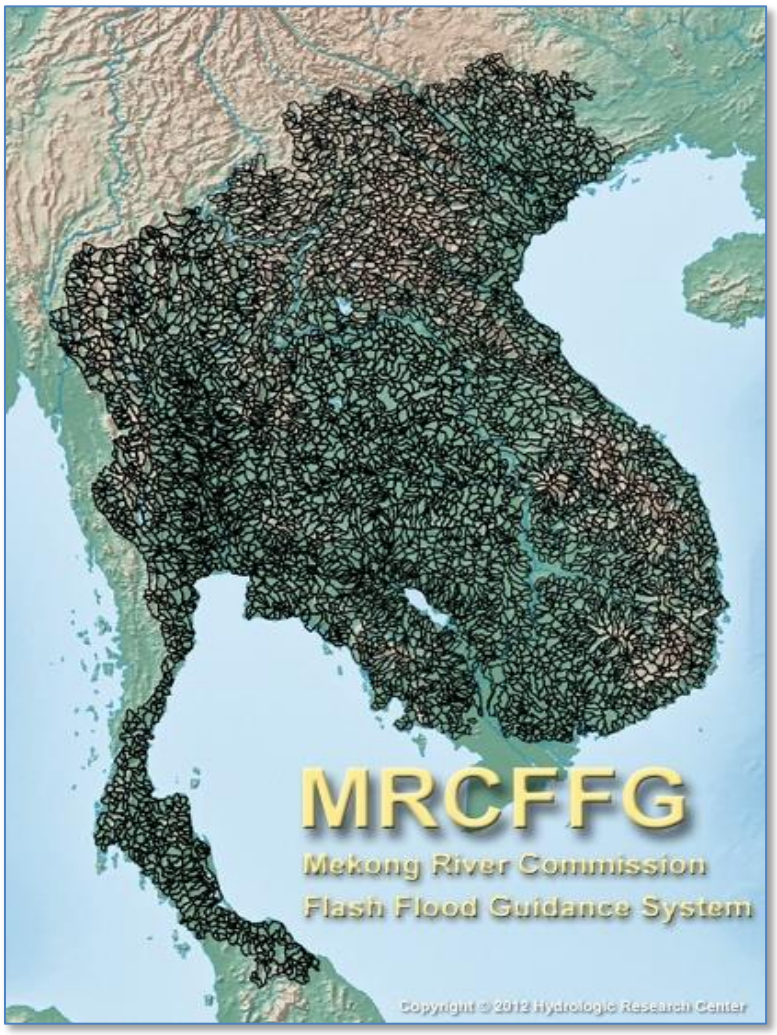
Mekong River Commission
Regional Flood and Drought Management Centre

Seasonal Flash Flood Situation Report 2021

Analysis of the MRC - Flash Flood Guidance System (MRC-FFGS)

Covering period from 1st June – 31st December 2021

(Draft Version)



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List of Abbreviations

ASM	Average Soil Moisture
FFG	Flash Flood Guidance
FFGS	Flash Flood Guidance System
HE-sat	Hydro-estimator Satellite Precipitation
HRC	Hydrological Research Centre in San Diego, California (USA)
ITCZ	Inter Tropical Conversion Zone
JMA	Japan Meteorological Agency
JTWC	Joint Typhoon Warning Center
LLCC	Low Level Circulation Center
LMB	Lower Mekong Basin
LTA	Long-Term Average
MAP	Mean Areal Precipitation
MCs	Member Countries
MRC	Mekong River Commission
MRC-FFGS	Mekong River Commission Flash Flood Guidance System
OFDA	Office of US Foreign Disaster Assistance
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
RFDMC	Regional Flood Management and Mitigation Centre
TMD	Thai Meteorological Department
U.S.NWS	U.S. National Weather Service
USAID	US Agency for International Development
UTC	Coordinated Universal Time
WMO	World Meteorological Organization

1 Introduction

1.1 Main objective of the report

The Regional Flood and Drought Management Centre (RFDMC) is part of the Technical Support Division (TD) of the MRC Secretariat (MRCS), the operational arm of the MRC, an intergovernmental organization established by the 1995 Agreement on Cooperation for the Sustainable Development of the Mekong River Basin, between the governments of Cambodia, Laos, Thailand and Viet Nam, further referred to as member countries (MCs).

This seasonal flash flood situation report on the wet season 2021 presents an analysis of the MRC Flash Flood Guidance System (MRC-FFGS) of the RFDMC.

The purpose of this report is to give an overview of the flash flood situation in the Lower Mekong Basin (LMB) during the wet season 2021 from June until the mid of December (one and a half month after the wet season) and to evaluate the performance of MRC-FFGS for the detection of flash flood risk areas in the LMB during that time. The first evaluation report on the MRC-FFGS was issued in 2011. The report has been produced to evaluate the performance of MRC-FFGS for the wet season 2011 from May (one month before the wet season) until the late of October. The present report is the eleventh evaluation report of the MRC-FFGS. The FFG warnings are issued for the respective national territories of Cambodia, Lao PDR and Viet Nam. The RFDMC provides flash flood risk information for Thailand only in the Thai territory located within the LMB.

1.2 Further References

The products of the MRC-FFGS are updated daily during the wet season and can be accessed from: http://ffw.mrcmekong.org/ffg.php

The Weekly Wet Season Situation Report in the LMB is available at:

http://ffw.mrcmekong.org/reportflood.php

Further information about the hydrological situation in the LMB can be found in the following reports of the RFDMC:

- Annual Mekong Hydrology Report
- Seasonal Mekong River Situation Report
- Seasonal Drought Situation Report in the LMB

1.3 The MRC-FFGS

Like many parts of the world, flash floods are destructive in the countries of the LMB. To respond to regional and national needs and in order to address the problem of flash floods in each MC of the MRC, the MRC and the US Agency for International Development (USAID), the Office of US Foreign Disaster Assistance (OFDA), have with the technical support from the Hydrologic Research Centre

(HRC) and through a program of the U.S. National Weather Service (U.S.NWS) jointly implemented a flash flood mitigation program in Cambodia, Lao PDR, Thailand, and Viet Nam.

