storm track.

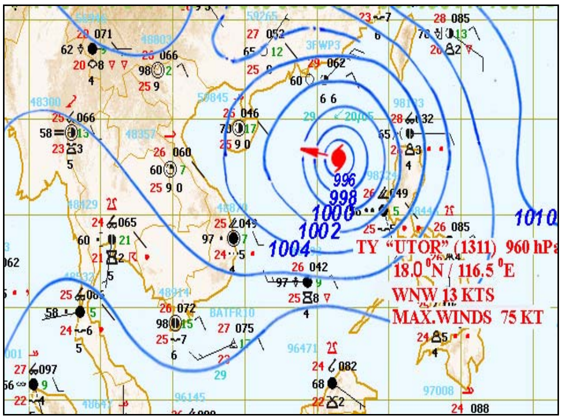


Figure 1-15 Weather map for 13th August 2013.

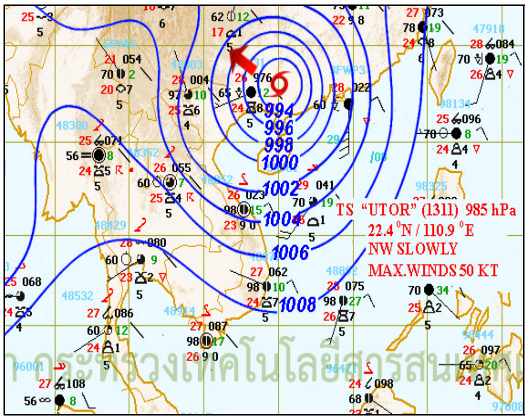


Figure 1-16 Weather map for 14th August 2013.

5. **WUTIP** was formed as a Typhoon (TY) on the 28th September, started from upper of South of the East Sea and then was downgraded to Tropical Depression (TD) on 01st October, then over the central part of Lao PDR and moved Westwards to the Northeast of Thailand before dissipating as low pressure area.

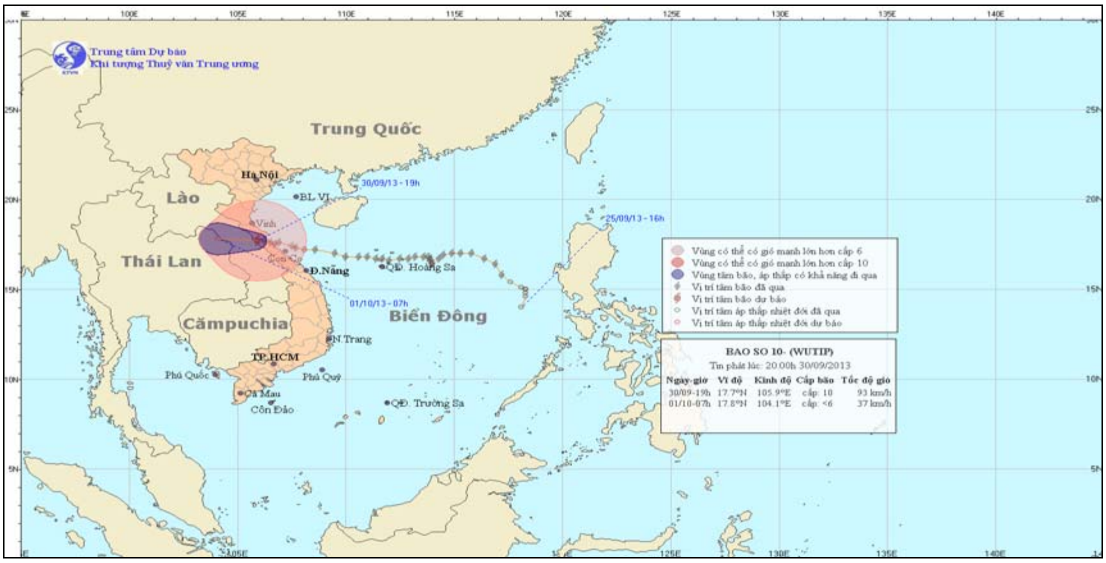


Figure 1-17 Typhoon WUTIP's track.

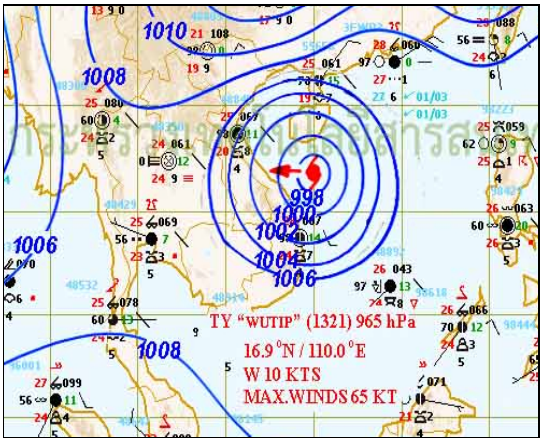


Figure 1-18 Weather map for 30th September 2013.

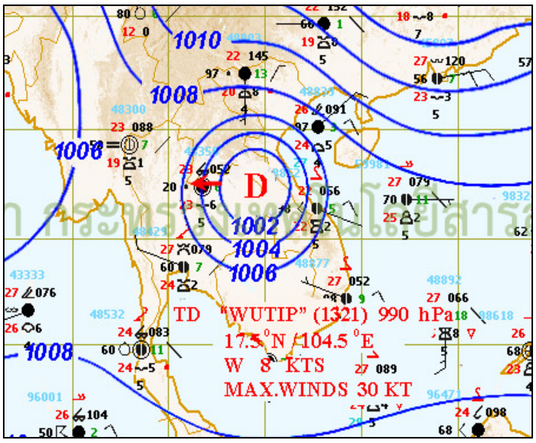


Figure 1-19 Weather map for 01st October 2013.

6. **NARI** was formed as TY on 12th October over the Central part of the Philippines and finally made landfall over Da Nang Province, Viet Nam before it was downgraded to TD over Lao PDR on 16th October 2013. Figure 1-10 presents the track of TY NARI and NESAT's weather maps before and after landing are shown in Figure 1-11 and Figure 1-12, respectively.

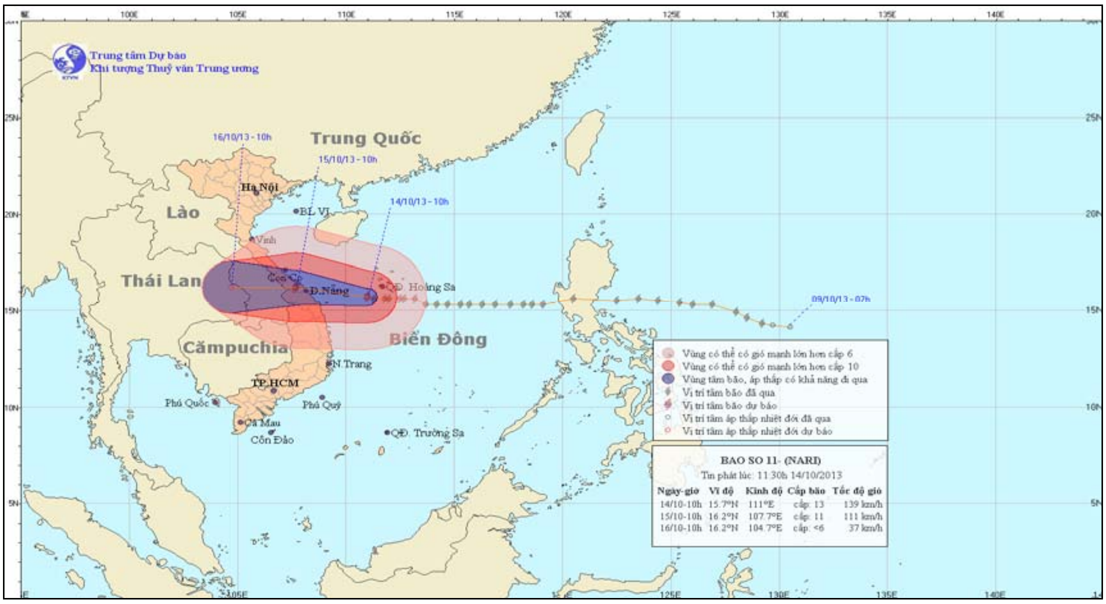


Figure 1-20 USAGI Storm Track.

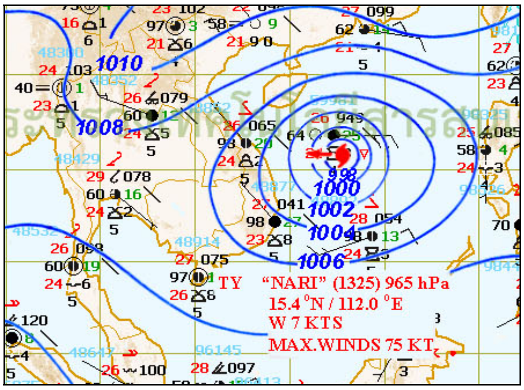


Figure 1-21 Weather map for 13th October 2013.

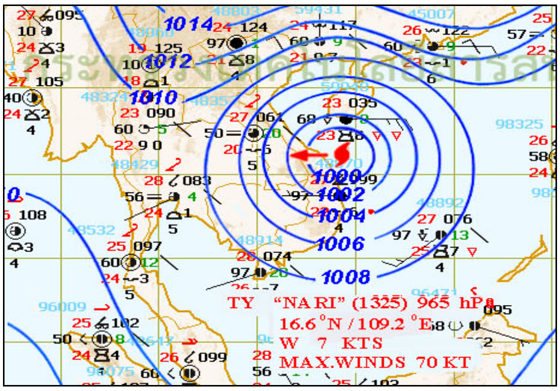


Figure 1-22 Weather map for 14th October 2013.

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 2013 flood season started later than in previous flood years. The first flood event occurred at end of June with the appearances and influences of low pressures and of tropical storm BEBINCA.

In general terms, the water levels in the LMB from Chiang Saen to Paksane station started under the long-term average (LTA) at the beginning of flood season to the end of July. From August to the end of flood season (and October) the WLs were strongly fluctuating and followed more or less the distribution of the precipitation in terms of space and time. Until the end of September almost all WLs at those stations continued above LTA level. From the beginning of October to the end of the flood season WLs were under LTA. By the end of June, due to the influences of the SW monsoon and BEBINCA, WLs at Mukdahan/Savannakhet stations were above the LTA.

During the flood season 2013, from midst September to the end of the flood season, WLs in almost all stations from Stung Treng to Tan Chau/Chau Doc appeared above alarm level. The WL at Pakse reached Flood Stage on 24th September, when the recorded water level was 0.35 m above the Flood Level of 12.00 m. Table 1 - 1 shows the list of stations and the durations of the periods that the WLs were above the alarm level during flood season 2013 (Annex C presents the hydrographs of 22 main hydrological stations along the Mekong River).

Table 1-1 list the stations has WL above alarm level in flood season 2013.

Station	Time started (above Alarm level)	Time ended (above Alarm level)	Durations
Paske	19th September	27th September	9 days
Kratie	20th September	01st October	11 days
Stung Treng	20th September	29th September	10 days
Kampong Cham	23rd September	03rd October	11 days
Koh Khel	23rd September	16th October	24 days
Neak Luong	29th September	05th October	7 days
Tan Chau	25th September	2nd November	38 days
Chau Doc	27th September	05th November	39 days

Table 1-2 The flood peaks of main locations along the Mekong mainstream during 2013 flood season.

Stations	Alarm level (m)	Flood level (m)	Day/Month of Peak	Hmax (m)	Comnent
Chiang Saen	11.50	11.80	27-Aug	6.56	Bellow Alarm level
Luang Prapang	17.50	18.00	09-Sep	13.60	Bellow Alarm level
Chiang Khan	17.32	17.40	10-Sep	12.56	Bellow Alarm level
Vientiane	11.50	12.50	10-Sep	9.62	Bellow Alarm level
Nong Khai	11.40	12.20	12-Aug	10.96	Bellow Alarm level
Paksane	13.50	14.50	10-Aug	12.94	Bellow Alarm level
Nakhon Phanom	12.60	12.70	07-Aug	10.70	Bellow Alarm level
Thakhek	13.00	14.00	12-Aug	11.79	Bellow Alarm level
Mukdahan	12.50	12.60	12-Aug	10.52	Bellow Alarm level
Sanannakhet	12.00	13.00	13-Aug	9.41	Bellow Alarm level
Khong Chiam	16.00	16.20	23-Sep	14.04	Bellow Alarm level
Pakse	11.00	12.00	24-Sep	12.30	Above Flood level
Stung Treng	10.70	12.00	24-Sep	11.74	Above Alarm level
Kratie	22.00	23.00	27-Sep	22.69	Above Alarm level
Kompong Cham	15.20	16.20	28-Sep	15.97	Above Alarm level
Pnom Penh (Basac)	10.50	12.00	01-Oct	10.26	Bellow Alarm level
Pnom Penh Port	9.50	11.00	29-Sep	9.42	Bellow Alarm level
Koh Khel (Bassac)	7.40	7.90	10-Oct	7.77	Above Alarm level
Neak Luong	7.50	8.00	04-Oct	7.65	Above Alarm level
Prek Kdam (Tonle Sap)	9.50	10.00	10-Oct	9.39	Bellow Alarm level
Tan Chau	3.50	4.50	03-Oct	4.33	Above Alarm level
Chau Doc	3.00	4.00	09-Oct	3.72	Above Alarm level

(Alarm levels and flood levels 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 2013 flood season, water levels (WL) at all stations started below the long-term average (LTA), and then increased a while above the LTA by the end of July and beginning of August by influences of Tropical Storms BENBICA, MANGKHUT, UTOR, USAGI and NARI, as well as the SW monsoon and ITCZ. There were three flood events (see the Figure 1-23):

- The first flood event in the period 22nd June to the beginning of July: the water level at Luang Prabang had an amplitude of more than 3 m (increased from 4.43

m on 22nd June to 7.51 m on 25th June), as a result of the impacts of TS BENICA in terms of heavy rain to tributary stations in the North of Lao PDR.

- The second event flood in the period 5th - 10th September. The WL at Luang Prapang increased from 10.65 m on 5th September) to 13.6 m on 9th September) as a result of the impacts from SW monsoon, ITCZ, and especially TY WUTIP. The total 24hrs rainfall observed at Luang Prapang was 98 mm and at Chiang Khan 38 mm on 7th September.
- The third flood event in the period 19th – 26th October. The WL at Luang Prapang had an amplitude of 3.31 m. It was impacted by TS NARI which brought heavy rainfall to areas in Thailand and Lao PDR.

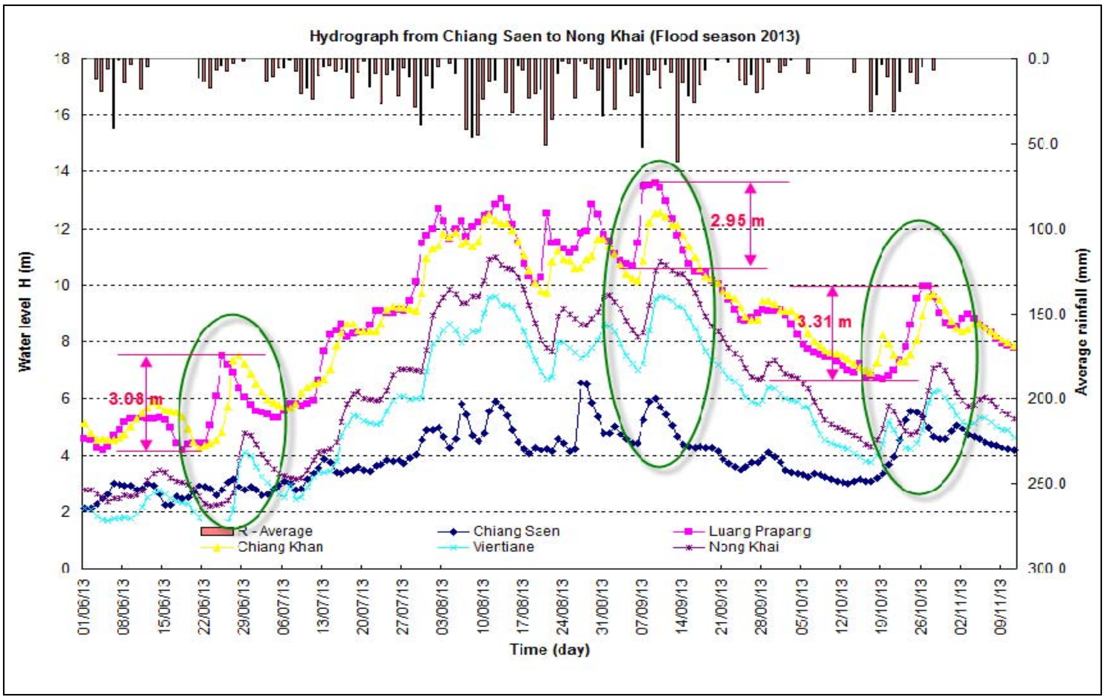


Figure 1-23 Rapidly rising of water levels at stations: Chiang Saen, Luang Prabang, Chiang Khan, Vientiane and NongKhai.

For stations from Paksane to Pakse

During the 2013 flood season the WL of all stations started under the LTA then quickly rose up above LTA around the end of June and the beginning of July by influences of TS BENICA, then dropped under the LTA until the end of July, then above the LTA until the middle of August by influences of TY MANGKHUT and UTOR, then under the LTA until the middle of September, and then finally above the LTA until the middle of October by influences of TY NARI (see for more details Annex A, Part 3, Table A-3).

During the period June to August there were three tropical storms: BENICA, MANGKHUT and UTOR. These brought moderate to heavy rainfall to this region. The total recorded rainfall in July was about or over 300 mm, such as 89.1 mm at Paksane, 608.9 mm at Nakhon Phnom, 590.1 mm at Thakhek, 319.1 mm at

Mukdahan, 294.9 mm at Savannakhet, 740.8 mm at Khong Chiam, and 385.2 mm at Pakse.

During the 2013 flood season, there were two flood events which had the amplitude over 3 m at Khong Chiam and Pakse:

- The first flood event in the period 22th - 28th June: The WLs at both stations were influenced by TS BENICA, which brought heavy rainfall and rising WLs in the tributaries of Lao PDR and Thailand. Figure 1-24 shows rapidly rising WLs at Khong Chiam, Pakse.

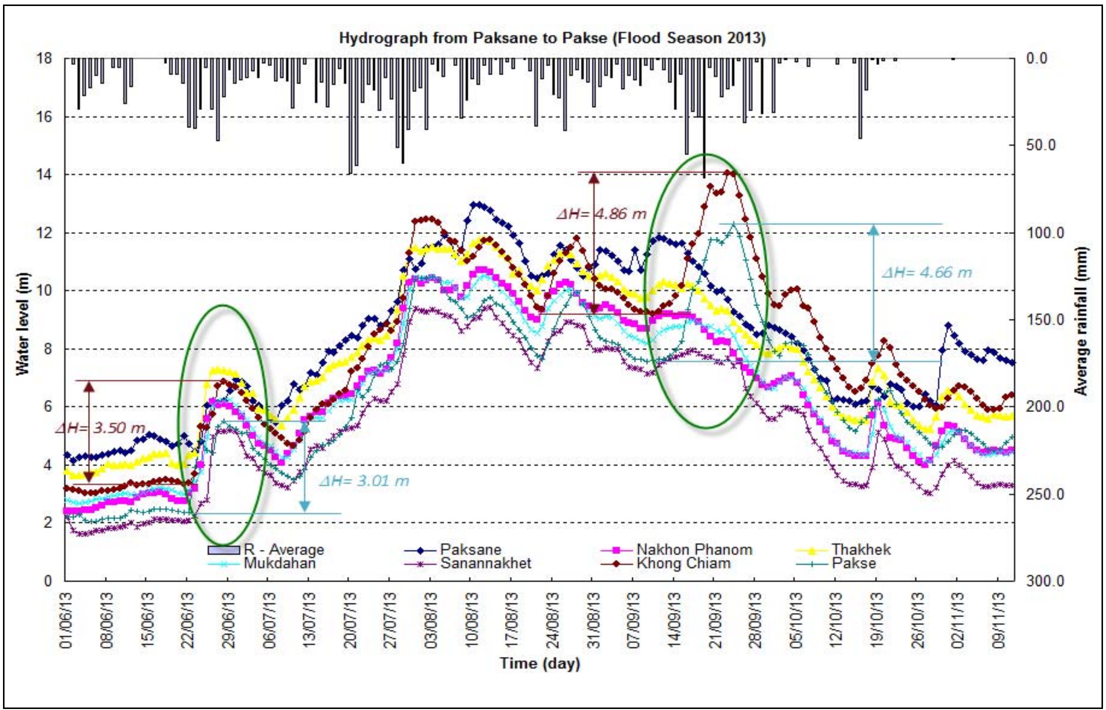


Figure 1-24 Rapidly rising of water levels at stations: Paksane, Nakhon Phanom, Thankhek, Mukdahan, Sanavakhet, Khong Chiam and Pakse.

- The second flood event in the period 10th - 24th September: Due to the influence of the SW monsoon and the ITCZ heavy rainfall was brought into the areas. The WLs at Khong Chiam, Paske showed amplitudes of over 4 m, such as 4.84 m at Khong Chiam and 4.66 m at Pakse. Especially the WL at Pakse rose quickly to a peak level of 12.35 m at 19:00hrs on 23rd September 2013, and overtopped the alarm level. The following 24hrs precipitation was recorded at Pakse: 188 mm on 16th September, 107 mm on 17th September, 59 mm on 18th September, and 153 mm on 19th September (see Figure 1-24).

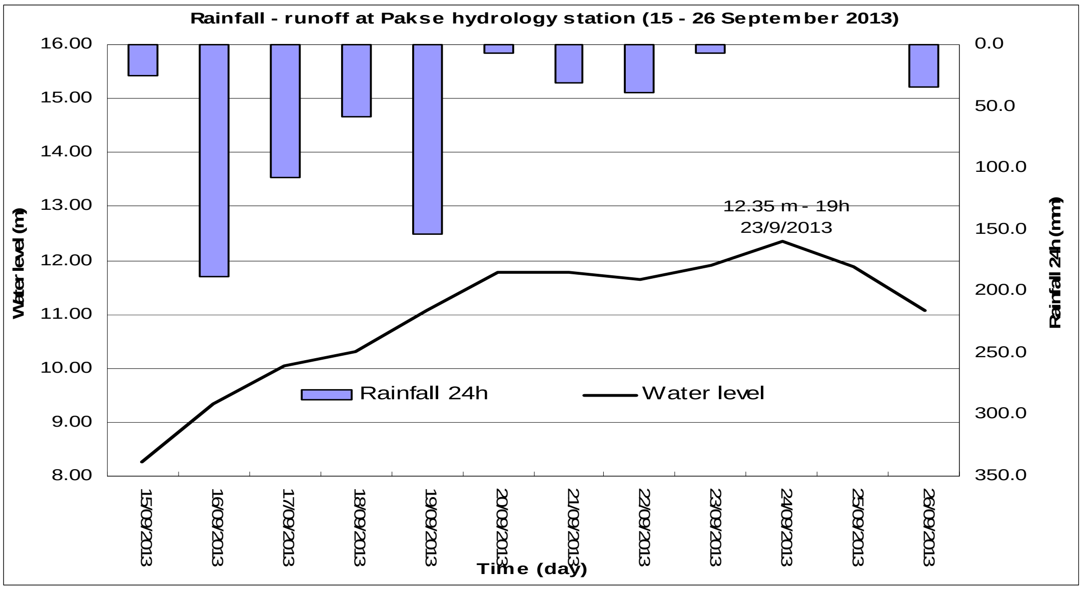


Figure 1-25 Flood event of rapidly rising of water levels at stations: Paksane during 15th – 26th September.

Continuous occurrences of SW monsoon and ITCZ activities across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar from midst July to September resulted in intensive rainfalls in the Eastern part of Thailand, upper part of Lao PDR, middle part of Viet Nam and the middle of the LMB. The accumulated rainfall recorded in this region in the period 15th - 30th September was 282.5 mm at Paksane, 258.1 mm at Nakhon Phnom, 241.3 mm at Thakhek, 50 mm at Mukdahan, 72.1 mm at Savannakhet, 281.5 mm at Khong Chiam, and 288.9 mm at Pakse. A flood event occurred at those stations where the flood amplitudes reached around and above 2 m (Annex A, Part 3, Table A-3).

It was noted that WLs at Thakhet were above the alarm level of 13 m during the periods 4th - 7th August, 10th - 13th August and 20th - 21st September. The WL at Mukdahan was above the flood level of 12.6 m during the periods 9th - 14th August and 20th - 21st September. The WLs in Pakse were above the flood level of 12 m during the periods 8th - 19th August and 19th - 24th September.

For stations from Stung Treng to Kampong Cham

During the 2013 flood season, the WLs at all stations fluctuated sharply above the long-term average (LTA) by end of June due to influences of TS BEBINCA, then dropped under the LTA until the end of July, then continued rising above the LTA until the end of August due to influences from TSs MANGKHUT, UTOR as well as the ITCZ. During the beginning to midst September the WLs were below the LTA, then quickly rose up above the LTA until midst October due to influences of the SW monsoon, ITCZ and the TS USAGI. During the period 14th – 25th September there was one flood event with amplitudes of over 4 m at Stung Treng, Kampong Cham and even over 5 m at Kratie (see figure and see more detail in Annex A, Part 3, Table A-4).

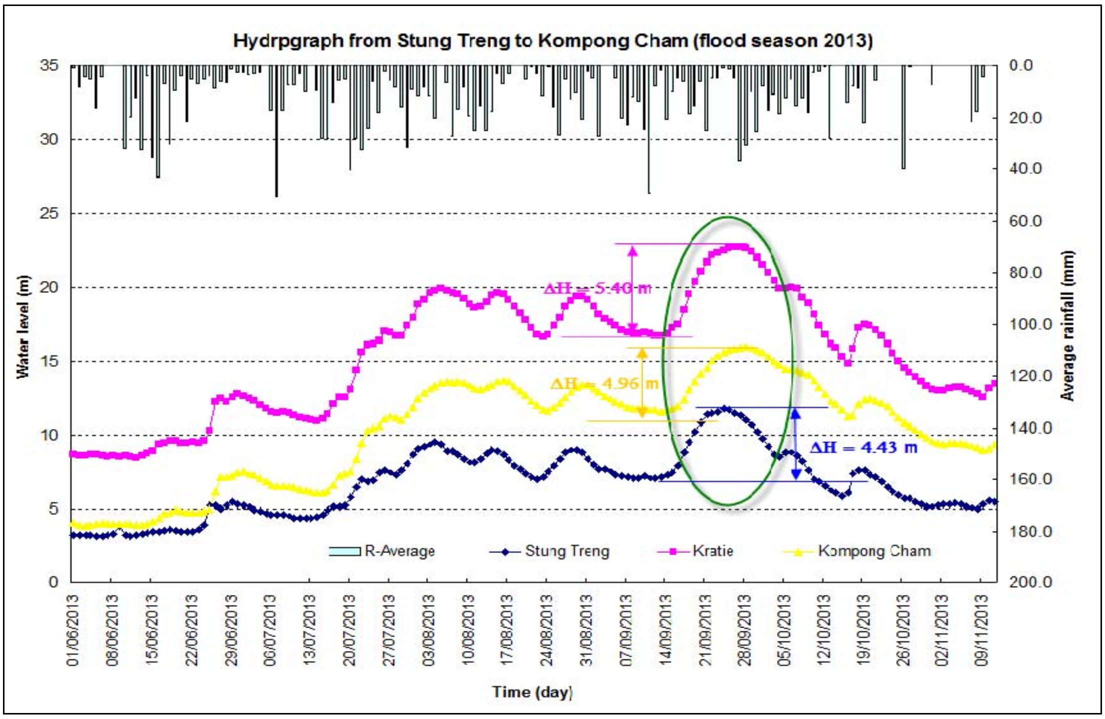


Figure 1-26 Rapidly rising of water levels at stations: Stung Treng, Kratie and Kampong Cham.

For stations from Phnom Penh to Koh Khel/Neak Luong

During the 2013 flood season, the WLs at all stations have fluctuated sharply above the LTA by the end of June due to influences of TS BEBINCA, then moved under LTA until the end of July, , then continue rising above the LTA until the end of August caused by influences of TSs MANGKHUT and UTOR, as well as the ITCZ.

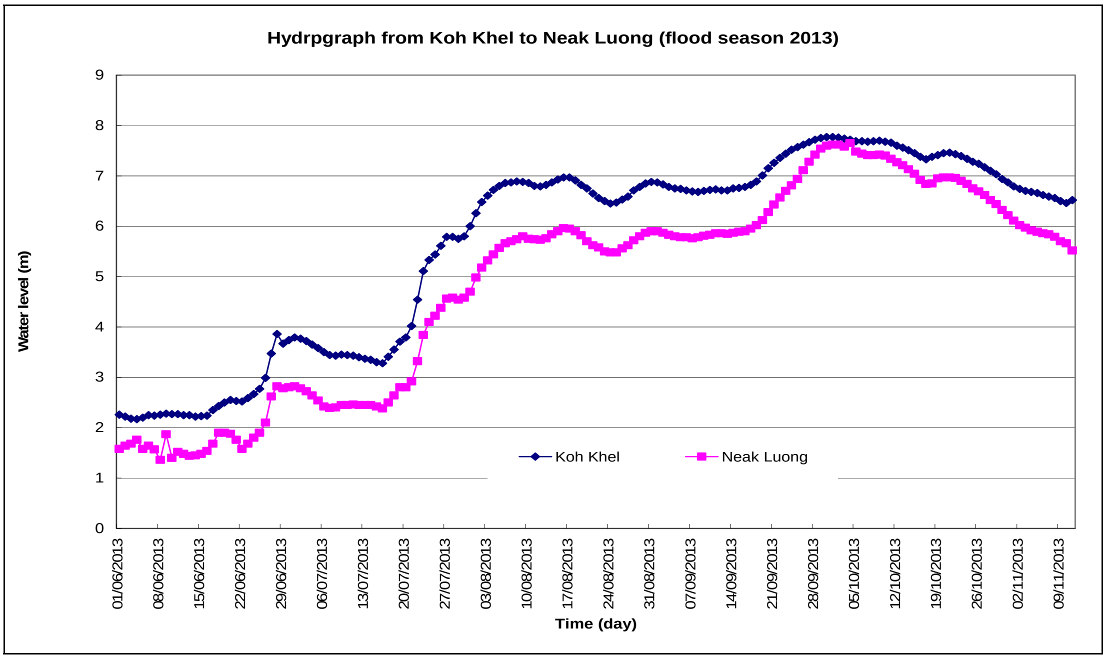


Figure 1-27 Hydrographic at stations: Kok Khel, Neak Luong.

During the months of June and July there was one tropical storm (BEBINCA) that had serious impact in this region. All recorded rainfalls in July were around or less than 200 mm, such as 210 mm at Bassac Chaktomuk, 90 mm at Koh Khel, 103.5 mm at Neak Luong, and 128.3 mm at Prek Kdam. However, as a result of flood waters caused by the influence of the ITCZ and the SW monsoon, heavy rain in combination with flood waters from the upper and middle reaches of the LMB, caused rising WLs in tributaries in Cambodia and Viet Nam.

There was one flood event with amplitudes over 2 m at Bassac Chaktomuk, Phnom Penh Port and Prek Kdam, Neak Luong (see Figure 1-27 and see for more details Annex A, Part 3, Table A-5). Continuous occurrences of the SW monsoon, ITCZ, typhoons and tropical storms across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar from mid-July to September resulted in mild rainfall in this region. Records of 24hrs precipitation in the period 05th - 15th August show 153 mm at Bassac Chaktomuk, 109 mm at Koh Khel, 152.5 mm at Neak Luong, and 45.4 mm at Prek Kdam. It can be noted that water levels were above alarm level at all stations from Phnom Penh Port to Neak Luong/Koh Khel (see Table 1-1 for more details on Day/Month of Peak and durations).

Tan Chau and Chau Doc

During the flood season 2013, these two stations recorded water levels that remained around the LTA, even though water levels at these stations are affected by the tidal regime. This was one of the main reasons why during the beginning of June to the end of July water levels at these two stations showed rising and falling trends with highly fluctuating amplitudes. From August to September, as a result of flood water from the upper and middle reaches of the LMB, water levels at these stations rose steadily with an average intensity of 0.10 - 0.15 m/day (see for more details Annex A, Part 3, Table A-6).

It can be noted that in the periods 21st September - 1st November 2013, and 19th September - 1st November 2013 water levels above flood levels of 4.2 and 3.5 m, respectively, were recorded at Tan Chau and Chau Doc.

2. Flood Forecast in 2013

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 B-1, Figure B-2 to Figure B-4).

The results of the evaluation show that the data from most of LAs normally arrived before 09:00 AM (Annex B, Table B-3 and Figure B-2). 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 B-3 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 2013 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 B-3 and Figure B-4) 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 10:30 AM, which is a prescribed time in the Operational Manual. It can be seen that the time of flood forecasting bulletin delivery in July to October of the flood season was a bit later than 10:30 AM. 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 2013 flood season, the data of several 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 B-5 in Annex B shows that during the 2013 flood season (in June) there was one station without forecasts.

2.2 Accuracy and limitations in forecasting

During the 2013 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 B-1). The evaluation of forecast achievement is presented in Table B-1 by indicating the % of days "successful" against a respective benchmark presented in Table B-2 (which were narrower than those of the year 2012). In general, the forecast errors for all lead time at all stations along the Mekong River did not show large differences, except for Paksane, Pakse and Kratie which were strongly affected by tropical storms where accuracies for 3-5 day forecast lead times were less than expect, if following the benchmarks of success (see Annex A, Table A-2 to Table A-4).

Forecast errors for 3-5 day lead time were less than 0.90 m for all stations in LMB, although the worse was at Luang Prabang times (Figure B-1: Average flood forecast accuracy along the Mekong mainstream, Annex B). T

For the lower reach of Mekong River, it can be seen that the use of a regression model is quite promising. Stations downstream from Phnom Penh Bassac, show average errors for 1-day and 2-day forecasts smaller than 0.05 m and 0.10 m respectively, while average errors for 4-day to 5-day forecasts were smaller than 0.25 m.

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

- Internal model functionality in forecasting at tidal affected stations in downstream: The limitations in developing URBS models were mentioned and analysed by Terry Malone in the report "*Sensitivity Analysis and Evaluation of the MRC Mekong Flood Forecasting Systems*", April 2009, in which the main factors, which influenced the results of model calibration can be found as rating curves, inventory of dams, reservoirs and operational regulations, future development of dams. At the same time the sparse gauge network was another reason leading to poor results for forecast at stations in the upstream of LMB. The forecast results at Luang Prabang were a specific illustration of this. The forecast performances by mean absolute error in using original forecast results from both regression and ISIS models were presented in Figure 1-15 and Figure 1-16 respectively. It was easily realized that the average error for 3-day to 5-day forecasts at Koh Khel, Neak Luong, Prek Kdam and Tan Chau were under 0.1 m for Regression model as compared to ISIS model.

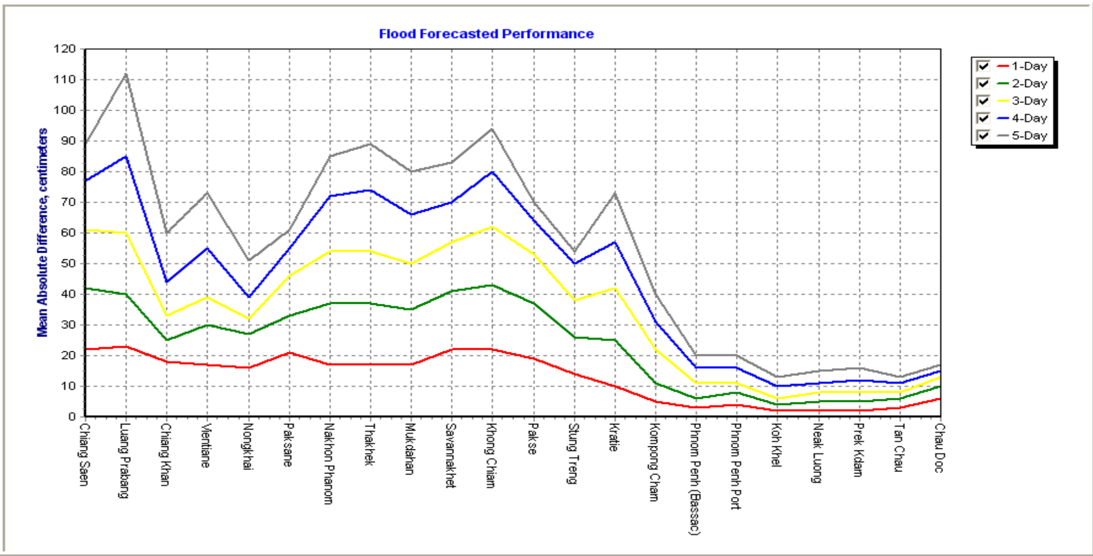


Figure 2-1 Forecast performance based on original results by URBS and Regression.

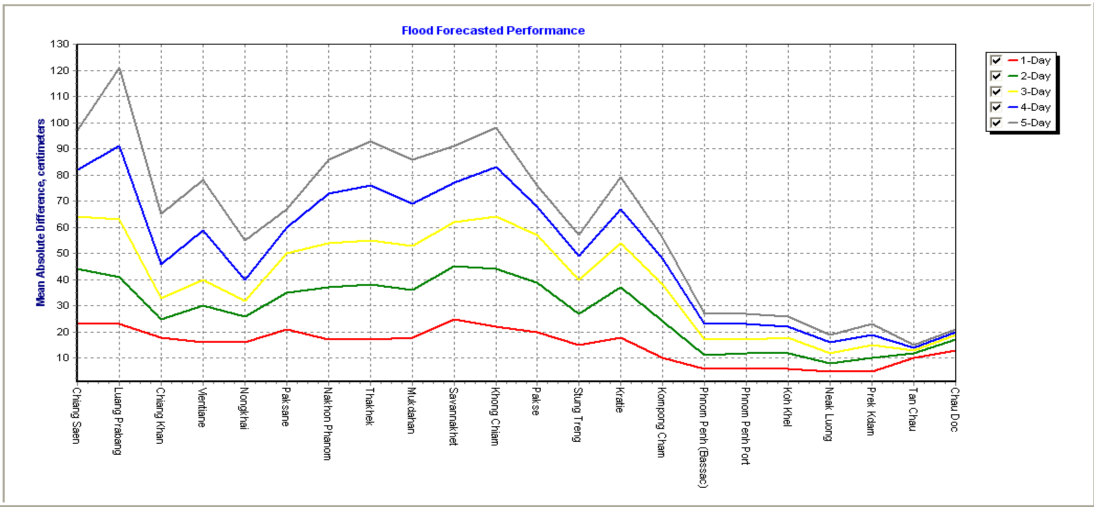


Figure 2-2 Forecast performance based on original results by URBS and ISIS

- The high variability of satellite rainfall estimate (SRE) and Numerical Weather Prediction (MWP): SRE rainfall was used instead of observed rainfall, and the NWP model provided a 7-day GFS rainfall forecast. Throughout the 2013 flood season, the vial data from NOAA was not received (around 2 weeks from mid of October)which was influence to the result output for the URBS model, as could be seen from the results of daily forecast, was really sensitive to both SRE and NWP. SRE could be either under- or overestimated if compared with the observed rainfall. NWP could 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 such as tropical storms occurred. Based on weekly investigation of the forecasting team, the original forecast results calculated from the model caused relatively large errors as compared to observations. This was a practical difficulty for forecaster-in-charge in forecast adjustment.