The MRC-FFGS is designed as a diagnostic tool for meteorological and hydrologic services to analyse weather-related events that can initiate flash floods (e.g. heavy rainfall or rainfall on saturated soils) and then to make a rapid evaluation on the potential for a flash flood to occur at a location inside the LMB. The system provides values of flash flood guidance and flash flood threat for small stream basins - the basins most prone to flash flooding. Evaluations of the threat of flash flooding may provide estimations from one-hourly to six-hourly time scales (depending on timely reporting of hydrometeorological data).

The system has been developed since 2005 and fully completed in August 2009 including the capacity building for the MRC-FFGS operators at 4 national Line Agencies (LAs), one in each MC. From 2009 to now, the system has been improved and developed further. Since the beginning of 2018, the system has implemented a bias correction of high-resolution satellite rainfall as input to the system (Figure 1-1)

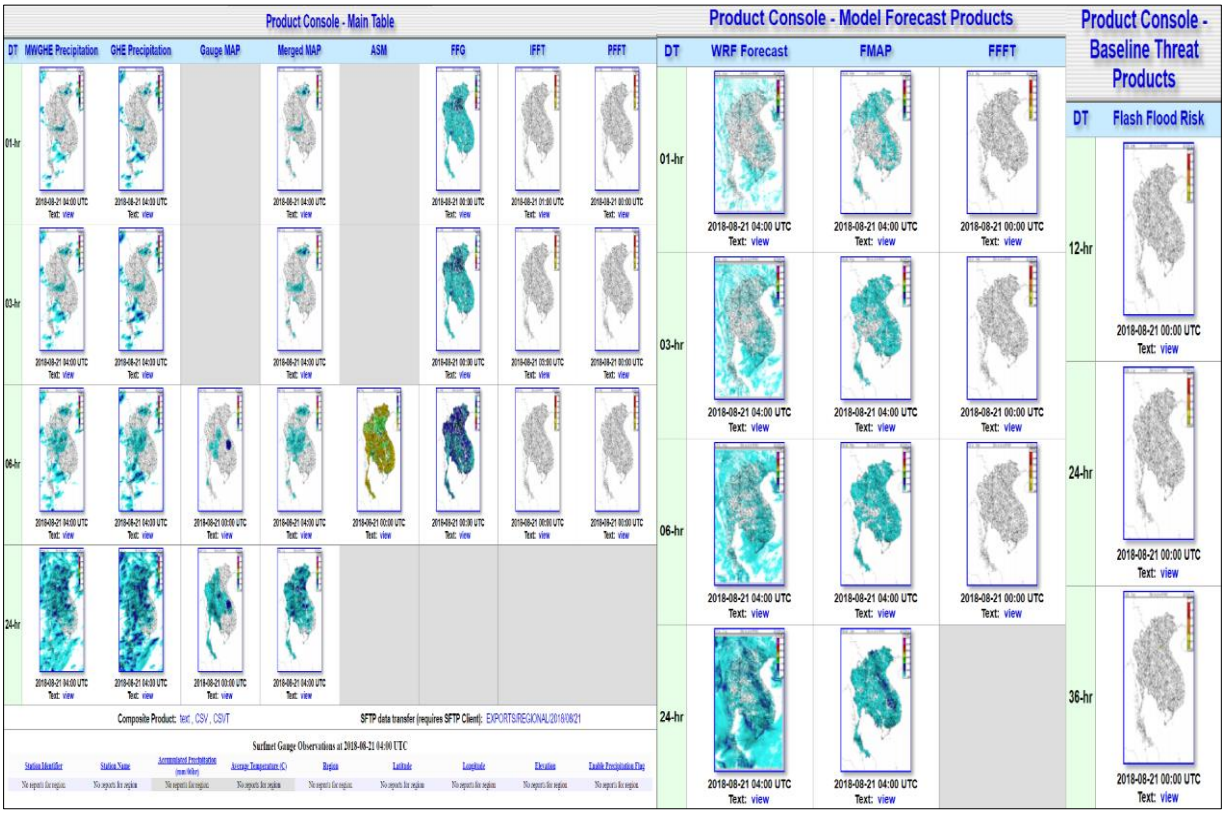

Figure 1-1: MRC-FFGS dissemination server user interface

In August 2019, the HRC completed and provided the Map-Server console interface for the MRC-FFGS to the RFDMC. It is very visually for forecasters to directly analyse the MRC-FFGS's products on the map during the routine work of flash flood operations (Figure 1-2).

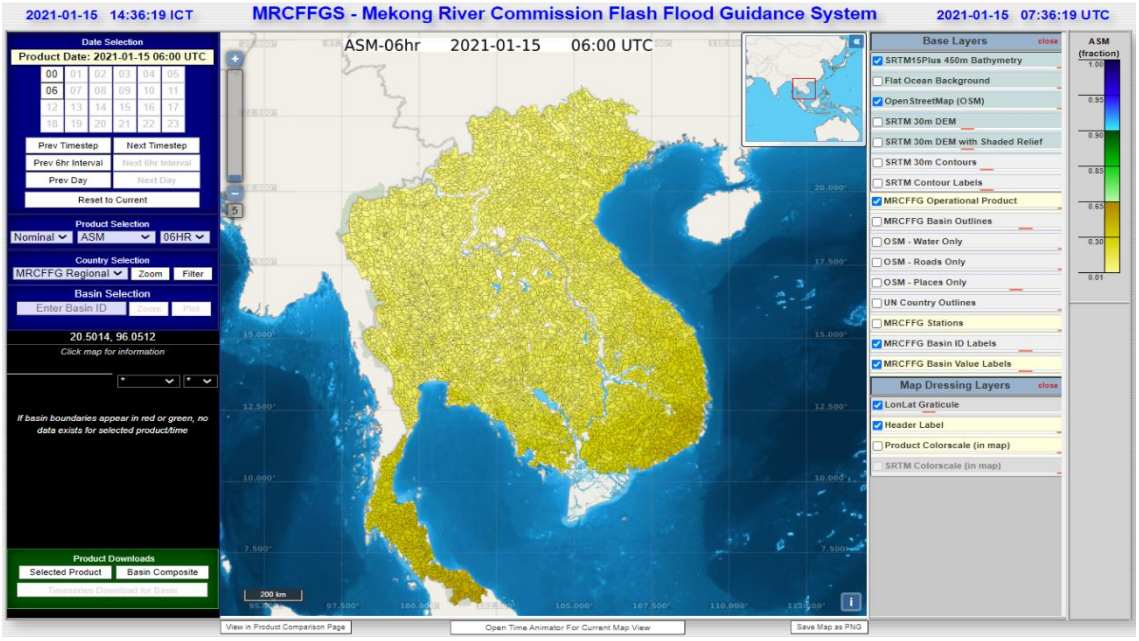

Figure 1-2: MRC-FFGS Map-server interface

Today the system has two console interfaces for flash flood operations with user-friendly interfaces providing a lot of essential products to support the forecasters.

The MRC-FFGS is a soil accounting model that needs satellite rainfall estimates as input data. The output is a warning for the next 1, 3 and 6 hours for sub-basins with a mean area of approximately 150 - 200 km^2 in size, that have a plausible chance of suffering from flash floods. The primary purpose of the MRC-FFGS is to provide near real-time guidance products pertaining to the imminence of potential small-scale flash floods (see Figure 1-3). For further detail description on the MRC-FFGS output products see Annex C2.

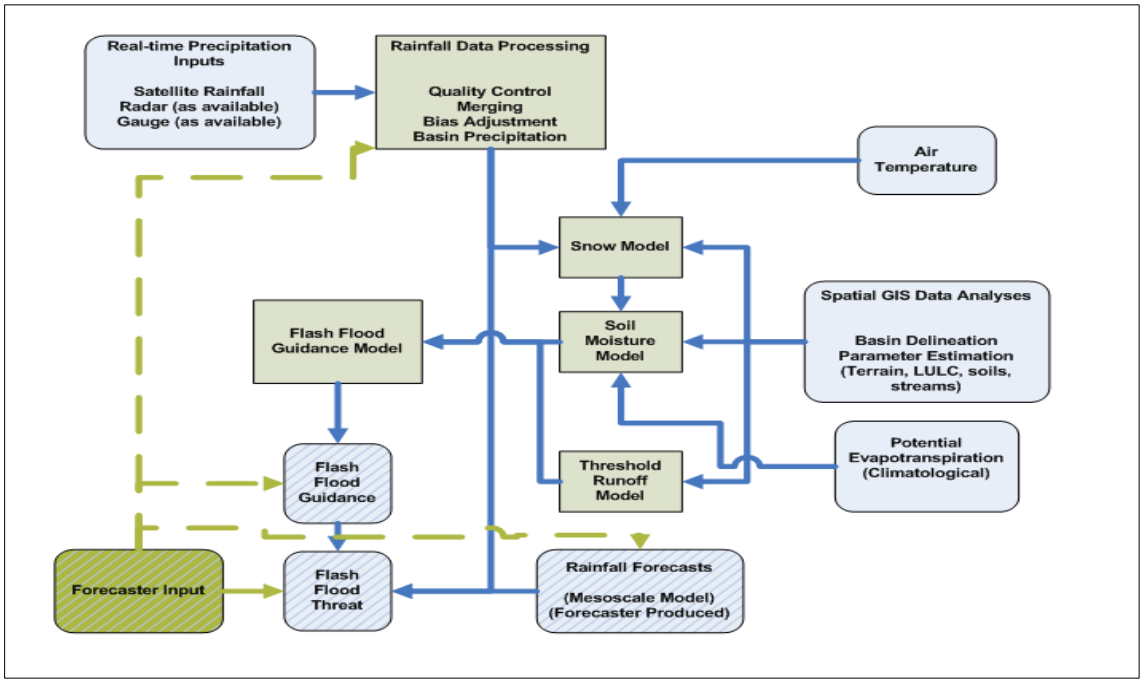

Figure 1-3: Key technical components of the FFGS (source: HRC)

If a warning is released depends on the hydrological characteristics of the watershed. The FFG is an index that indicates how much rainfall is needed to cause minimal flooding in that basin. The FFG value indicates the total volume of rainfall of a given duration (1-6 hours) over a given small catchment that is just enough to cause bank-full flow in the draining stream outlet. Consequently, rainfall volumes of the same duration that are greater than the FFG value indicate a likelihood overbank flows at the draining stream outlet. The FFG warning scale is shown in Figure 1-4.

Scale of Flash Flood risk	FFG-1H (mm/1hr)	FFG-3H (mm/3hr)	FFG-6H (mm/6hr)
Extreme-Risk	0.01<FFG-1H<10	0.01<FFG-3H<10	0.01<FFG-6H<15
High-Risk	10.01<FFG-1H<25	10.01<FFG-3H<25	15.01<FFG-6H<30
Moderate-Risk	25.01<FFG-1H<40	25.01<FFG-3H<40	30.01<FFG-6H<60
Low-Risk	40.01<FFG-1H<60	40.01<FFG-3H<70	60.01<FFG-6H<100

Figure 1-4: FFG warning scale

The computer server was installed and located in the Regional Flood and Drought Centre (RFDMC) of the MRC since mid-May 2018. During the wet season 2020, the forecaster of RFDMC has continued operating routinely the MRC-FFGS daily for the provision of flash flood guidance products. The information on flash flood risk areas that were detected by the MRC-FFGS was uploaded on the MRC flood forecasting webpage (http://ffw.mrcmekong.org/ffg.php, see Figure 1-5) in parallel with the river flood forecast . The warnings that the MRC-FFGS has identified according to the warning scale in Figure 1-4 are daily analysed and can be downloaded from the website in Excel and Google Earth KML format. Additionally, information regarding 'critical' weather conditions and risk of flash floods is disseminated through e-mail to alert the LAs and non-governmental organization.