- The quality and accuracy of forecast is also determined by the quality of forecast adjustment, which was usually performed by forecaster-in-charge so their knowledge, expertise and experiences were 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 2013 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:

- 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. A Senior International Satellite Precipitation Expert was engaged by the RFMMC in 2010 to develop a tool of bias correction of SRE to produce corrected SRE-rainfall. The product depends very much on observed rainfalls provided from LAs which contained lot of missing data (see Annex B, Table B-3 and Figure B-3). Correct SRE can provide better results if less missing data.

- 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 2013-2014.

- 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.

- Improving model calibration by updating the rating curves and other parameters at stations in the MRC's member countries to be supported by LAs.

- 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 2014, a number of additional actions need to be undertaken as follows:

- Performance of the ISIS model in the Cambodian Floodplain and the Mekong Delta should be compared with that of the Regression Model during the 2014 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.

- 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.

- Watch closely situations of the sudden increasing water levels of left bank tributaries in the middle part of the LMB, such as Ban Mixay and Muong Ngoy, Moung Mai, Moung Kao, Ban Phone Si, 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.

- Through the 2013 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 3-day and 4-day forecasts at hydrological stations affected by tidal at Tan Chau and Chau Doc were high although forecaster had referred to the reference of tidal regime forecast documentation in 2013 provided by National Centre for Hydro-meteorology of Viet Nam.

- Learn more about the weather products of rainfall forecast published on the websites of the World Meteorological Organization and their practical applications.

- 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 2013
- Graphs for monthly rainfall in flood season from 2000 to 2013 and long-term average along the Mekong River
- Tables of flood event characteristics along the Mekong River during flood season 2013

Annex B:

- Graph for flood forecast accuracy along the Mekong mainstream

- Table of forecast achievement
- Tables and graphs for performance

Annex C:

- Seasonal Water Level Graphs

Annex A Graphs and Tables

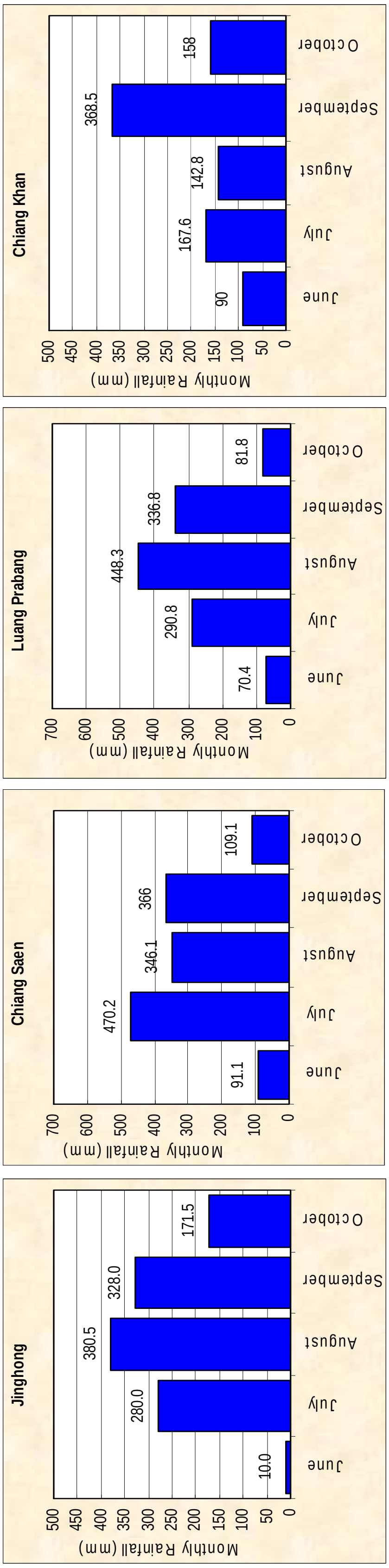
1. Graphs and Tables for monthly observed rainfall distribution during flood season 2013

Table A-1 Monthly observed rainfall in flood season 2013

Unit in mm

2013	Jinghong	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	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
June	10.0	91.1	70.4	90	189.4	151.8	693.5	220.7	276.1	182.6	208.7	215.4	293.2	248.7	345.7	153.1	272.1	-	170.8	194.9	141.8	77.3	124.4
July	280.0	470.2	290.8	167.6	258.5	295.1	896.1	608.9	590.1	319.1	294.9	740.8	385.2	526	422.9	282.2	220.7	-	92.2	103.8	128.5	137.3	127
August	380.5	346.1	448.3	142.8	456.2	323.3	615.3	280.7	300.3	133.3	107	299.3	334	324	425.6	207	197.3	-	157.8	183.8	97.3	82.3	110.9
September	328.0	366	336.8	368.5	305	176.7	337.1	163.3	192.5	370.6	298.3	778.7	870.1	560	271.1	294.1	174.4	-	170.4	239.9	171.6	234.4	240.5
October	171.5	109.1	81.8	158	62.7	76.8	46.7	118	112.6	85.5	85.7	120.4	110.1	194	118	65.6	241.2	-	223.2	221.9	144.9	171.7	290.5

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



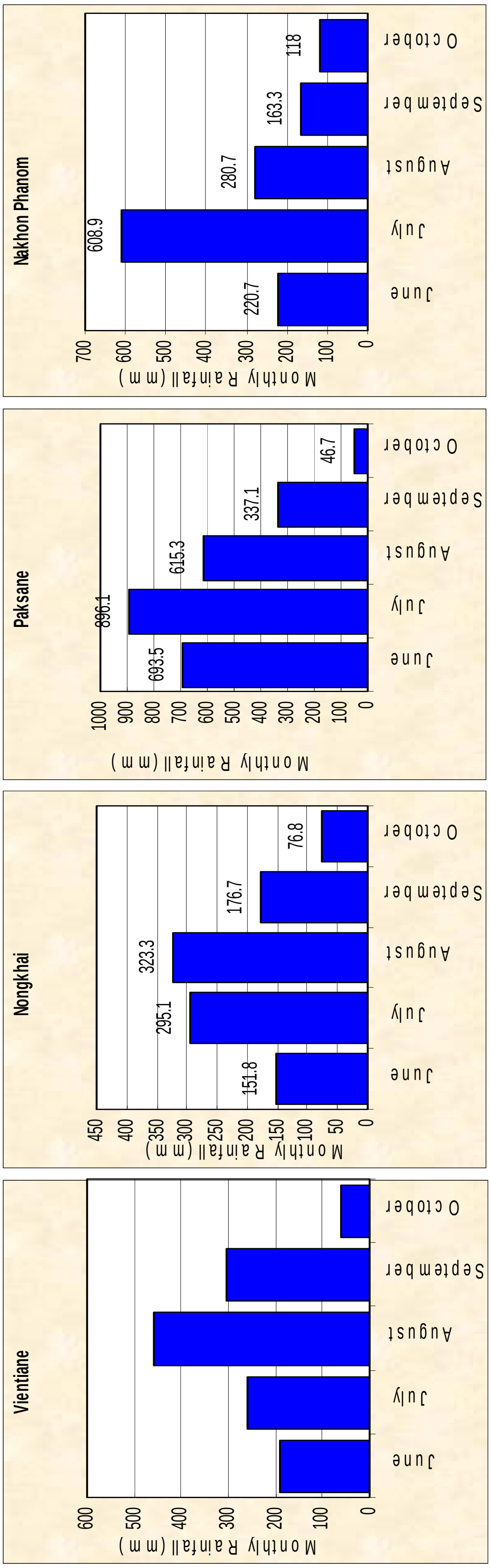


Figure A-1 Monthly rainfall distribution for Jinghong, Chiang Saen, Luang Prabang and Chiang Khan.

Figure A-2 Monthly rainfall distribution for Chiang Khan, Vientiane, Nongkhai, Paksane and Nakon Phanom.

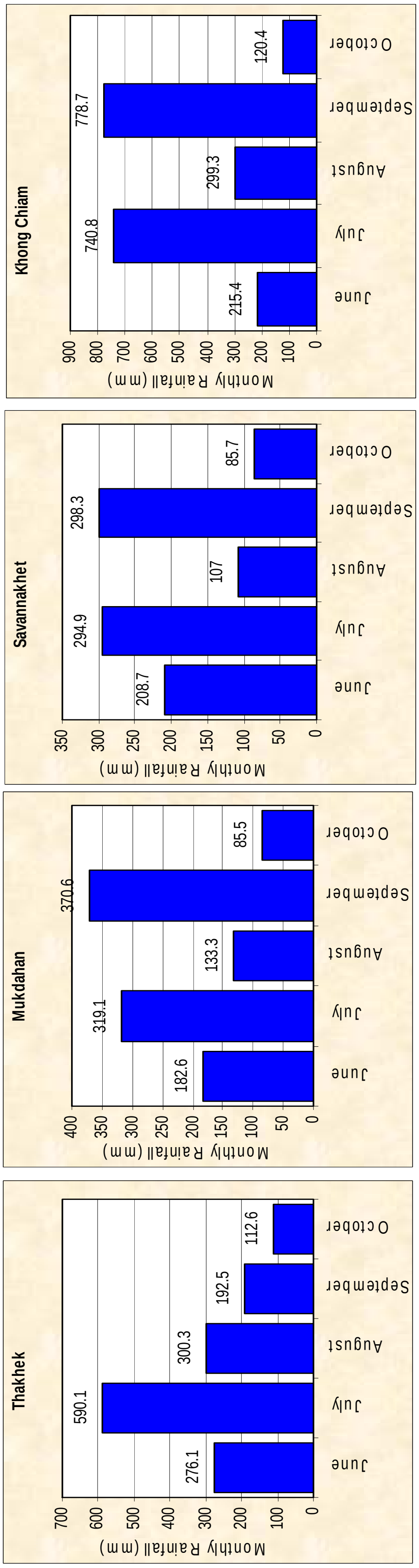


Figure A-3 Monthly rainfall distribution for Thakhek, Mukdahan, Savannakhet and Khong Chiam.

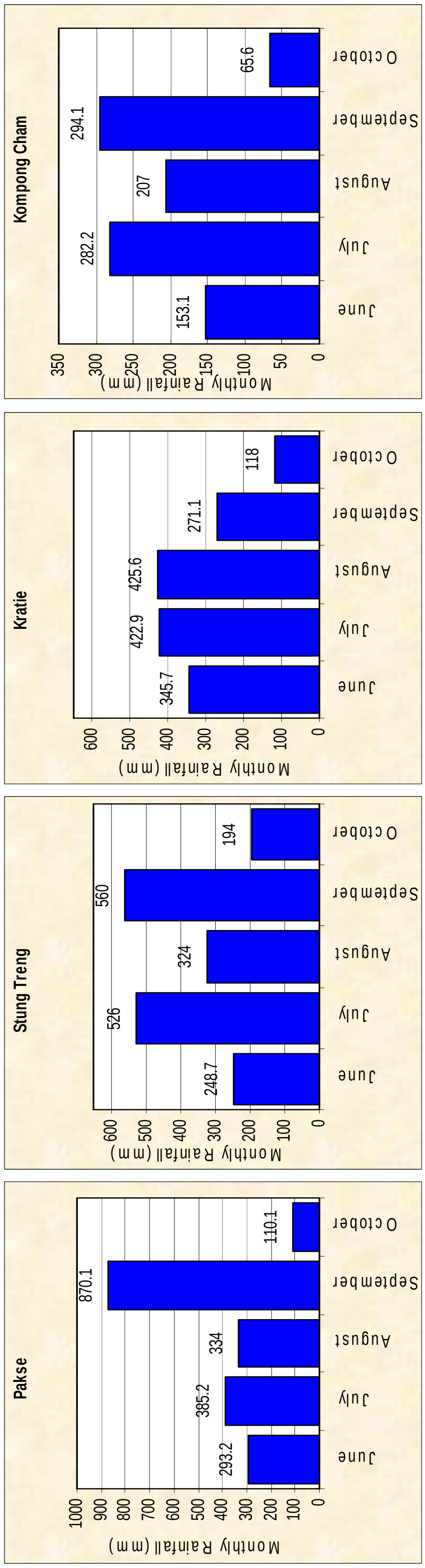


Figure A-4 Monthly rainfall distribution for, Pakse, Stung Treng , Kratie and Kampong Chiam.

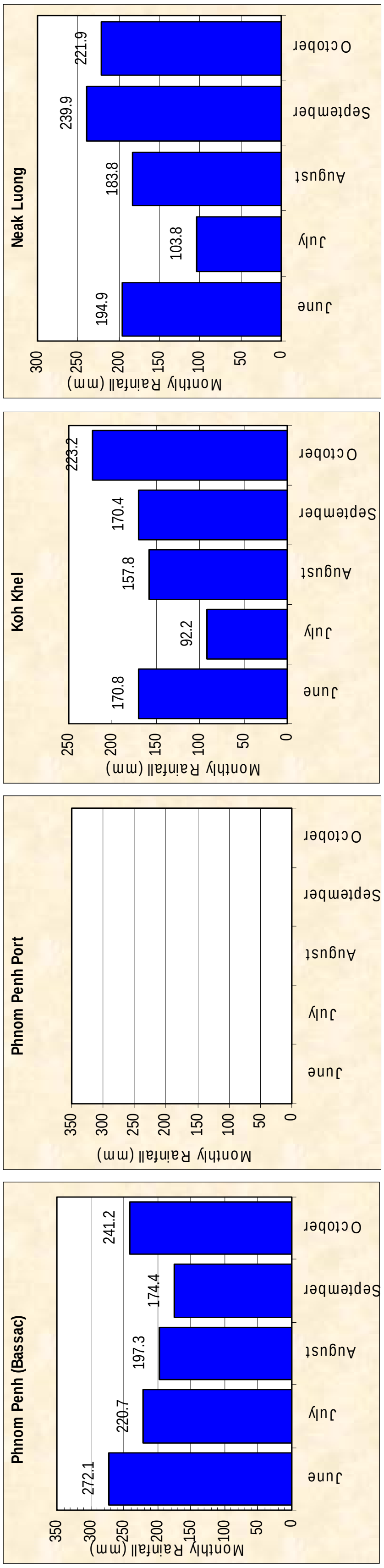


Figure A-5 Monthly rainfall distribution for Phnom Penh (Bassac and Port), Koh Khel and Neak Luong.

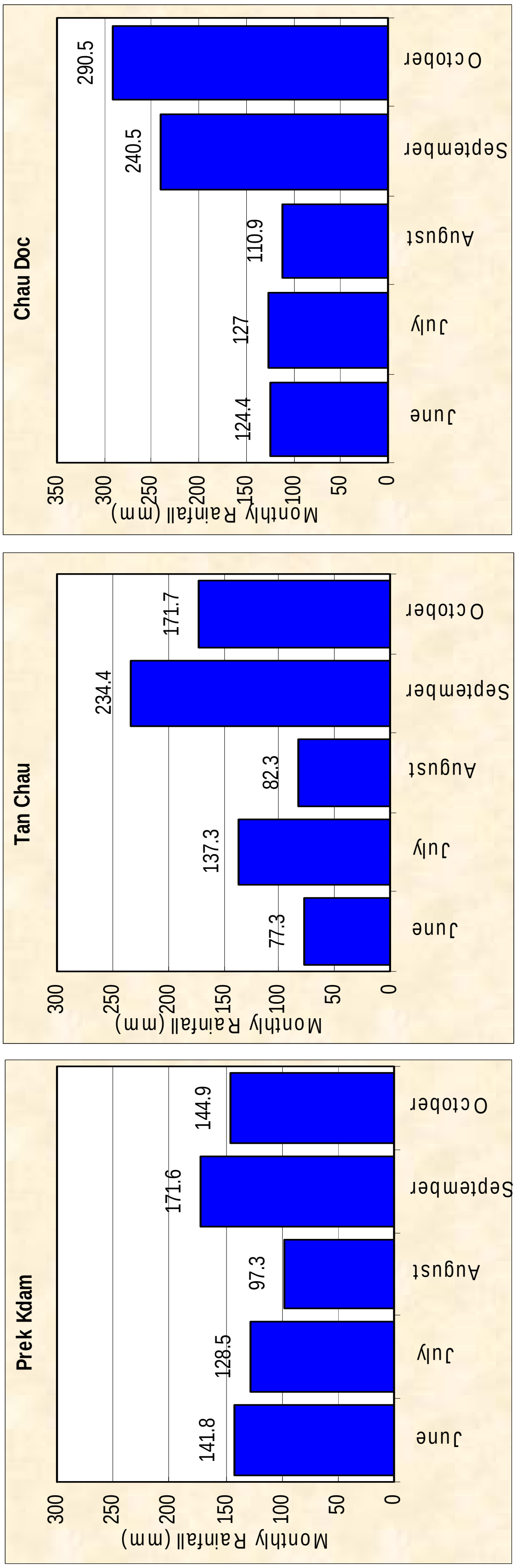


Figure A-6 Monthly rainfall distribution for Prek Kdam, Tan Chau and Chau Doc.

2. Graphs for monthly rainfall in flood season from 2000 to 2013 and long-term average along the Mekong River.

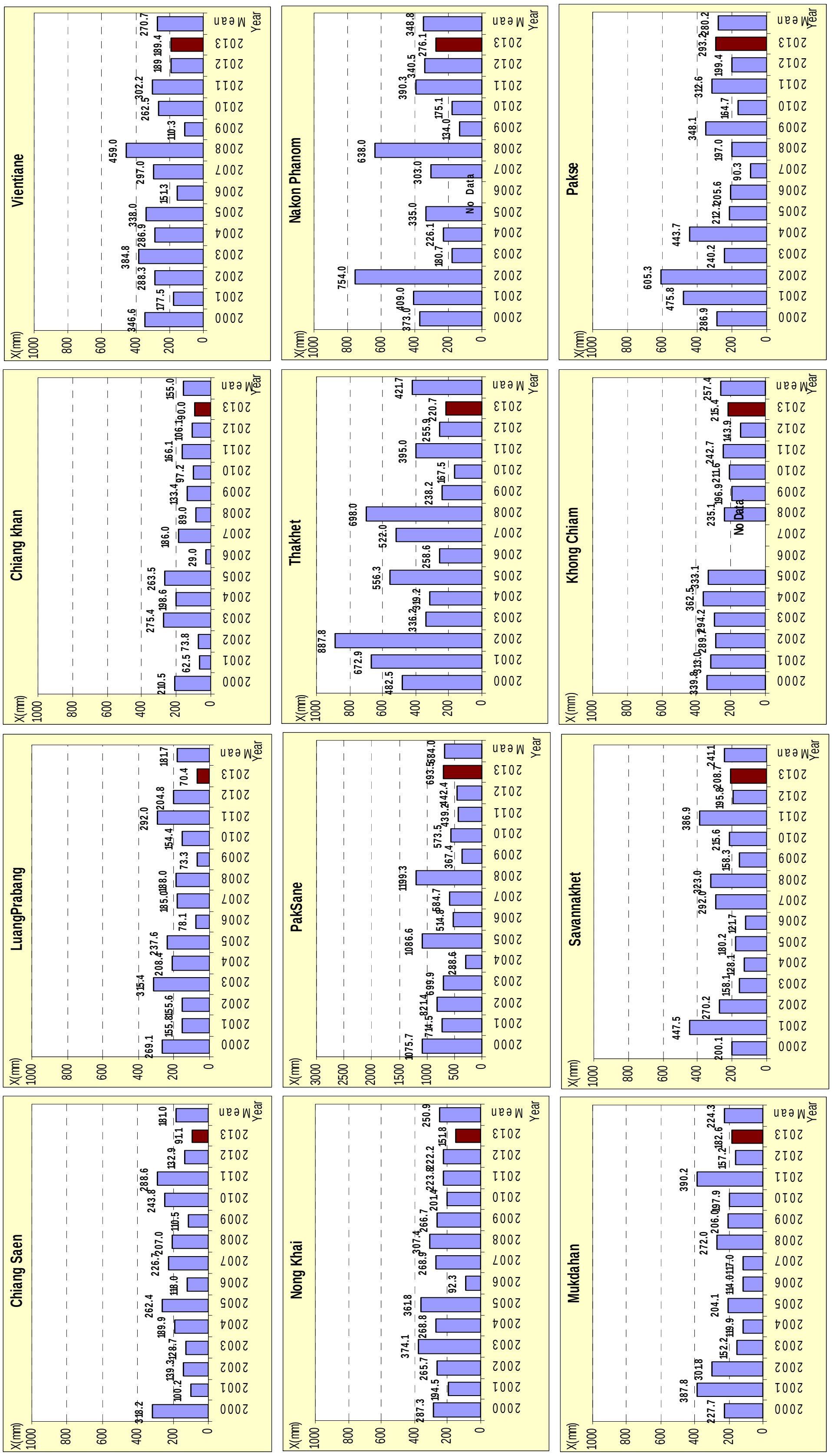


Figure A-7 Monthly rainfall in June for main stations along the Mekong River.