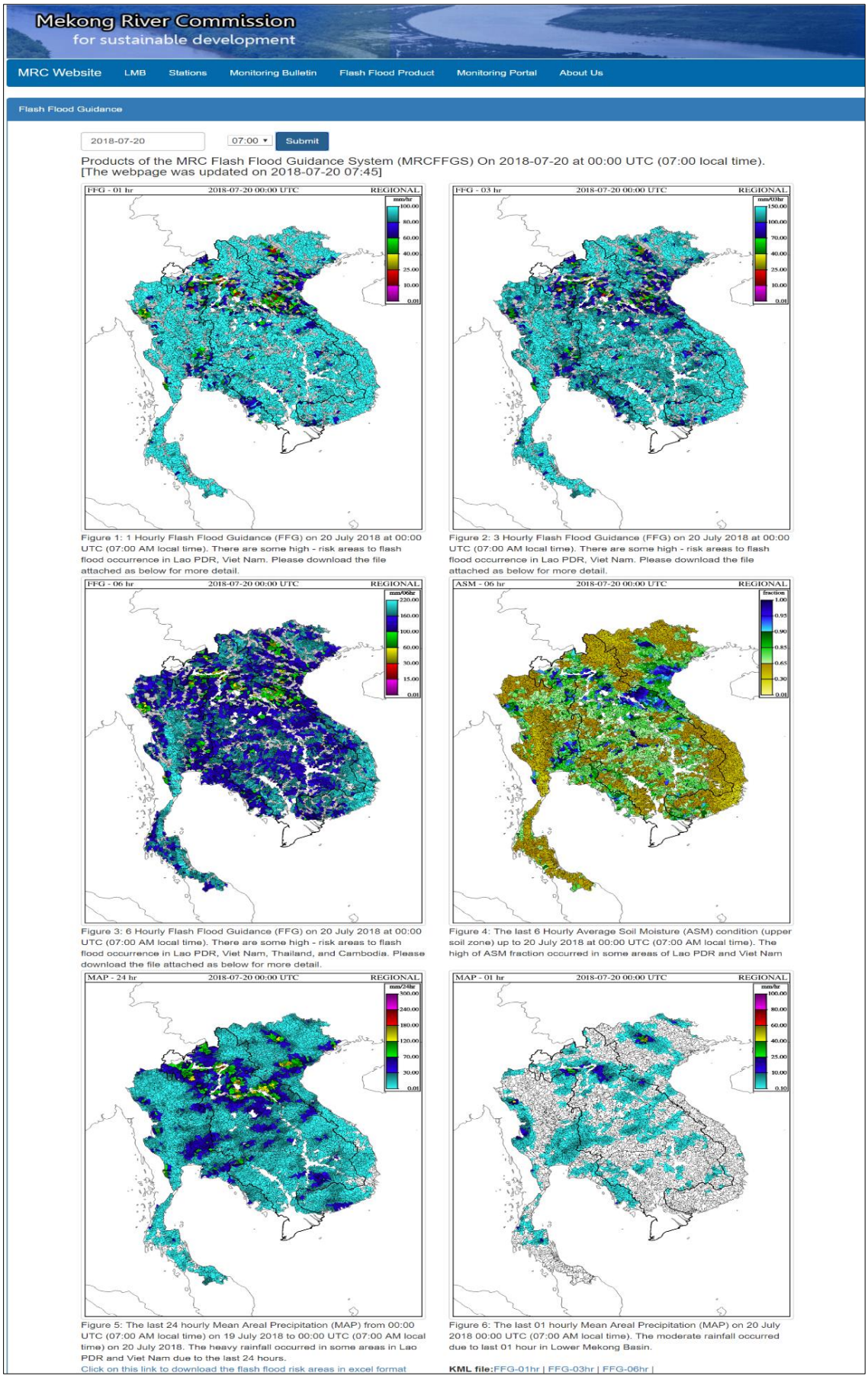

Figure 1: 1 Hourly Flash Flood Guidance (FFG) on 20 July 2018 at 00:00 UTC (07:00 AM local time). There are some high - risk areas to flash flood occurrence in Lao PDR, Viet Nam. Please download the file attached as below for more detail.

Figure 2: 3 Hourly Flash Flood Guidance (FFG) on 20 July 2018 at 00:00 UTC (07:00 AM local time). There are some high - risk areas to flash flood occurrence in Lao PDR, Viet Nam. Please download the file attached as below for more detail.

Figure 3: 6 Hourly Flash Flood Guidance (FFG) on 20 July 2018 at 00:00 UTC (07:00 AM local time). There are some high - risk areas to flash flood occurrence in Lao PDR, Viet Nam, Thailand, and Cambodia. Please download the file attached as below for more detail.

Figure 4: The last 6 Hourly Average Soil Moisture (ASM) condition (upper soil zone) up to 20 July 2018 at 00:00 UTC (07:00 AM local time). The high of ASM fraction occurred in some areas of Lao PDR and Viet Nam

Figure 5: The last 24 hourly Mean Areal Precipitation (MAP) from 00:00 UTC (07:00 AM local time) on 19 July 2018 to 00:00 UTC (07:00 AM local time) on 20 July 2018. The heavy rainfall occurred in some areas in Lao PDR and Viet Nam due to the last 24 hours.
Click on this link to download the flash flood risk areas in excel format

Figure 6: The last 01 hourly Mean Areal Precipitation (MAP) on 20 July 2018 00:00 UTC (07:00 AM local time). The moderate rainfall occurred due to last 01 hour in Lower Mekong Basin.

Figure 1-5: MRC-FFGS on the MRC flood forecasting website

2 Flash Floods in the Lower Mekong Basin (LMB) during the wet season 2021

2.1 Weather phenomena impact to flash floods in the LMB

In general, climate of the Mekong Basin is dominated by the Southwest (SW) Monsoon, which generates wet and dry season of equal length. Monsoon season usually lasts from May until late September or early October. There is usually heavy rain (50 – 100 mm/day) over most of the region. Later in the season, tropical cyclones occur over most areas so that August and September and even October (especially in the Delta) are the wettest months of the year. The Northeast (NE) Monsoon, which sets in toward late October, brings lower temperature. Rainfall during the months of the NE Monsoon is generally confined to Viet Nam since the rest of the LMB lies in the lee of Animate Mountains of the Central Highland.

Table 2-1: Generalized climate season in the LMB

Cool/Cold			Hot/Dry		Wet					Cool/Cold	
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE Monsoon			Transition		SW Monsoon					NE Monsoon	

In total 22 tropical storms occurred, which developed over the Pacific Ocean or over the East Sea (Figure 2-1). This number is lower than 2020 (23 tropical storms). There were 8 tropical storms, namely (1) CHOI-WAN, (2) KOGUMA, (3) CEMPAKA, (4) LUPIT, (5) CONSON, (6) DIAMU, (7) LIONROCK, and (8) KOMPASU, which caused serious flash floods affecting the LMB (Table 2-2). The other cause of flash floods in the LMB is the Inter Tropical Convergence Zone (ITCZ), producing low pressure and tropical depression which lead to flash floods in some areas in the LMB.

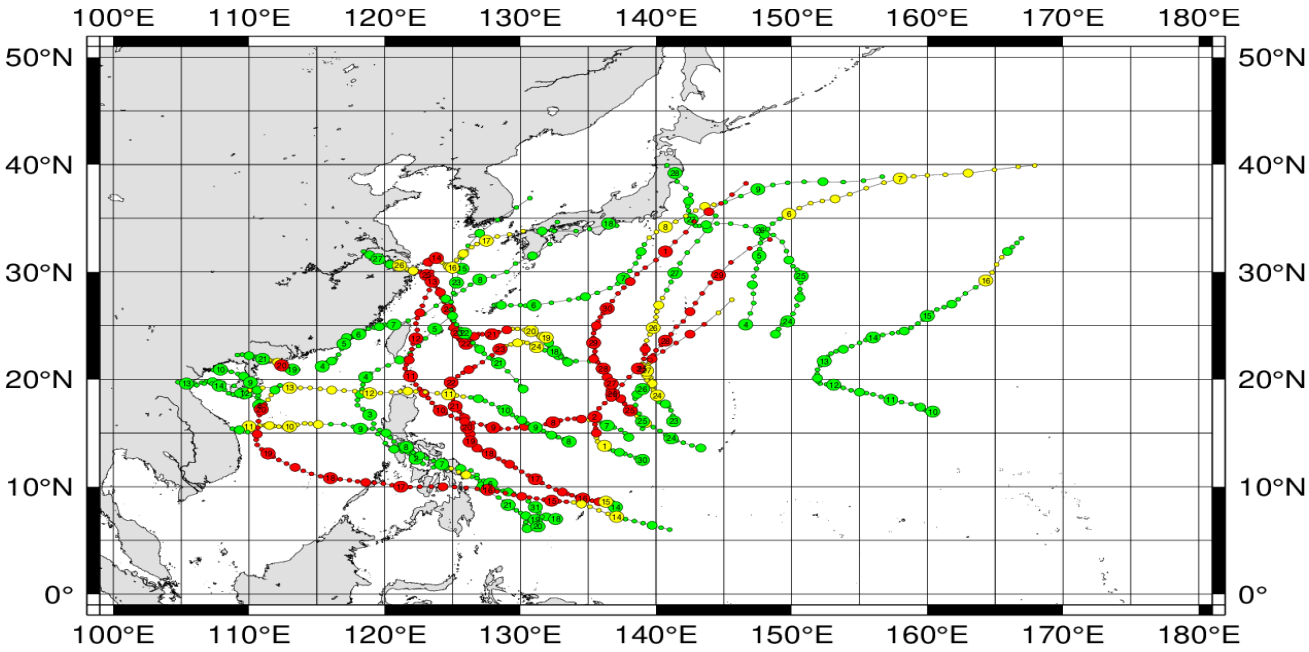

Figure 2-1 Tropical storm track for the Western Pacific in 2021 (Source: Digital typhoon, National Institute of Informatics, Japan)

Table 2-2: Tropical storm developed over the Pacific Ocean and East Sea in 2021 (Source: Digital typhoon, National Institute of Informatics, Japan)

	Number	Name	Basin	Birth (UTC)	Death (UTC)	Duration	Min. Pres.
1	202101	DUJUAN	W. N. Pacific	18/02/2021 00:00	21/02/2021 12:00	3 Days 12 Hours	996
2	202102	SURIGAE	W. N. Pacific	13/04/2021 18:00	25/04/2021 00:00	11 Days 6 Hours	895
3	202103	CHOI-WAN	W. N. Pacific	30/05/2021 18:00	05/06/2021 06:00	5 Days 12 Hours	998
4	202104	KOGUMA	W. N. Pacific	11/06/2021 18:00	13/06/2021 06:00	1 Days 12 Hours	996
5	202105	CHAMPI	W. N. Pacific	23/06/2021 00:00	27/06/2021 18:00	4 Days 18 Hours	980
6	202106	IN-FA	W. N. Pacific	17/07/2021 12:00	27/07/2021 18:00	10 Days 6 Hours	950
7	202107	CEMPAKA	W. N. Pacific	18/07/2021 18:00	22/07/2021 00:00	3 Days 6 Hours	980
8	202108	NEPARTAK	W. N. Pacific	23/07/2021 12:00	28/07/2021 06:00	4 Days 18 Hours	990
9	202109	LUPIT	W. N. Pacific	04/08/2021 00:00	09/08/2021 00:00	5 Days 0 Hours	984
10	202110	MIRINAE	W. N. Pacific	05/08/2021 06:00	10/08/2021 00:00	4 Days 18 Hours	980
11	202111	NIDA	W. N. Pacific	04/08/2021 00:00	08/08/2021 00:00	4 Days 0 Hours	992
12	202112	OMAIS	W. N. Pacific	20/08/2021 12:00	24/08/2021 00:00	3 Days 12 Hours	994
13	202113	CONSON	W. N. Pacific	06/09/2021 00:00	11/09/2021 18:00	5 Days 18 Hours	992
14	202114	CHANTHU	W. N. Pacific	06/09/2021 12:00	18/09/2021 06:00	11 Days 18 Hours	905
15	202115	DIANMU	W. N. Pacific	23/09/2021 06:00	23/09/2021 18:00	0 Days 12 Hours	1000
16	202116	MINDULLE	W. N. Pacific	23/09/2021 12:00	02/10/2021 00:00	8 Days 12 Hours	920
17	202117	LIONROCK	W. N. Pacific	07/10/2021 18:00	10/10/2021 06:00	2 Days 12 Hours	994
18	202118	KOMPASU	W. N. Pacific	08/10/2021 00:00	14/10/2021 12:00	6 Days 12 Hours	975
19	202119	NAMTHEUN	W. N. Pacific	10/10/2021 00:00	17/10/2021 00:00	7 Days 0 Hours	996
20	202120	MALOU	W. N. Pacific	24/10/2021 18:00	29/10/2021 12:00	4 Days 18 Hours	965
21	202121	NYATOH	W. N. Pacific	30/11/2021 00:00	04/12/2021 00:00	4 Days 0 Hours	925
22	202122	RAI	W. N. Pacific	13/12/2021 06:00	20/12/2021 18:00	7 Days 12 Hours	915