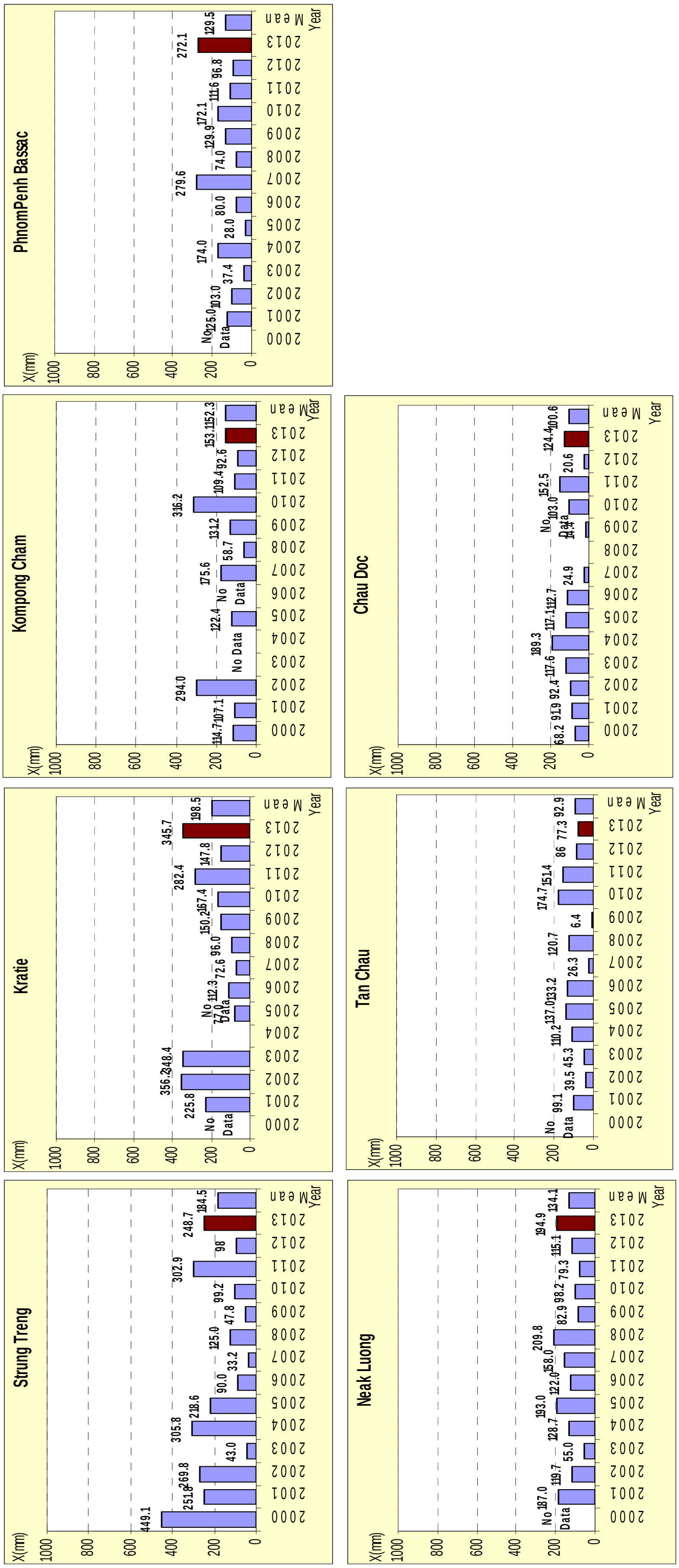


Figure A-7 (Cont.)

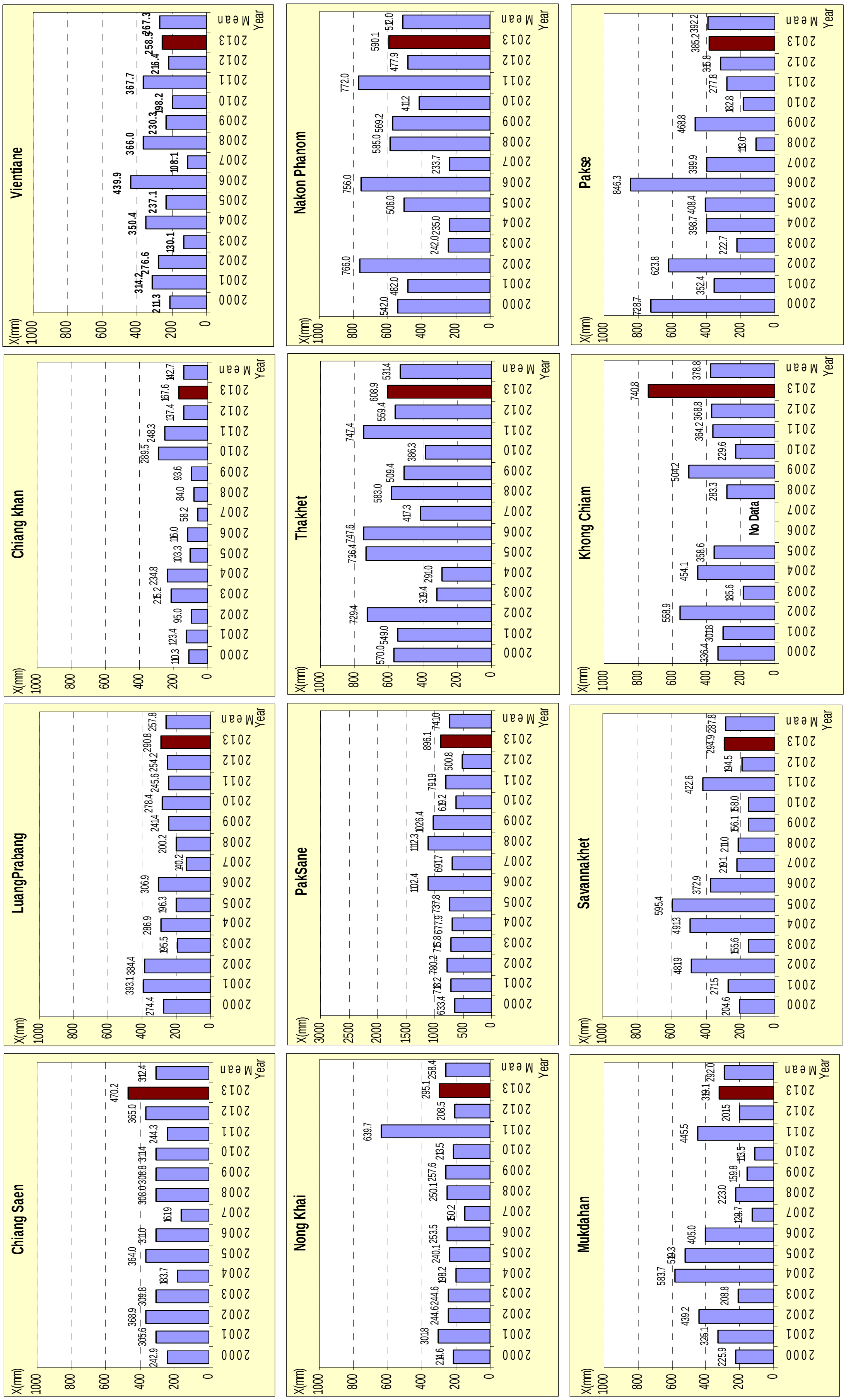


Figure A- 8 Monthly rainfall in July for main stations along the Mekong River.

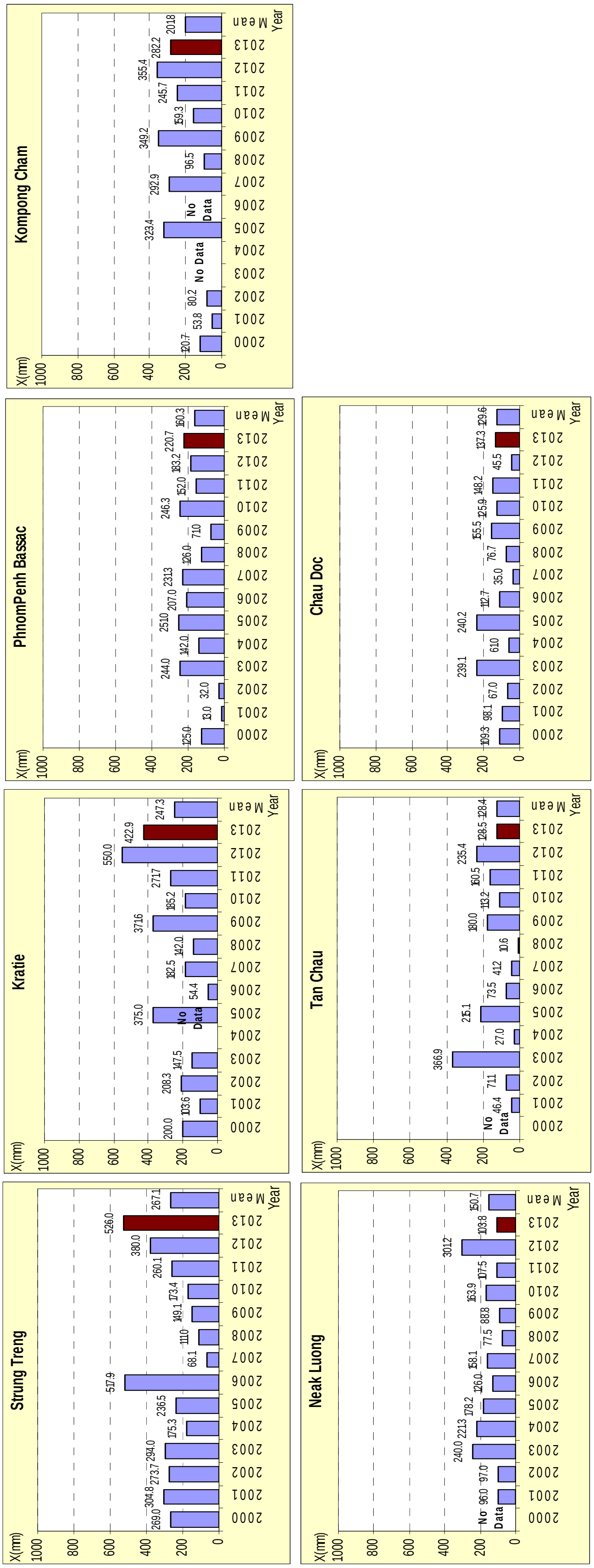


Figure A-8 (Cont.)

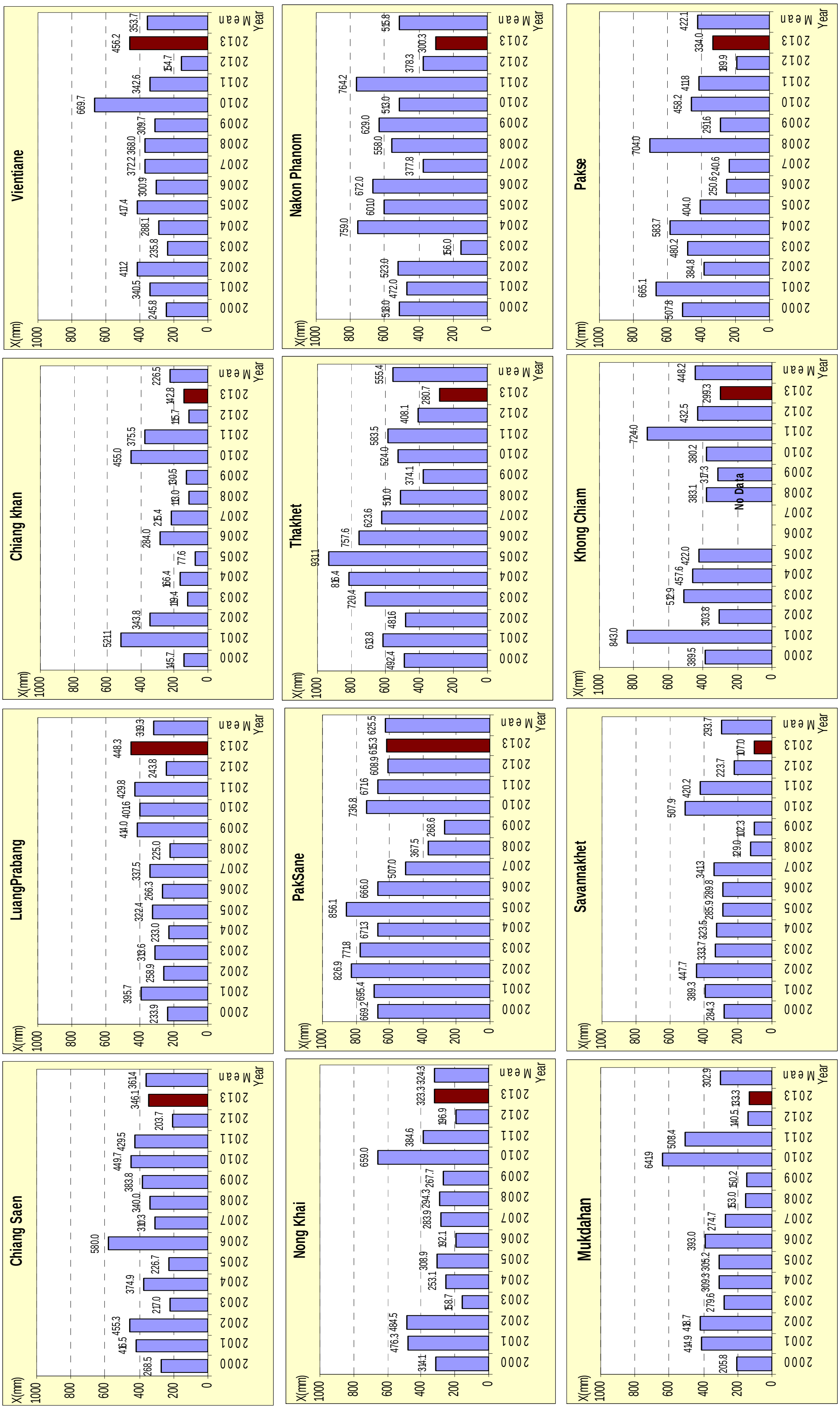


Figure A-9 Monthly rainfall in August for main stations along the Mekong River.

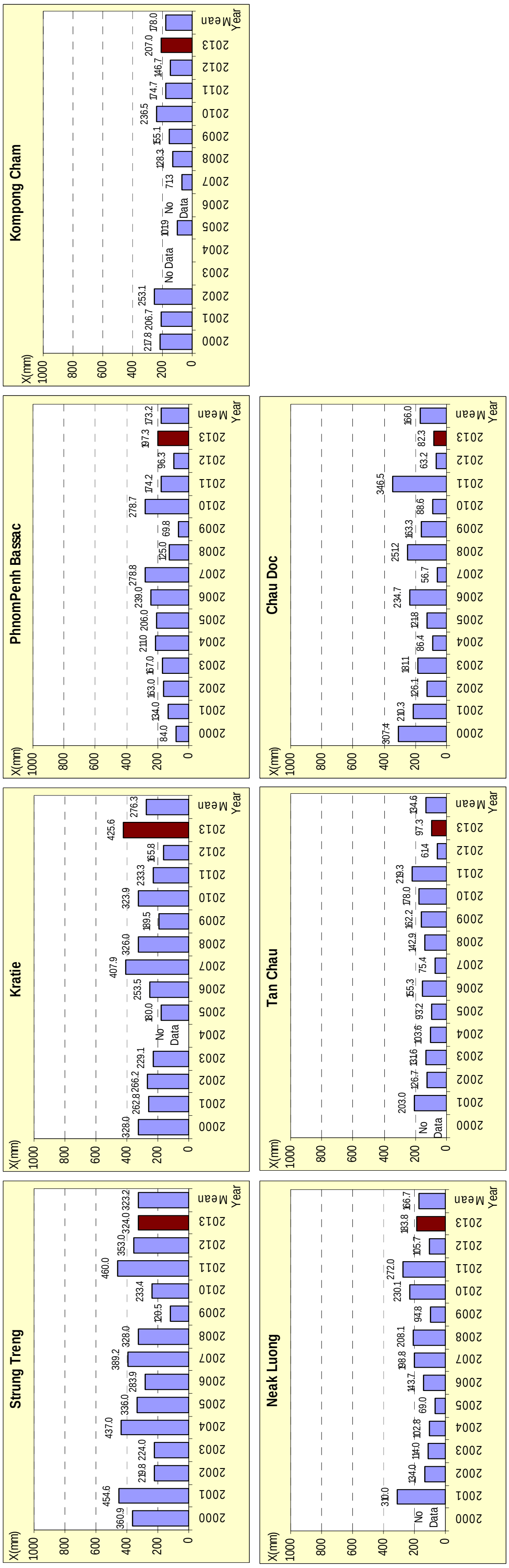


Figure A-9 (Cont.)

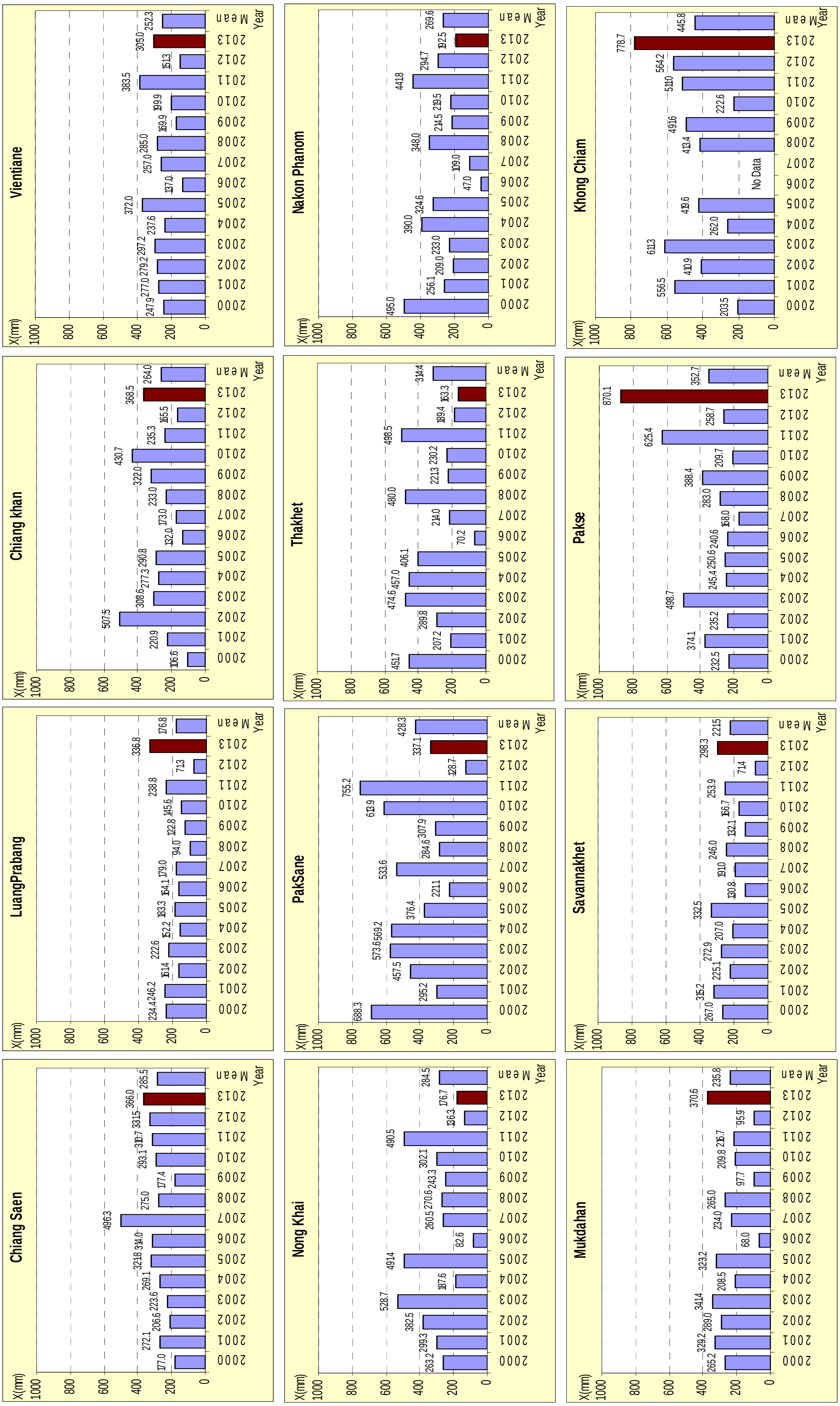


Figure A-10 Monthly rainfall in September for main stations along the Mekong River.

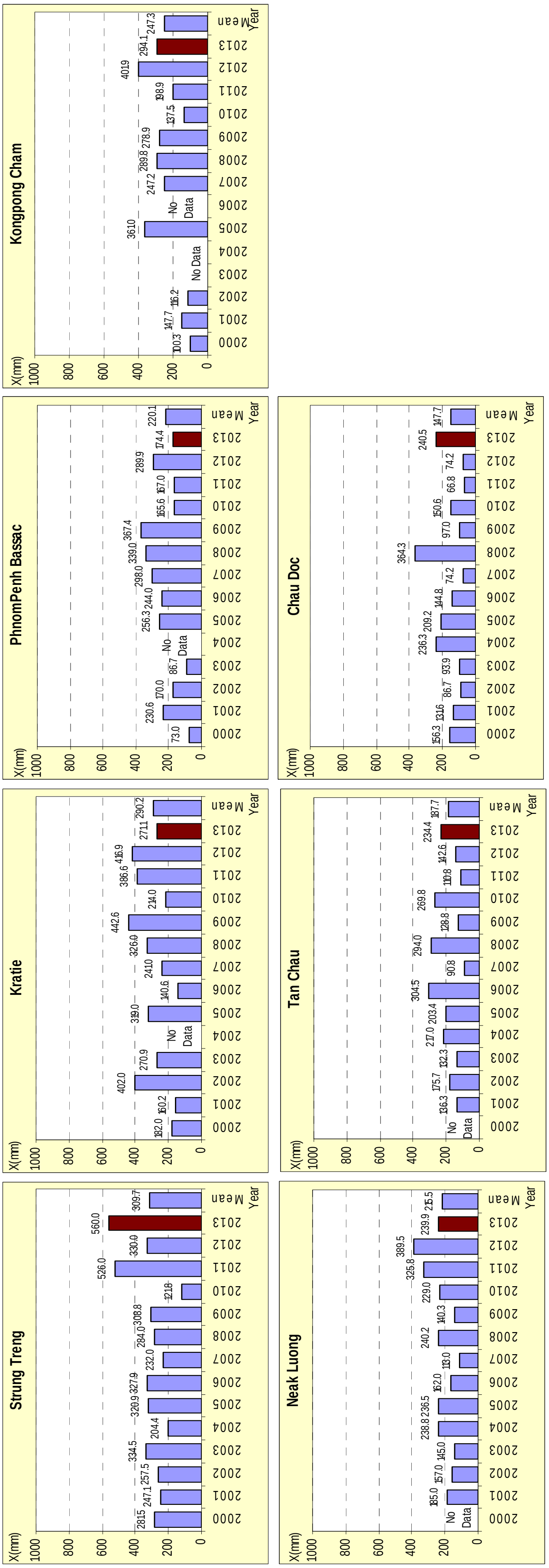


Figure A-10 (Cont.)

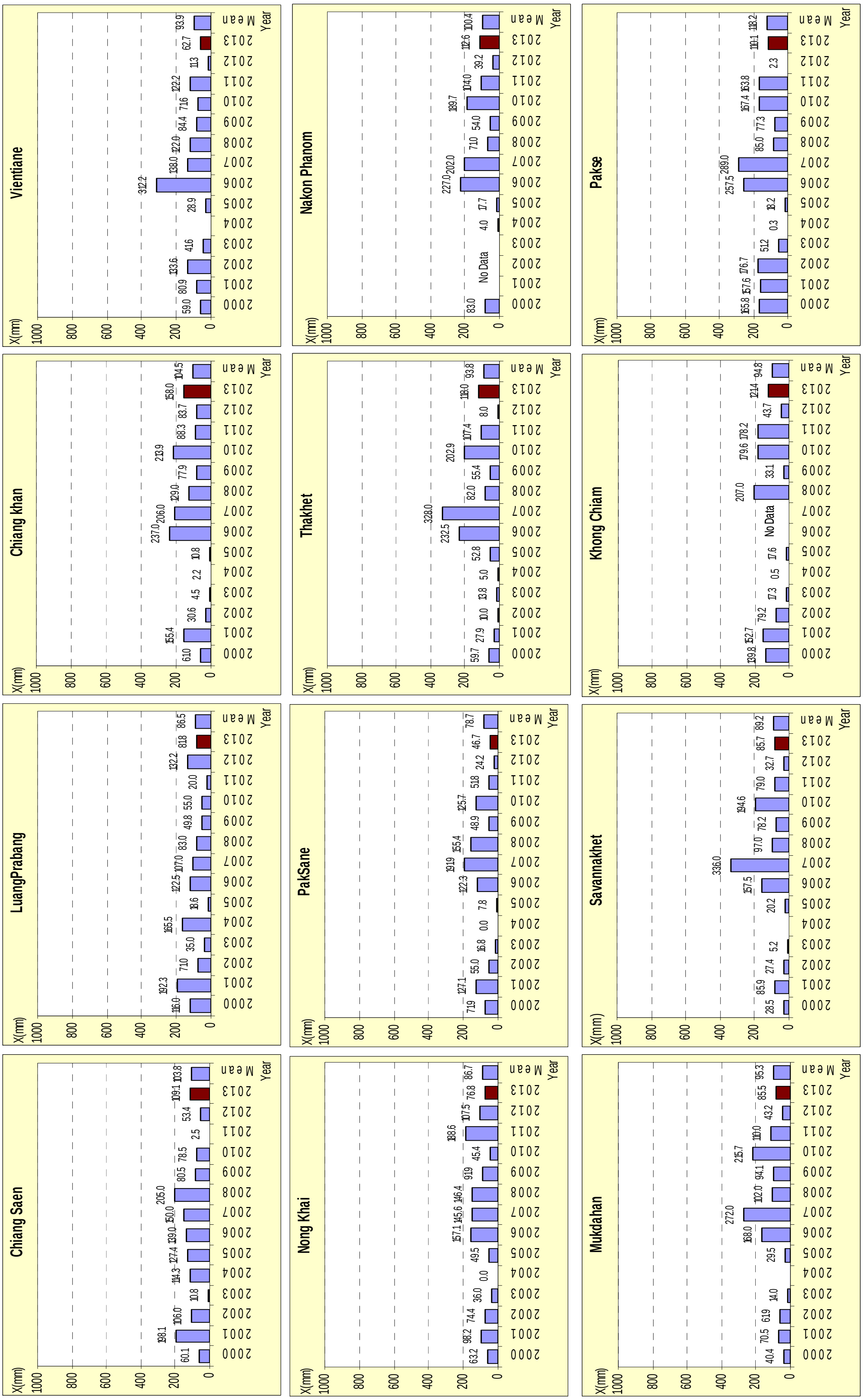


Figure A-11 Monthly rainfall in October for main stations along the Mekong River.

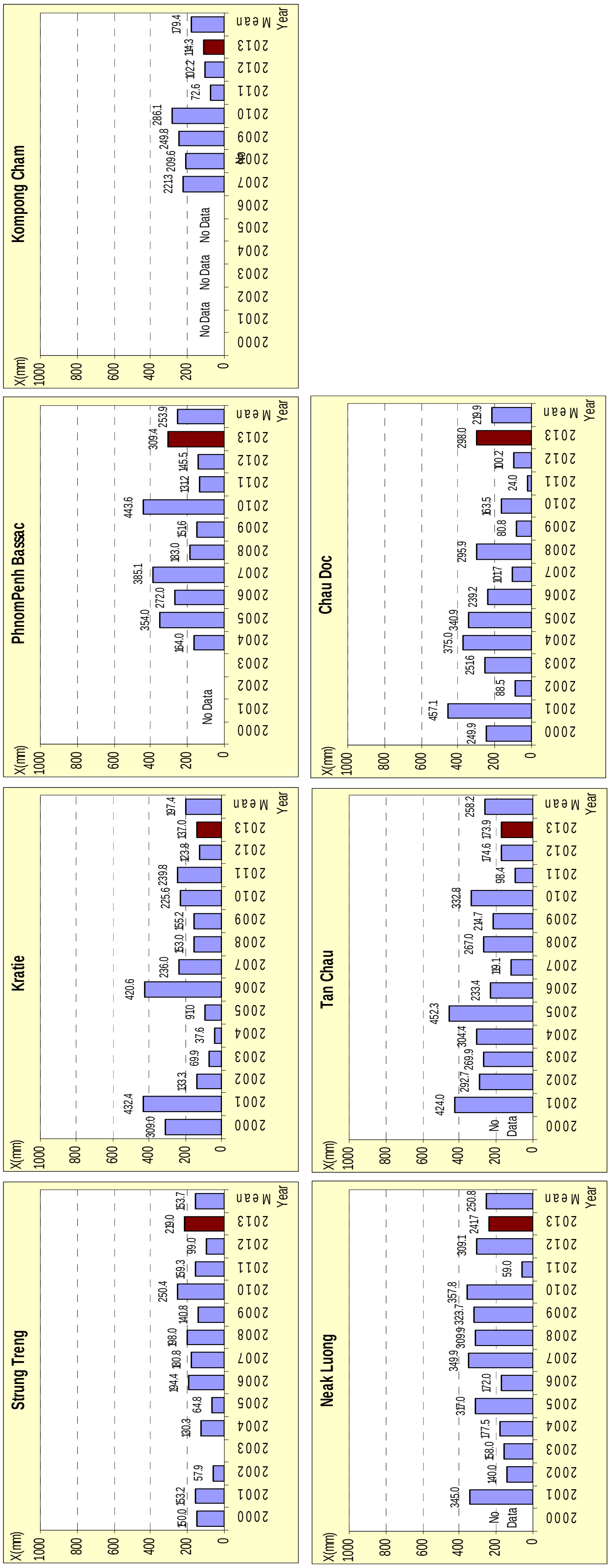


Figure A-11 (Cont.)

3. Tables of flood event characteristics along the Mekong River during flood season 2013.

Table A-2 The characteristics of flood events for station from Chiang Saen to Vientiane/Nong Khai.

Stations	Beginning of Flood Event: Date	Beginning of Flood Event: H_b (m)	Peak of Flood Event: Date	Peak of Flood Event: H_p (m)	Rising time: T_p (day)	Flood Amplitude (m)	Intensity of Flood Rising: Interval of I_{max} (Date)	Intensity of Flood Rising: I_{max} (m/day)	Intensity of Flood Rising: $I_{average}$ (m/day)	Comment
Luang Prabang	20-Jun	4.41	25-Jun	7.51	5	3.10	24 - 25/Jun	1.40	0.62	TS-BEBINCA
	20-Oct	6.8	26-Oct	9.97	6	3.17	24 - 25/Oct	0.95	0.53	TY-NARI
	05-Sep	10.65	09-Sep	13.60	4	2.95	7 - 8/Sep	2.00	0.74	SW, ITCZs, TY WUTIP
Chiang Khan	24-Jun	4.41	28-Jun	7.54	5	3.13	26 - 27/Jun	1.64	0.63	TS-BEBINCA
	23-Oct	7.29	28-Oct	9.70	5	2.41	25 - 26/Oct	0.92	0.48	TS-NARI
	06-Sep	10.16	10-Sep	12.56	4	2.40	7 - 8/Sep	1.40	0.60	SW, ITCZs, TY WUTIP
Vientiane	24-Jun	1.46	29-Jun	4.10	5	2.64	27 - 28/Jun	1.60	0.53	TS-BEBINCA
	25-Oct	4.4	29-Oct	6.28	4	1.88	26 - 27/Oct	0.99	0.47	TS-NARI
	07-Sep	7.24	10-Sep	9.62	3	2.38	7 - 8/Sep	1.16	0.79	SW, ITCZs, TY WUTIP
Nong Khai	24-Jun	2.21	29-Jun	4.77	5	2.56	27 - 28/Jun	1.24	0.51	TS-BEBINCA
	25-Oct	4.8	29-Oct	7.18	4	2.38	26 - 27/Oct	1.00	0.60	TS-NARI
	07-Sep	8.3	10-Sep	10.80	3	2.50	8 - 9/Sep	1.22	0.83	SW, ITCZs, TY WUTIP

Table A-3 The characteristics of flood events for stations from Paksane to Pakse.

Stations	Beginning of Flood Event: Date	Beginning of Flood Event: H_b (m)	Peak of Flood Event: Date	Peak of Flood Event: H_p (m)	Rising time: T_p (day)	Flood Amplitude (m)	Intensity of Flood Rising: Interval of I_{max} (Date)	Intensity of Flood Rising: I_{max} (m/day)	Intensity of Flood Rising: $I_{average}$ (m/day)	Comment
Paksane	23-Jun	4.46	30-Jun	6.95	7	2.49	24 - 25/Jun	1.26	0.36	TS-BEBINCA
Nakhon Phanom	23-Jun	3.18	26-Jun	6.18	3	3.00	24 - 25/Jun	1.59	1.00	TS-BEBINCA
Thakhek	23-Jun	4.43	27-Jun	7.28	4	2.85	24 - 25/Jun	1.39	0.71	TS-BEBINCA
Kukdahan	23-Jun	3.43	29-Jun	6.24	6	2.81	24 - 25/Jun	1.19	0.47	TS-BEBINCA
Savannakhet	23-Jun	2.25	29-Jun	5.19	6	2.94	25 - 26/Jun	2.19	0.49	TS-BEBINCA
Khong Chiam	23-Jun	3.7	28-Jun	6.87	5	3.17	23 - 24/Jun	1.61	0.63	TS-BEBINCA
	15-Sep	10.17	23-Sep	14.04	8	3.87	18 - 19/Sep	0.95	0.48	ITCZs,SW
Pakse	23-Jun	3.9	28-Jun	5.51	5	1.61	26 - 27/Jun	1.61	0.32	TS-BEBINCA
	15-Sep	8.27	23-Sep	12.35	8	4.08	15 - 16/Sep	1.08	0.51	ITCZs,SW

Table A-4 The characteristics of flood events for stations from Strung Treng to Kampong Cham.

Stations	Beginning of Flood Event		Peak of Flood Event		Rising time	Flood Amplitude	Intensity of Flood Rising			Comment
	Date	H_b (m)	Date	H_p (m)	T_p (day)	(m)	Interval of I_{max} (Date)	I_{max} (m/day)	Iaverage (m/day)	
Stung Treng	14-Sep	7.29	24-Sep	11.7	10	4.41	18 - 19/Sep	1.08	0.44	ITCZs,SW
Kratie	14-Sep	16.82	27-Sep	22.69	13	5.87	17 - 18/Sep	0.71	0.45	ITCZs,SW
Kompong Cham	14-Sep	11.66	27-Sep	15.97	13	4.31	17 - 18/Sep	0.71	0.33	ITCZs,SW

Table A-5 The characteristics of flood events for stations from Phnom Penh Bassac/Phnom Penh Port, Koh Khel/Neak Luong to Prek Kdam.

Stations	Beginning of Flood Event		Peak of Flood Event		Rising time	Flood Amplitude	Intensity of Flood Rising			Comment
	Date	H_b (m)	Date	H_p (m)	T_p (day)	(m)	Interval of I_{max} (Date)	I_{max} (m/day)	Iaverage (m/day)	
Bassac Charktomuk	19-Sep	8.67	30-Sep	10.3	11	1.63	19 - 20/Sep	0.22	0.15	ITCZs,SW
Phnom Penh	19-Sep	7.9	29-Sep	9.42	10	1.52	20 - 21/Sep	0.28	0.15	ITCZs,SW
Koh Khel	19-Sep	7.01	30-Sep	7.77	11	0.76	19 - 20/Sep	0.14	0.07	ITCZs,SW
Neak Luong	19-Sep	5.95	30-Sep	7.62	11	1.67	19 - 20/Sep	0.14	0.15	ITCZs,SW
Prek Kdam	19-Sep	7.73	01-Oct	9.25	12	1.52	19 - 20/Sep	0.16	0.13	ITCZs,SW

Table A-6 The characteristics of flood events for stations from Tan Chau and Chau Doc (**)

Stations	Beginning of Flood Event		Peak of Flood Event		Rising time	Flood Amplitude	Intensity of Flood Rising			Comment
	Date	H_b (m)	Date	H_p (m)	T_p (day)	(m)	Interval of I_{max} (Date)	I_{max} (m/day)	Iaverage (m/day)	
Tan Chau	15-Sep	2.84	03-Oct	4.3	18	1.46	28 - 29/Sep	0.15	0.08	ITCZs
Chau Doc	15-Sep	2.35	06-Oct	3.72	21	1.37	30/Sep - 6/Oct	0.13	0.07	ITCZs

(**) Water levels at Tan Chau and Chau Doc are influenced by tidal, the WL in the Table A6 were recorded at 7AM during 2013 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 a normal pattern.

In general terms, the accuracy is good for all forecasts lead time at most stations along Mekong River, however the accuracy for 3-day forecast at Vientiane, Nakhon Phanom, Mukdahan to Kratie. The detail analysis is presented in paragraph 2.2.