2.2 Features of precipitation

- In general, the mean monthly rainfall during the wet season 2021 over LMB was 4.15 % more than the long-term average (LTA) but it was unevenly distributed over time and space.
- In the upstream part of the LMB from Chiang Sean to Paksane, a shortage of -9.85 % of rainfall compared to the LTA was estimated.
- In the middle part of the LMB (from Thakhek to Pakse) the mean monthly amount of rainfall was about +13.26 % higher that its LTA especially in the last two months of September and October. Heavy rains were concentrated in October due to the influence of the SW Monsoon and storm

circulation.

- In the meanwhile, in the lower part of the LMB, the average rainfall was with about +0.74 % slightly higher than the LTA. Heavy rainfall concentrated in late September and October due to the influence of tropical storms.

Table 2-3: Mean monthly rainfall distribution along the Mekong mainstream

Year	Upper part					Middle part					Downstream part				
	Jun	Jul	Aug	Sep	Oct	Jun	Jul	Aug	Sep	Oct	Jun	Jul	Aug	Sep	Oct
2000	417.90	281.15	312.87	286.23	71.87	318.33	434.60	399.63	319.15	86.20	210.67	164.80	259.62	158.62	236.30
2001	234.17	359.38	474.25	268.45	142.00	451.00	380.30	566.35	339.72	98.92	155.39	102.24	254.49	176.93	362.34
2002	290.69	358.28	463.43	332.45	78.43	518.13	599.87	426.60	276.50	71.04	182.09	118.47	184.13	195.01	142.48
2003	363.05	301.83	302.72	359.05	24.12	226.93	222.35	413.80	405.32	20.30	107.78	255.25	174.47	177.22	187.35
2004	240.20	321.98	331.13	282.17	56.40	266.58	408.97	541.58	294.98	2.45	181.60	125.32	188.16	224.13	198.13
2005	424.98	313.10	368.18	339.28	40.50	303.47	520.68	491.53	342.77	26.00	127.59	259.91	158.27	272.33	270.00
2006	163.92	421.62	381.55	175.13	181.68	174.98	625.56	472.60	111.32	208.50	108.37	181.92	218.35	220.63	255.27
2007	291.38	218.38	337.72	316.57	156.42	264.86	279.74	371.61	183.20	285.40	124.04	147.57	197.05	180.68	210.82
2008	408.28	386.77	284.63	240.37	140.13	393.85	333.05	406.18	339.23	107.33	115.03	80.31	205.79	302.38	234.34
2009	176.93	359.68	295.72	223.88	72.23	213.58	394.58	310.75	257.60	65.35	81.82	189.59	138.83	249.13	204.29
2010	255.47	318.37	561.97	330.88	98.35	188.73	246.90	504.20	209.75	191.65	166.51	149.93	208.71	177.19	337.54
2011	285.32	422.92	438.93	402.33	78.90	352.95	504.92	568.68	424.55	123.73	167.60	184.31	254.62	253.08	119.80
2012	216.23	280.38	253.95	164.10	68.72	215.45	352.98	295.50	245.72	28.18	86.17	253.38	128.33	274.51	138.74
2013	214.37	396.38	388.67	315.02	89.18	232.78	489.83	242.43	445.58	105.55	192.09	226.90	196.93	261.82	206.82
2014	299.05	423.47	352.75	337.93	33.67	506.53	626.28	394.47	216.87	40.10	175.12	245.08	130.63	204.88	212.53
2015	129.87	452.77	371.52	258.77	100.98	89.90	408.52	322.22	252.70	79.38	118.80	120.67	179.40	245.17	195.87
2016	267.67	311.28	364.95	296.15	104.55	310.68	320.70	366.22	376.60	95.93	229.74	191.82	119.60	347.57	397.46
2017	293.78	446.73	368.25	233.15	168.37	276.32	727.18	282.22	315.20	105.73	164.82	256.37	206.82	201.02	256.77
2018	274.22	382.87	360.03	189.20	96.68	305.07	765.85	427.70	206.00	23.02	170.73	142.26	188.33	171.28	217.79
2019	237.67	147.70	517.88	96.37	29.05	194.10	343.68	663.63	428.13	22.63	124.83	181.34	205.47	235.68	151.37
2020	202.80	211.70	604.98	269.48	80.08	83.90	175.22	342.07	153.35	226.77	121.43	151.71	217.08	258.10	344.36
2021	309.42	291.45	246.98	244.97	86.77	290.02	403.88	223.73	371.37	190.67	94.97	186.58	180.01	273.29	282.88
Long Term Average (LTA) (mm)	**272.61**	**336.74**	**381.05**	**271.00**	**90.87**	**280.83**	**434.80**	**410.62**	**296.16**	**100.22**	**145.78**	**177.99**	**190.69**	**230.03**	**234.69**
2021															
%	113.50	86.55	64.82	90.39	95.49	103.27	92.89	54.49	125.39	190.25	65.14	104.83	94.40	118.81	120.53
Month (%) comparison LTA	**+13.5 %**	**-13.45 %**	**-35.18 %**	**-9.61 %**	**-4.51 %**	**+3.27 %**	**-7.11 %**	**-45.51 %**	**+25.39 %**	**+90.25 %**	**-34.86 %**	**+4.83 %**	**-5.6 %**	**+18.81 %**	**+20.53 %**
(%) in regions comparison LTA	**-9.85 %**					**+13.26 %**					**+0.74 %**				
(%) over LMB comparison LTA	**+ 4.15%**														

The scattered moderate rainfall that occurred in the LMB from May to November 2021 is shown in **Figure 2-2 compared to 2019, 2020 and its LTA**.

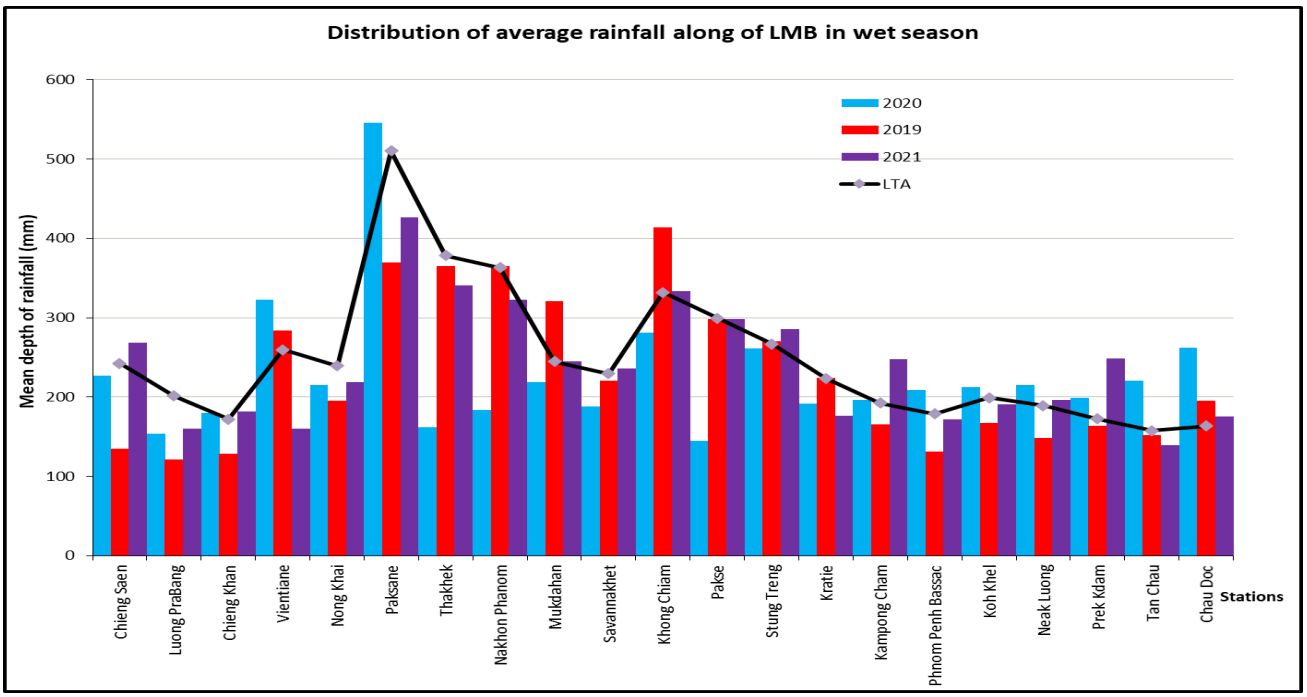

Figure 2-2: Distribution of total rainfall along the MRC Mekong mainstream stations

2.3 Flash flood events on 13th June 2021 caused by the circulation of storm KOGUMA

2.3.1 Weather condition from 10th to 17th June 2021

SW Monsoon which prevailed over the Gulf of Thailand was strengthened during late period. In addition, the low-pressure cell covered the upper Lao PDR and upper Viet Nam. Moreover, the monsoon trough lay across the upper northern and the upper portion of the northeastern part toward the lower pressure cell over the mentioned areas during the second half of the period. These conditions caused heavy rainfall over the upper northern and northeastern parts. **Figure 2-4** shows the weather maps.

Tropical storm KOGUMA: On June 10, the Joint Typhoon Warning Center (JTWC) started to monitor an area of low-pressure in the East Sea, classifying the system as a monsoon depression. Tracking west-north-westward, the storm was located in a favourable environment for further development, with warm sea surface temperatures and low wind shear, being offset by lack of divergence aloft. At 06:00 Coordinated Universal Time (UTC) on June 11, the Japan Meteorological Agency (JMA) upgraded the system into a tropical depression. Six hours later, the JTWC issued a Tropical Cyclone Formation Alert (TCFA) for the system. On June 12 at 03:00 UTC, the JTWC upgraded the system into a tropical depression, assigning it the designation 05W. Three hours later at 06:00 UTC, the JMA upgraded the system to a tropical storm, assigning it the name KOGUMA. Another three hours later, the JTWC also upgraded the system to a tropical storm. On the early next day (13 June), the storm made landfall in Thai Binh province, Viet Nam. The depression was predicted to dissipate over northern Viet Nam June 14 after tracking north-westward over the next 24 hours. KOGUMA's track is shown in **Figure 2-3**.