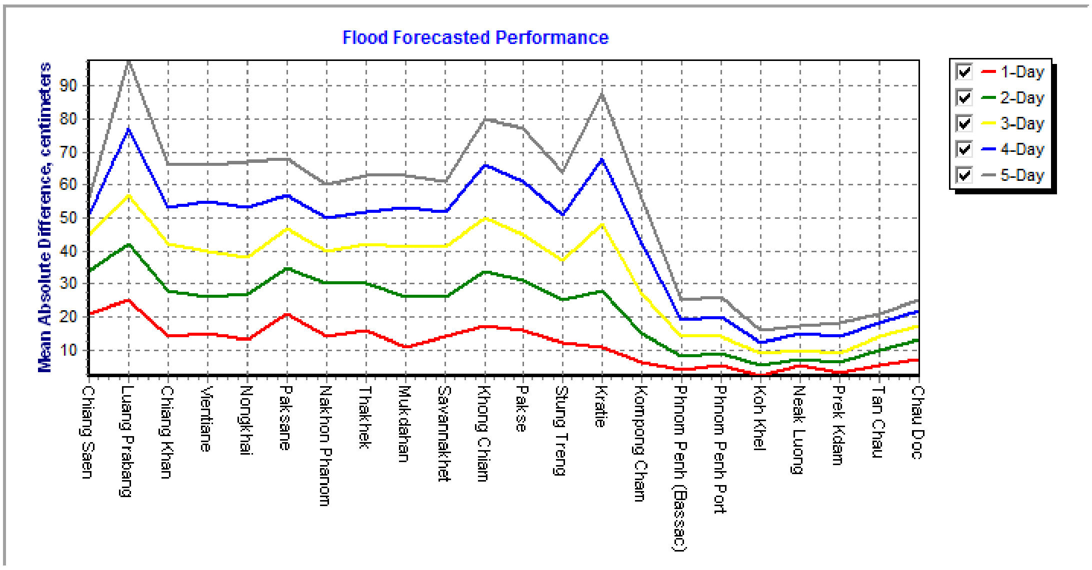


Figure B-1 Average flood forecast accuracy along the Mekong mainstream

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 B-2).

Table B-1 Achievement of daily forecast against benchmarks.

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	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	*Average*
1-day	79.0	73.3	86.3	57.5	65.7	41.3	57.2	54.7	63.6	57.8	58.8	60.0	64.8	67.2	83.5	95.6	91.8	97.8	92.1	97.7	87.7	80.9	***73.4***
2-day	76.1	70.9	85.2	61.2	56.7	55.7	60.9	58.9	63.6	68.8	54.4	61.4	68.9	54.5	84.6	81.3	75.0	87.4	77.9	83.6	71.1	62.5	***69.1***
3-day	66.4	58.4	69.2	46.3	45.1	40.3	53.4	46.7	45.4	45.6	37.6	44.1	54.7	34.0	60.0	54.0	45.6	74.9	61.6	68.0	60.0	52.1	***52.9***
4-day	75.6	61.6	58.0	63.0	59.4	53.8	68.3	62.9	60.6	62.6	52.5	52.2	62.9	49.6	70.4	43.7	74.0	66.4	84.1	89.5	59.2	45.0	***62.5***
5-day	74.1	51.0	52.4	47.5	44.5	41.7	58.8	55.6	51.9	59.6	46.6	47.7	53.3	41.0	59.7	69.4	64.7	84.3	76.3	77.2	76.7	69.4	***59.2***

unit in %

Table B-2 Benchmarks of success (Indicator of accuracy in mean absolute error).

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	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

Unit in cm

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 2013 onward.

Performance

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

Table B-3 Overview of performance indicators for flood season 2013 from June to October.

2013	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	*10:31*	*3*	-	*16*	*08:14*	-	*07:12*	*06:27*	*09:00*	*07:07*	*07:05*	*0*	*12*	*52*	*247*	*862*	*2*	*168*
July	*10:29*	*0*	-	*16*	*08:13*	-	*07:15*	*05:43*	*08:52*	*07:34*	*07:16*	*3*	*5*	*15*	*291*	*926*	*2*	*154*
August	*10:21*	*2*	-	*15*	*08:15*	-	*07:06*	*05:21*	*08:55*	*07:44*	*07:12*	*10*	*0*	*6*	*353*	*760*	*25*	*188*
September	*10:14*	*0*	-	*20*	*08:16*	-	*07:13*	*05:50*	*08:27*	*07:28*	*07:01*	*3*	*0*	*18*	*413*	*601*	*0*	*111*
Octorber	*10:15*	*0*	-	*29*	*08:14*	-	*07:08*	*06:29*	*08:48*	*07:23*	*07:08*	*30*	*0*	*11*	*504*	*730*	*2*	*122*
season	*10:21*	*5*	-	*96*	*08:14*	-	*07:11*	*05:59*	*08:48*	*07:27*	*07:09*	*46*	*17*	*101*	*1888*	*4067*	*31*	*767*

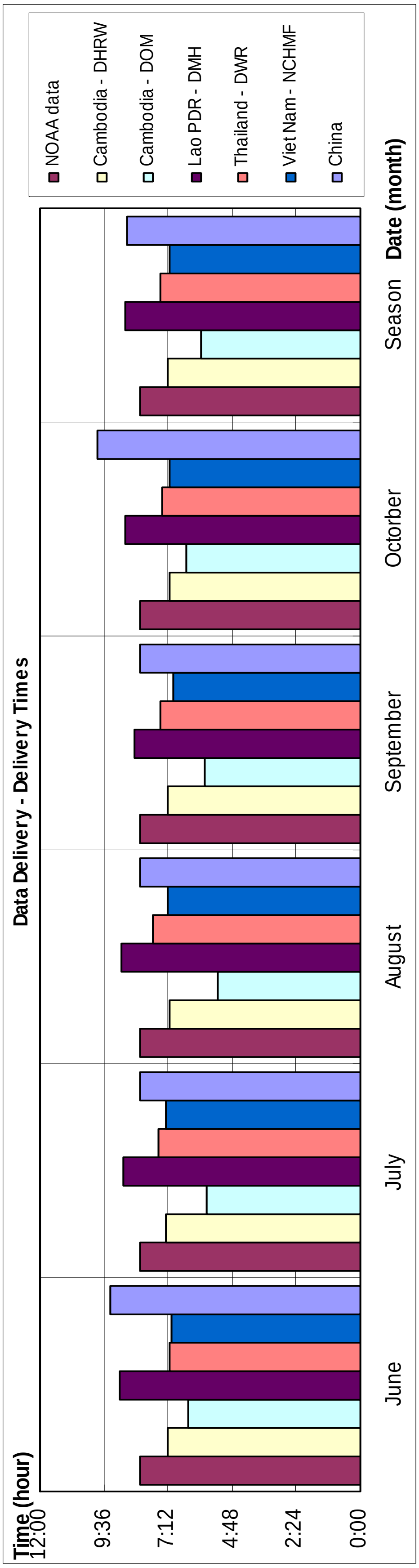


Figure B-2 Data delivery times for flood season 2013 from June to October.

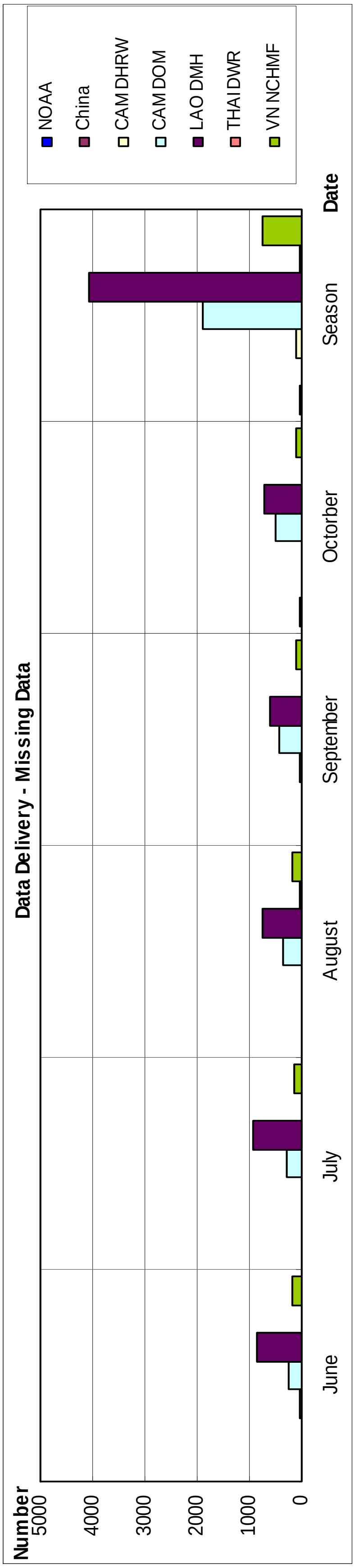


Figure B-3 Missing data for flood season 2013 from June to October.

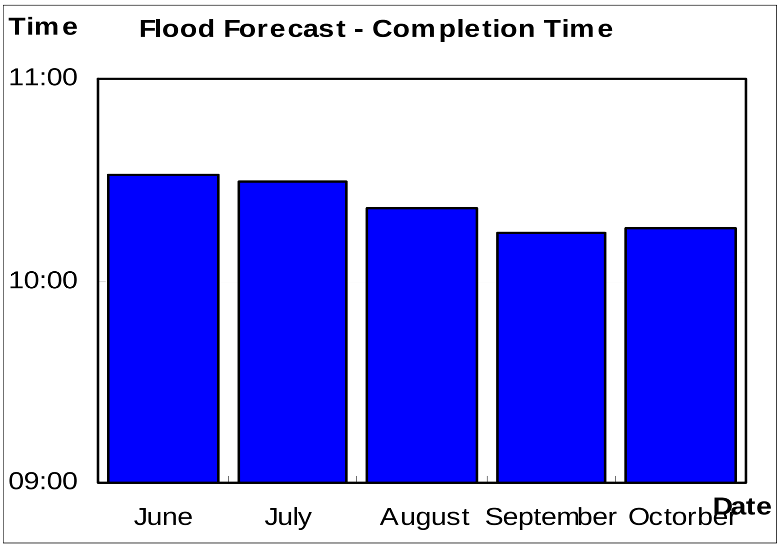


Figure B-4 Flood forecast completion time.

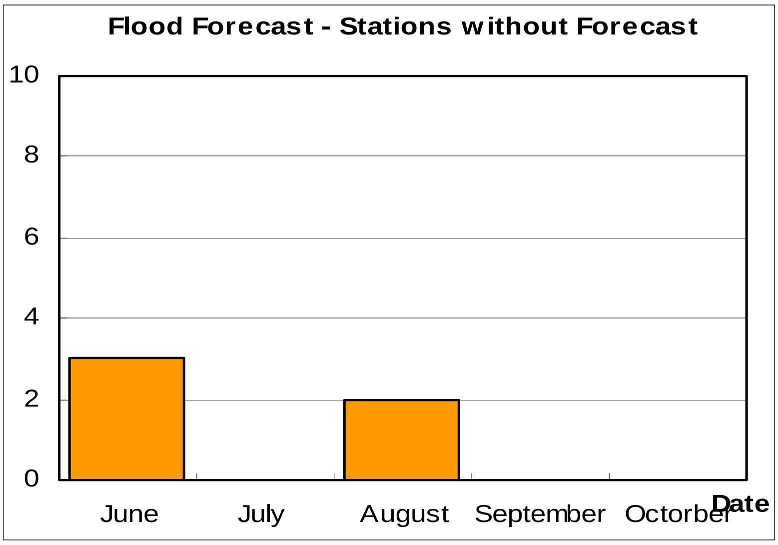


Figure B-5 Flood forecast stations without forecast.

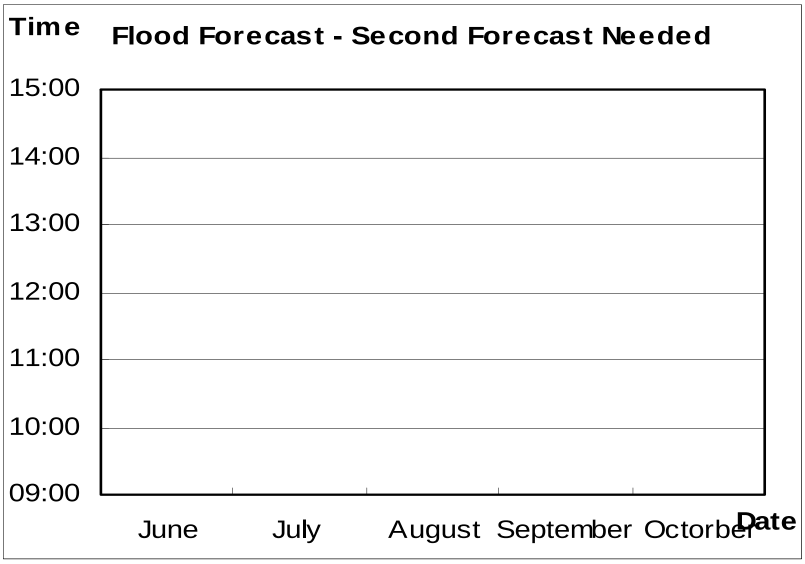
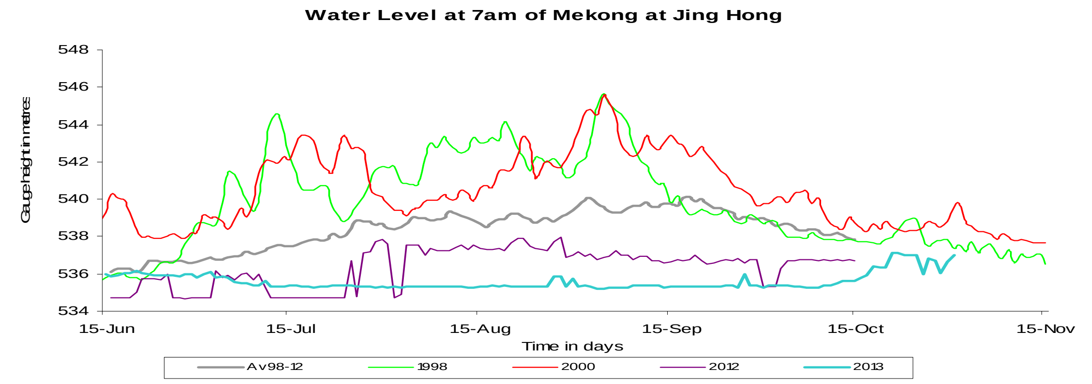


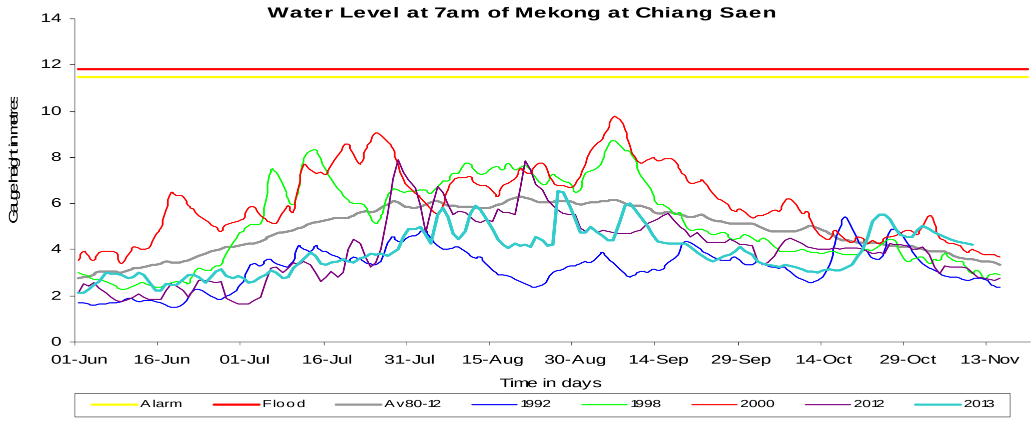
Figure B-6 Second forecast needed.

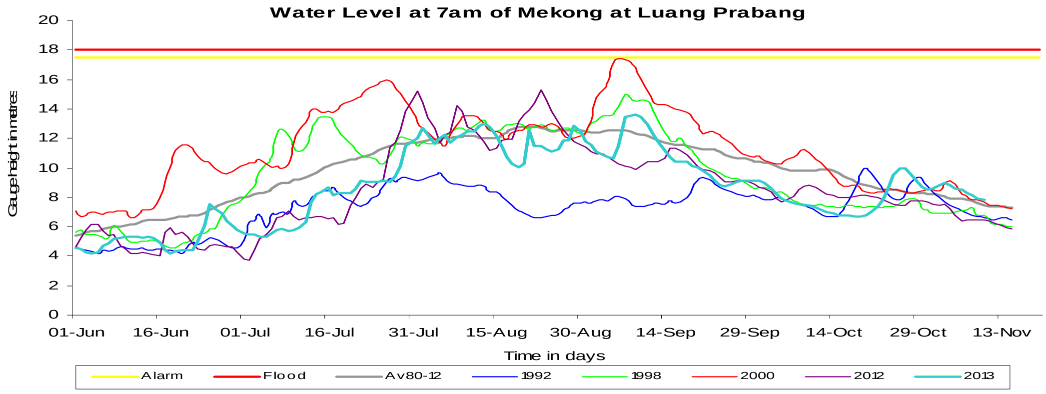
Annex C Season Water Level Graphs

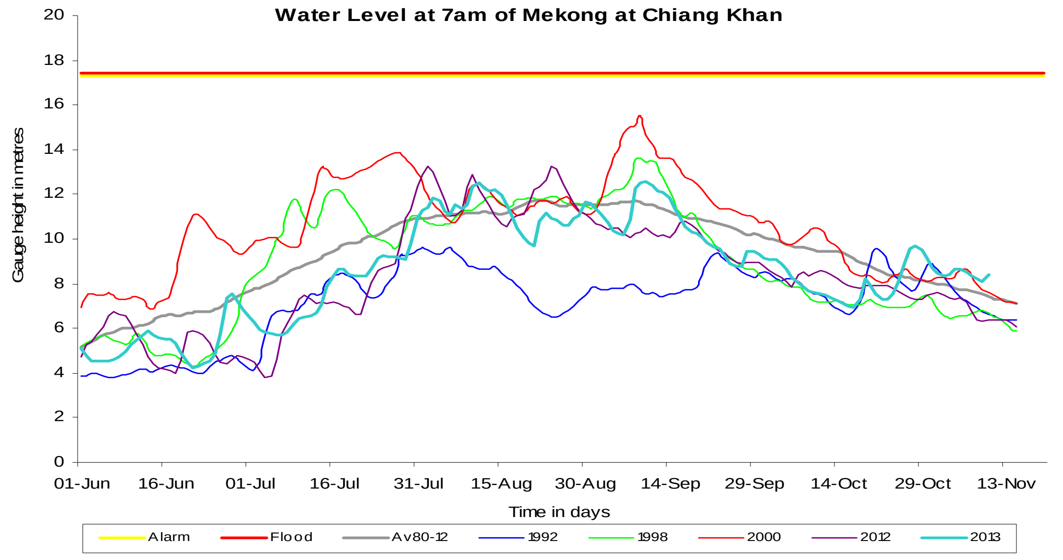
This Annex has the water level and rainfall graphs of the report date. These graphs are distributed daily by email together with the Flood Bulletins.

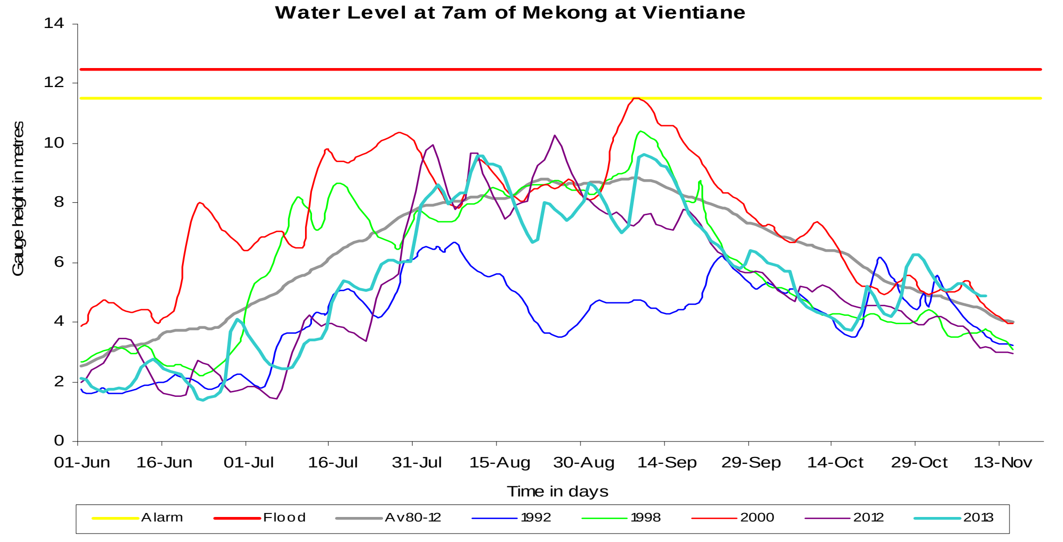
HYDROGRAPHS OF THE MEKONG AT MAINSTREAM STATIONS IN FLOOD SEASON FROM 1st JUNE TO 31st OCTOBER








Water Level at 7am of Mekong at Chiang Khan
Gauge height in metres
Time in days
Alarm
Flood
Av80-12
1992
1998
2000
2012
2013


Water Level at 7am of Mekong at Vientiane
Gauge height in metres
Time in days
Alarm
Flood
Av80-12
1992
1998
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2012
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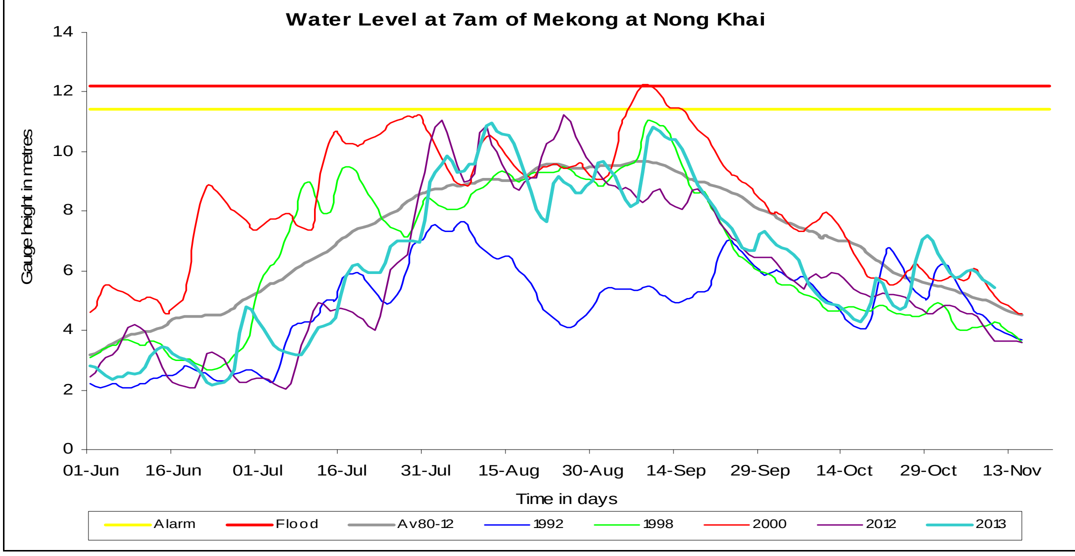
Water Level at 7am of Mekong at Nong Khai
Gauge height in metres
Time in days
Alarm
Flood
Av80-12
1992
1998
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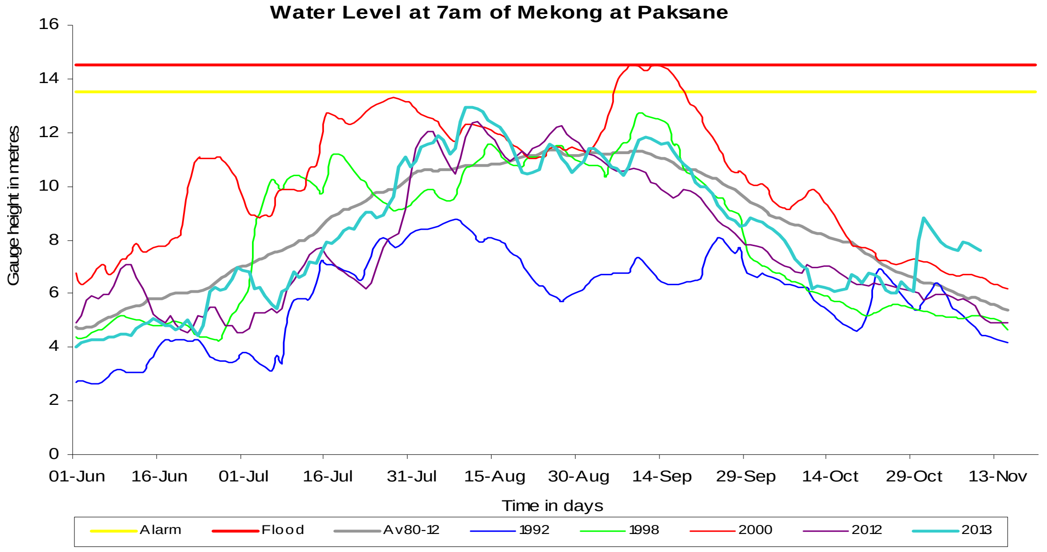
Water Level at 7am of Mekong at Paksane
Gauge height in metres
Time in days
01-Jun 16-Jun 01-Jul 16-Jul 31-Jul 15-Aug 30-Aug 14-Sep 29-Sep 14-Oct 29-Oct 13-Nov
Alarm
Flood
Av80-12
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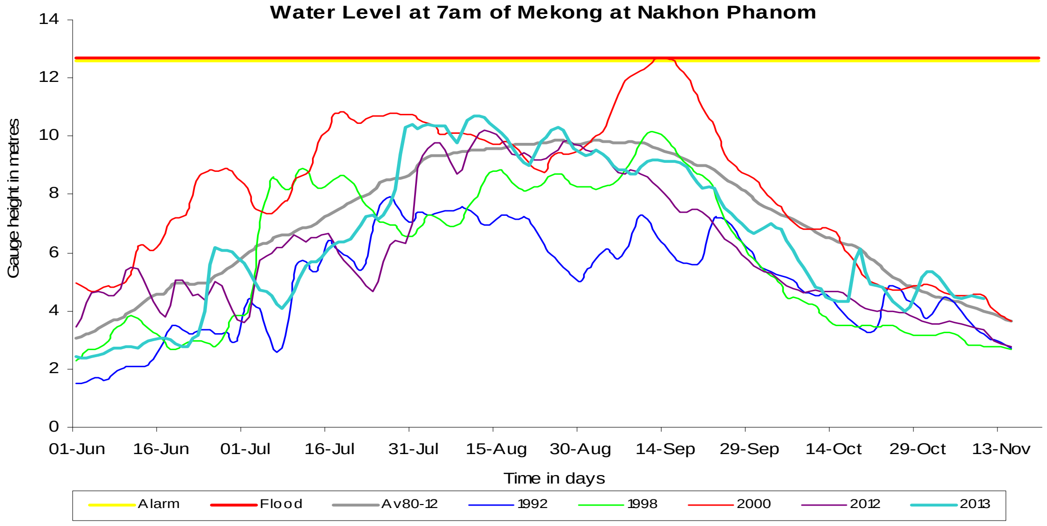
2013


Water Level at 7am of Mekong at Nakhon Phanom
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
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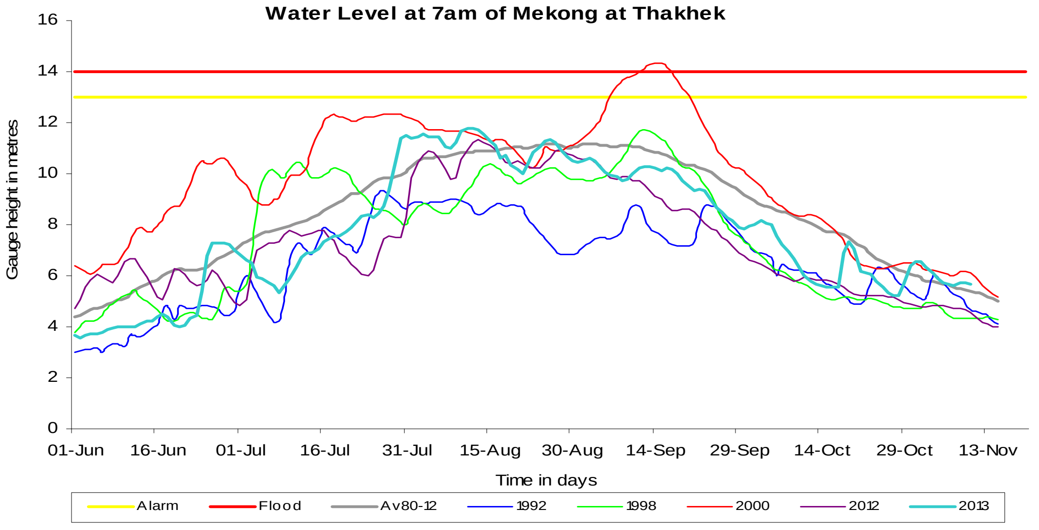
Water Level at 7am of Mekong at Thakhek
Gauge height in metres
Time in days
01-Jun 16-Jun 01-Jul 16-Jul 31-Jul 15-Aug 30-Aug 14-Sep 29-Sep 14-Oct 29-Oct 13-Nov
Alarm
Flood
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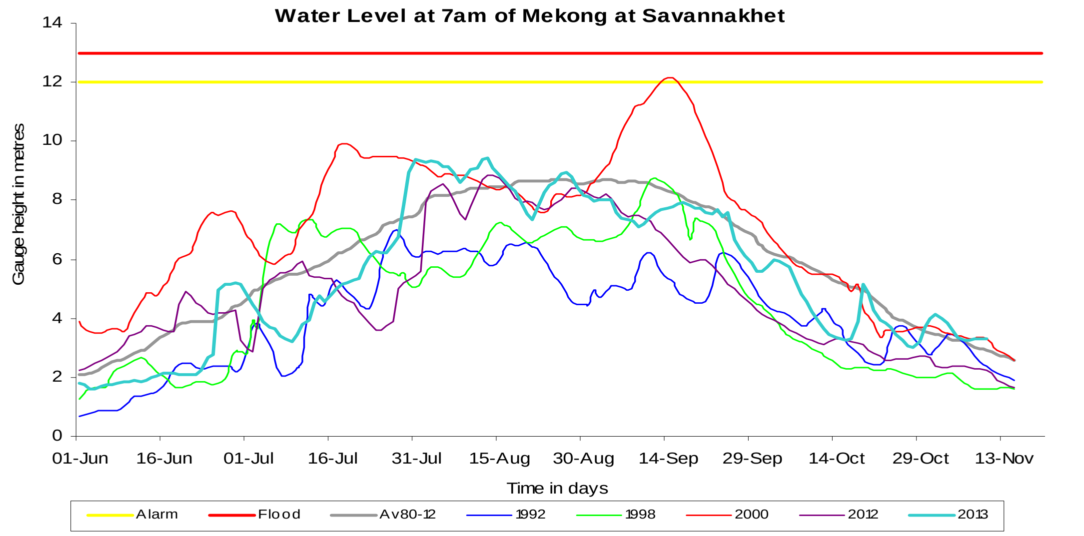
2013


Water Level at 7am of Mekong at Savannakhet
Gauge height in metres
0
2
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01-Jun
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16-Jul
31-Jul
15-Aug
30-Aug
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29-Oct
13-Nov
Time in days
Alarm
Flood
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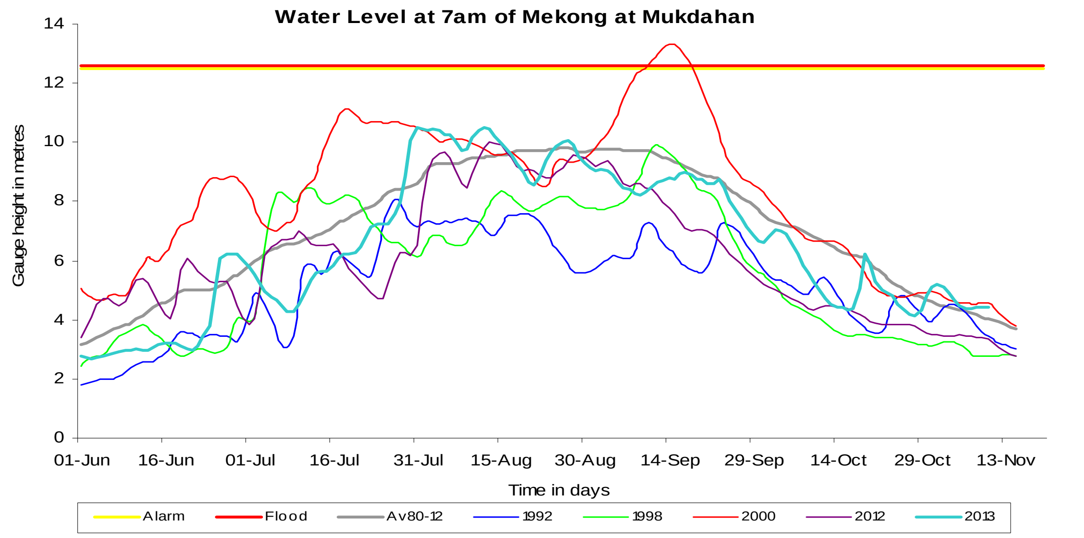
Water Level at 7am of Mekong at Mukdahan
Gauge height in metres
0
2
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14
01-Jun
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01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
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Time in days
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Flood
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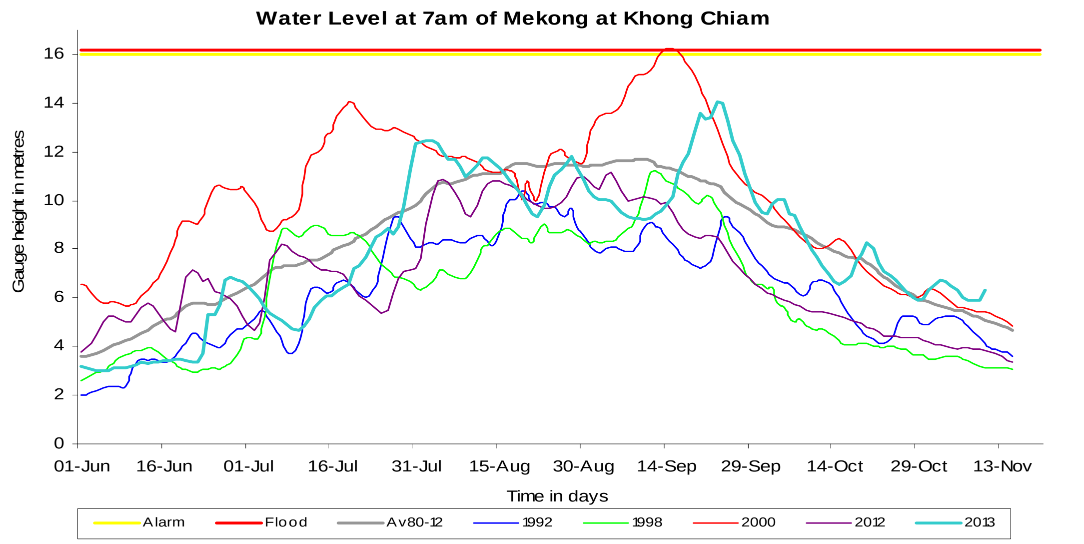
Water Level at 7am of Mekong at Khong Chiam
Gauge height in metres
0
2
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16
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
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Time in days
Alarm
Flood
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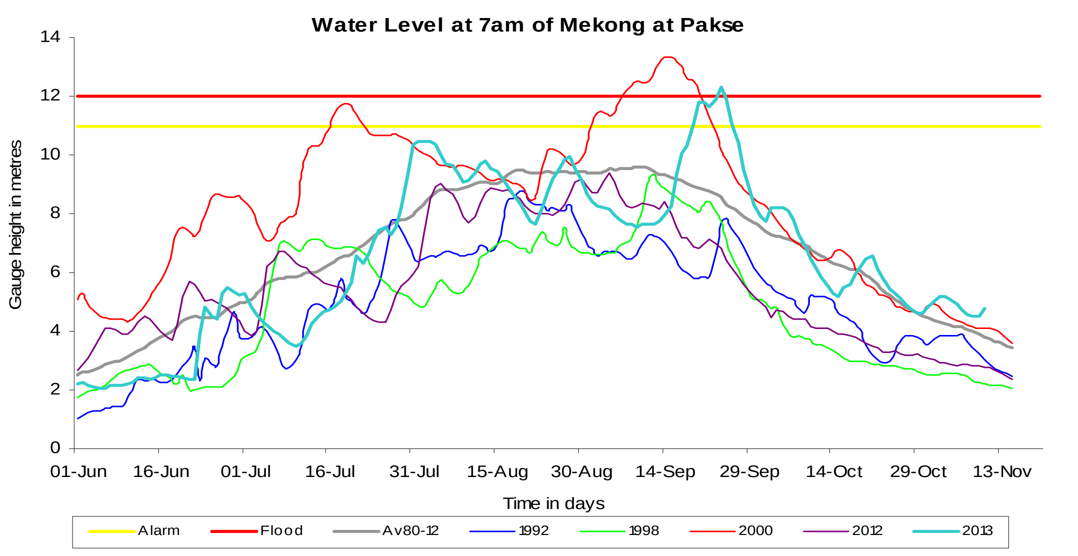
Water Level at 7am of Mekong at Pakse
Gauge height in metres
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01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
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Time in days
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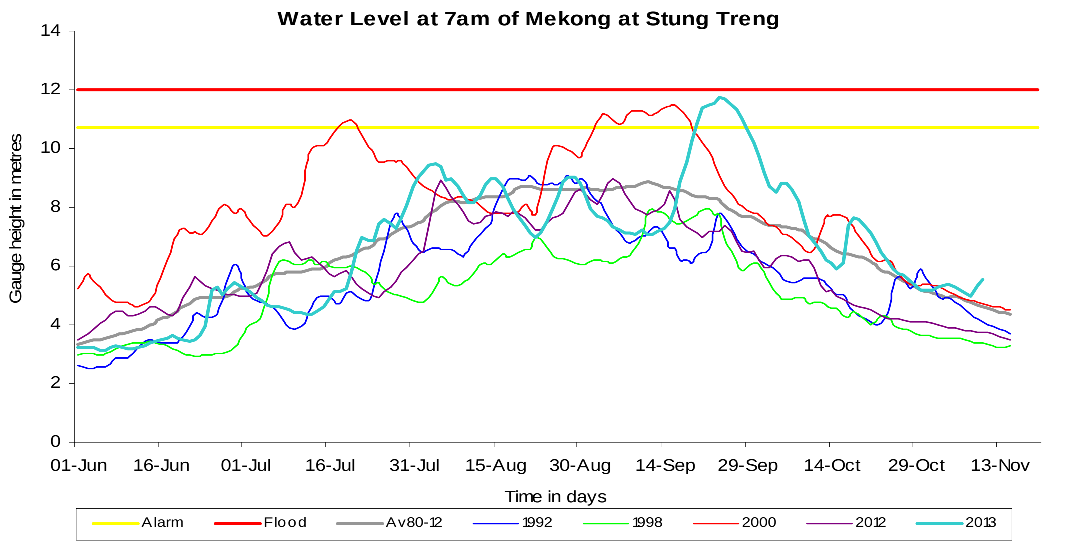
Water Level at 7am of Mekong at Stung Treng
Gauge height in metres
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2
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01-Jul
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31-Jul
15-Aug
30-Aug
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Time in days
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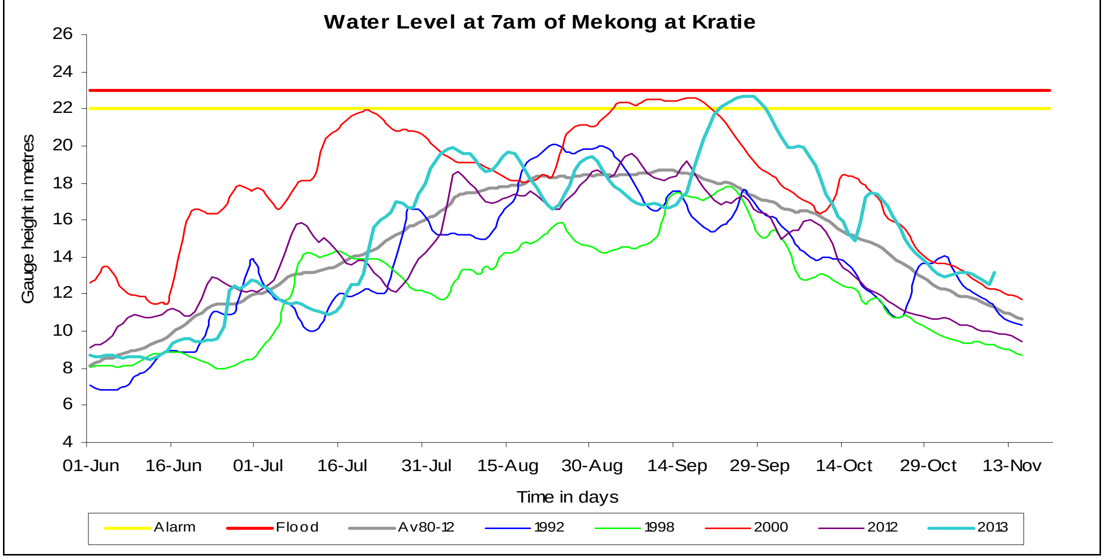
2013


Water Level at 7am of Mekong at Kratie
Gauge height in metres
4
6
8
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22
24
26
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
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13-Nov
Time in days
Alarm
Flood
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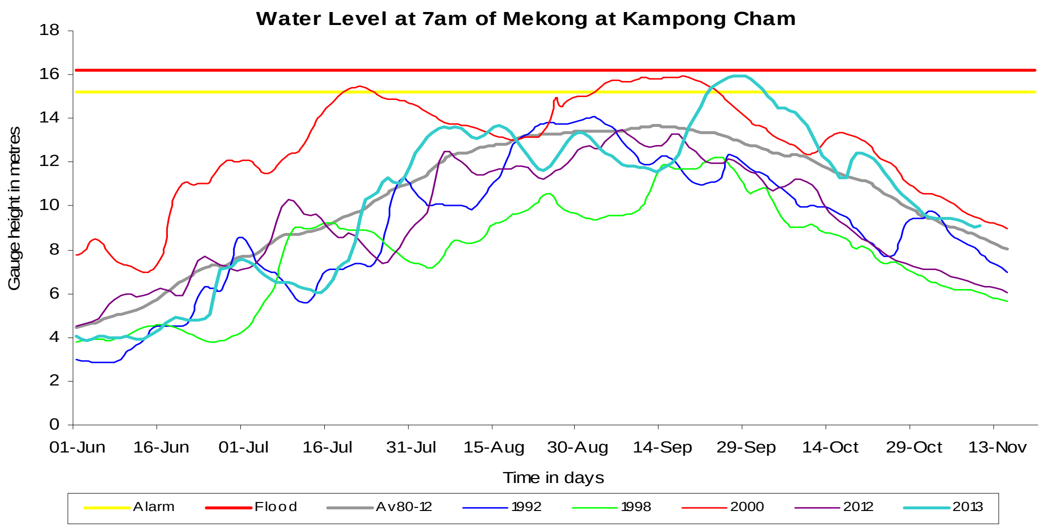
2012
2013


Water Level at 7am of Mekong at Kampong Cham
Gauge height in metres
0
2
4
6
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14
16
18
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
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13-Nov
Time in days
Alarm
Flood
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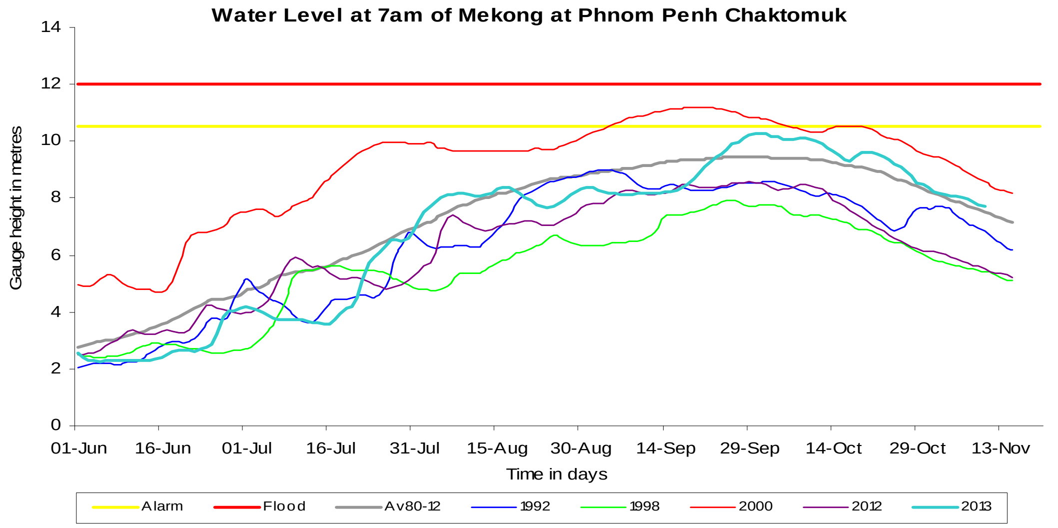
1992
1998
2000
2012
2013


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
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Time in days
Alarm
Flood
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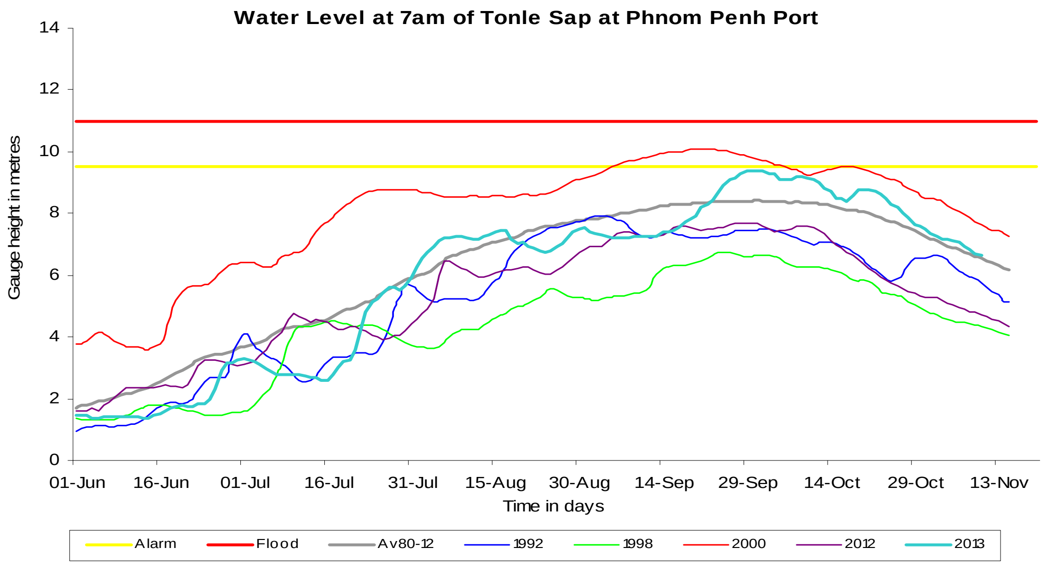
1992
1998
2000
2012
2013


Water Level at 7am of Tonle Sap at Phnom Penh Port
Gauge height in metres
0
2
4
6
8
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12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
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13-Nov
Time in days
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1992
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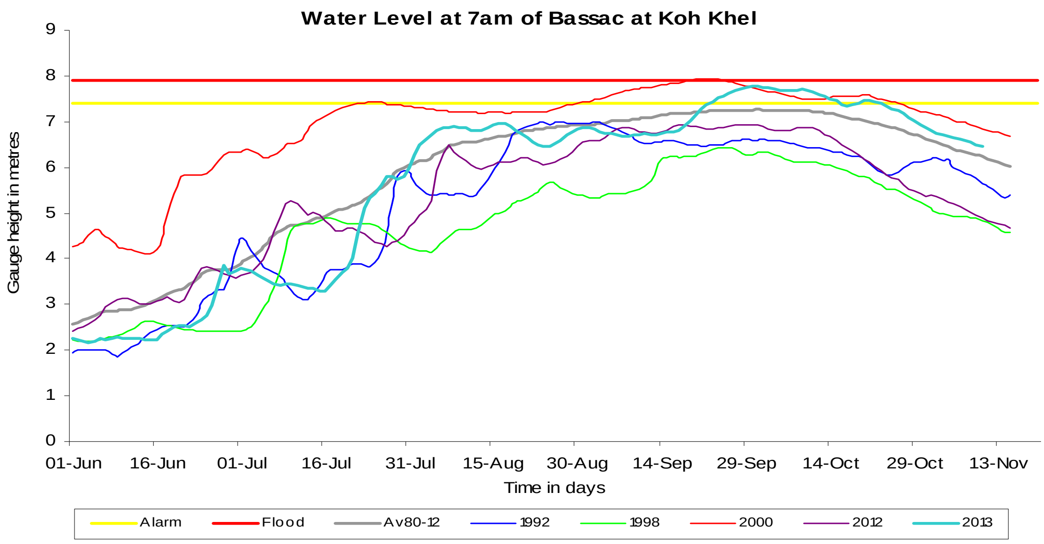
Water Level at 7am of Bassac at Koh Khel
Gauge height in metres
0
1
2
3
4
5
6
7
8
9
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
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Time in days
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Flood
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1992
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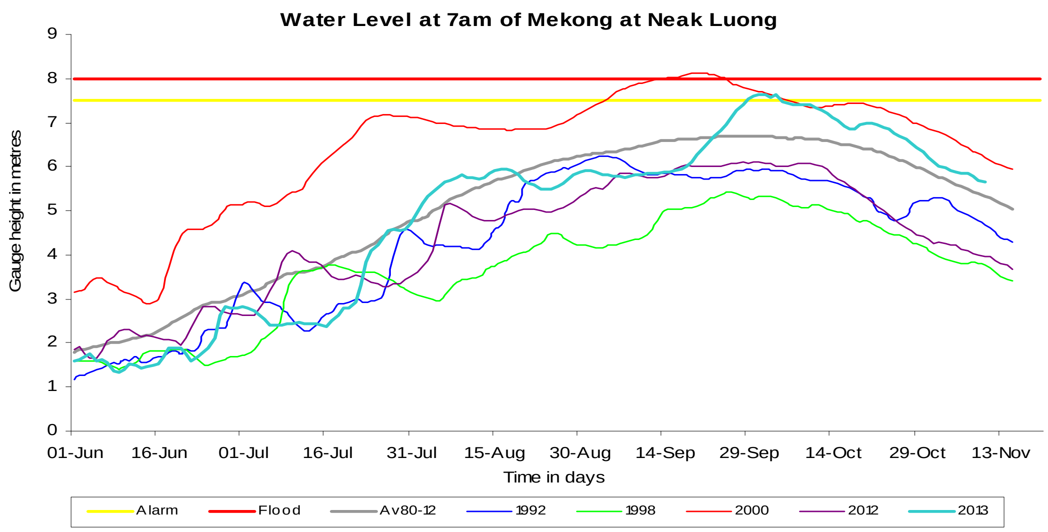
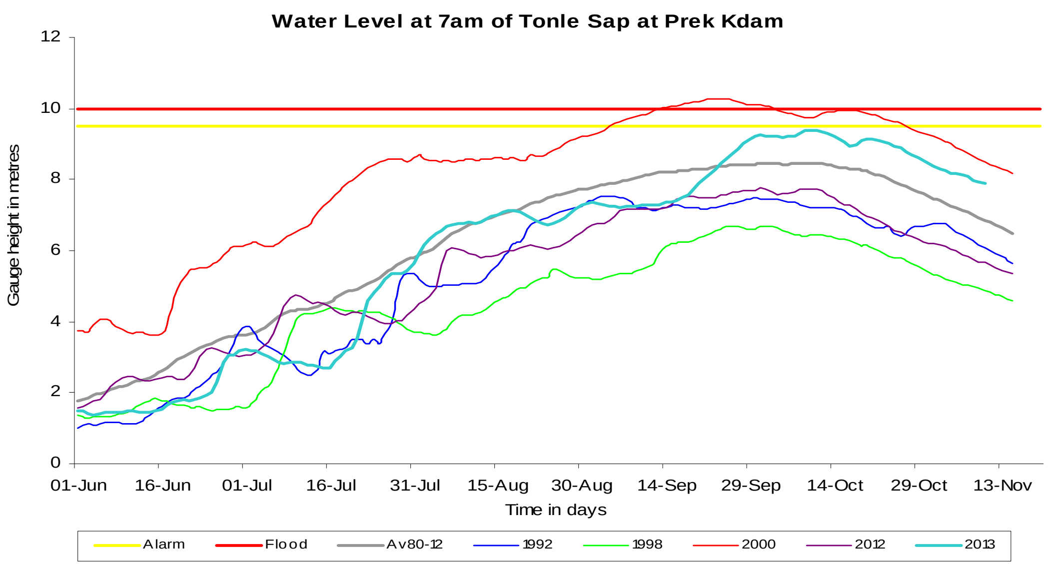
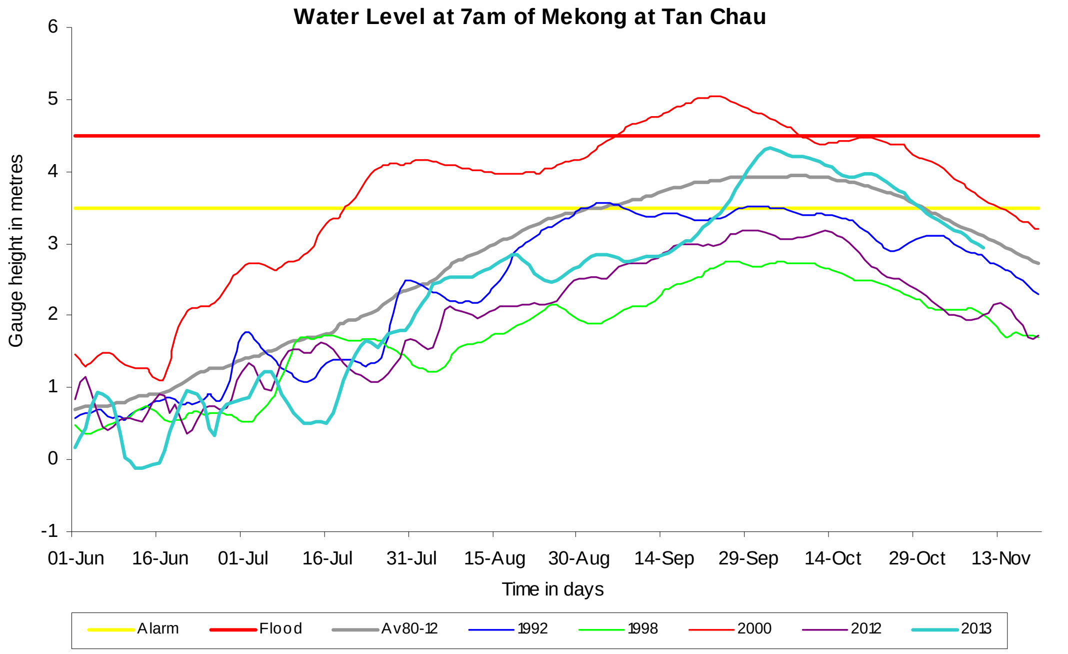
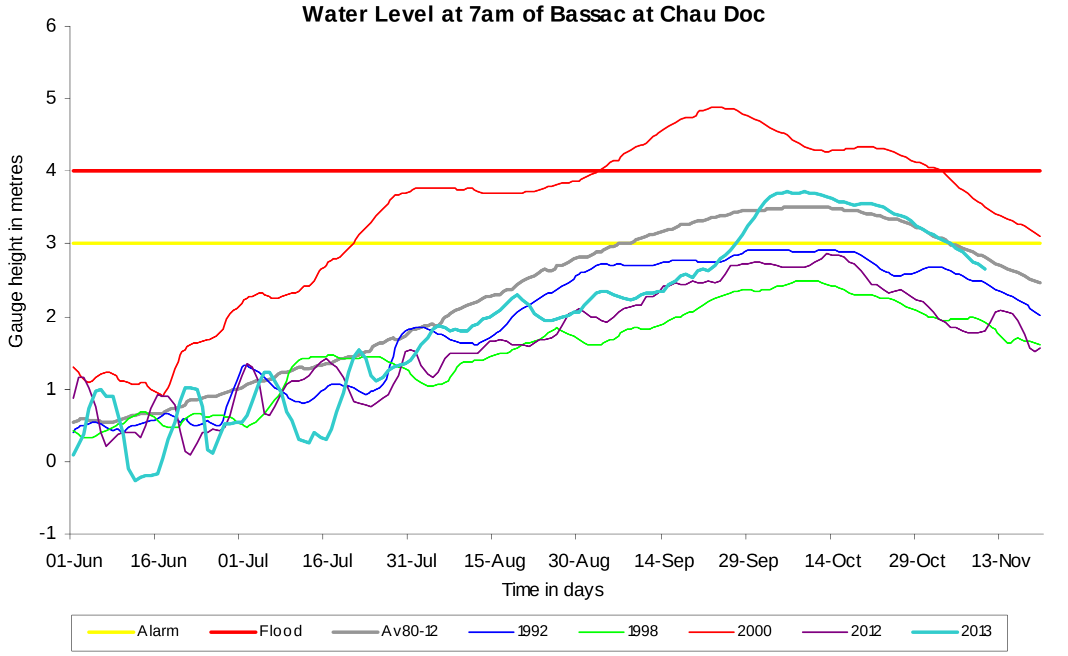

Water Level at 7am of Mekong at Neak Luong
Gauge height in metres
0
1
2
3
4
5
6
7
8
9
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Time in days
Alarm
Flood
Av80-12
1992
1998
2000
2012
2013


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
Av80-12
1992
1998
2000
2012
2013


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
Av80-12
1992
1998
2000
2012
2013


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
Av80-12
1992
1998
2000
2012
2013