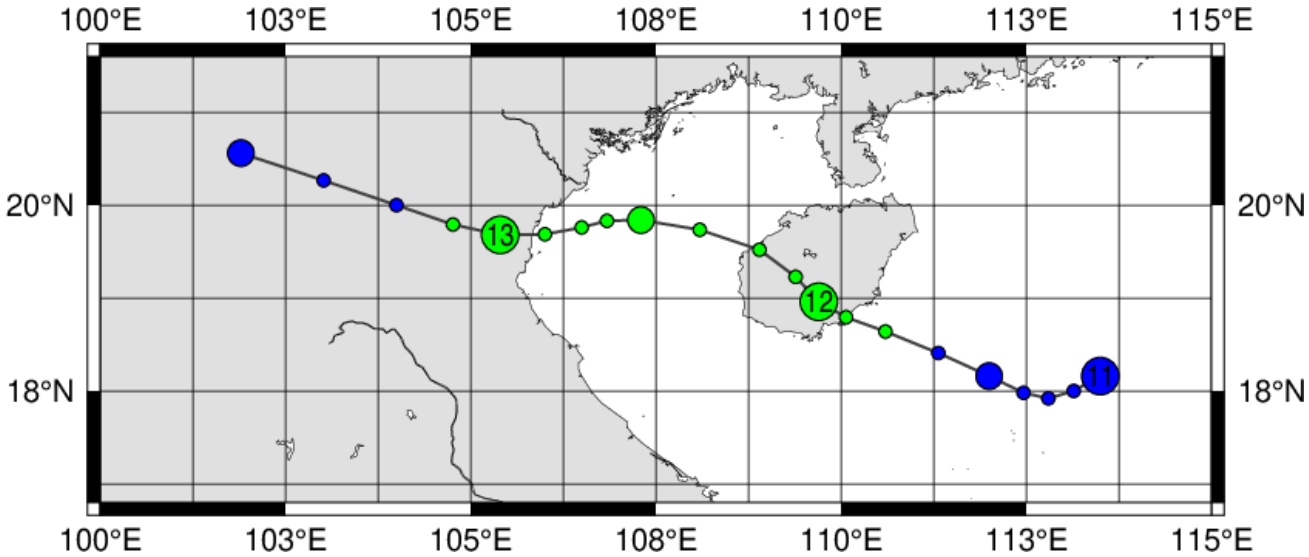

Figure 2-3: The track of KOGUMA (Source: JMA)

These conditions caused increasing amount and distribution of rainfall in some areas in the LMB in including upper Thailand and North of Viet Nam and Lao PDR.

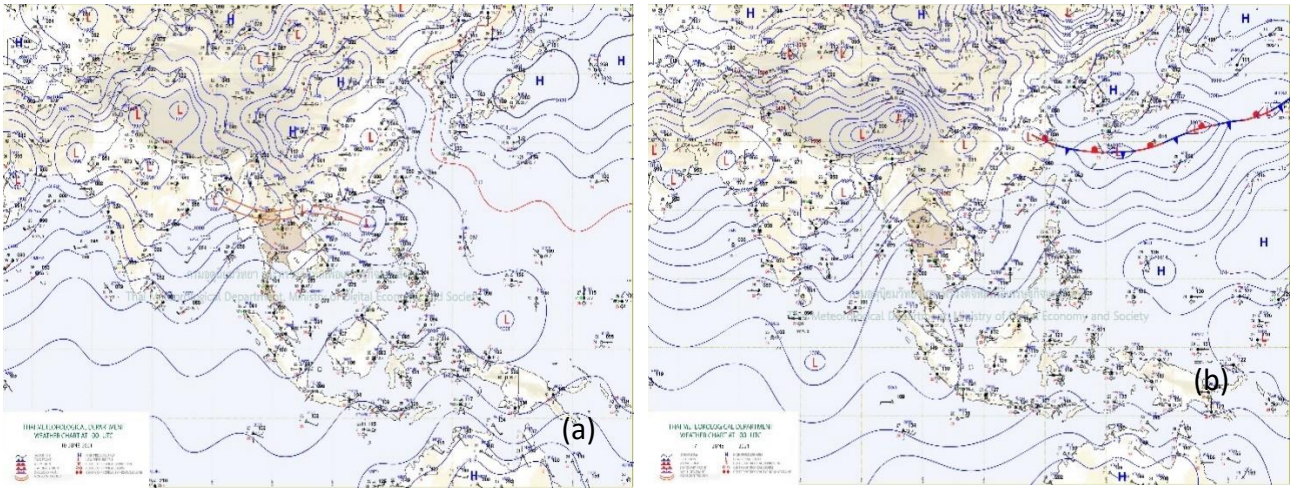

Figure 2-4: Weather map for (a) 10th June 2021 and (b) 17th June 2021 (Source: Thai Meteorological Department (TMD))

2.3.2 Heavy rainfall from 10th to 17th June 2021

Due to the influence of the meteorological factors mentioned above, heavy rain has concentrated mainly in the northeast parts of Lao PDR, north parts of Thailand, and north central parts of Viet Nam from 11-14 June 2021. **Table 2-4** shows the daily rainfall observed at some locations in the LMB during June 10 -17. The total rainfall measured during this period at some stations is very large such as 531.9 mm at Vang Vieng and291.6 mm at Highway Bridge in Lao PDR , 257.9 mm at Chieng Sean, Thailand and 294 mm at Huong Khe, 293 mm at Ha Tinh and 219 mm at Ky Anh in the north central of Viet Nam. The rainfall distribution over the LMB is depicted in **Figure 2-5**.

Table 2-4: Daily rainfall observed at some stations in the LMB (10 -17 June 2021)

Unit: mm

Time	Vang Vieng	Phiengluang	Kuanpho	Highway Bridge	Chiang Saen	Mukdahan	Huong Khe	Ha Tinh	Ky Anh
6/10/2021	61.3	16.2	14.6	71.9	61.4	26.5	0	0	0
6/11/2021	81.4	18.4	0	4.5	55.3	22.2	16.1	0	0
6/12/2021	27.6	7.7	72.1	127.8	9.2	57	86.9	27	8
6/13/2021	25.7	38	83.7	69.1	0.0.4	31.8	191	265	211
6/14/2021	281	58.2	1.1	0	36.6	3.1	0	1	0
6/15/2021	32.2	1.2	0	0	92	1.4	0	0	0
6/16/2021	11	0.06	0	18.3	0	0	0	0	0
6/17/2021	11.7	6.7	0	0	3	4.5	0	0	0
Total	**531.9**	**146.46**	**171.5**	**291.6**	**257.5**	**146.5**	**294**	**293**	**219**

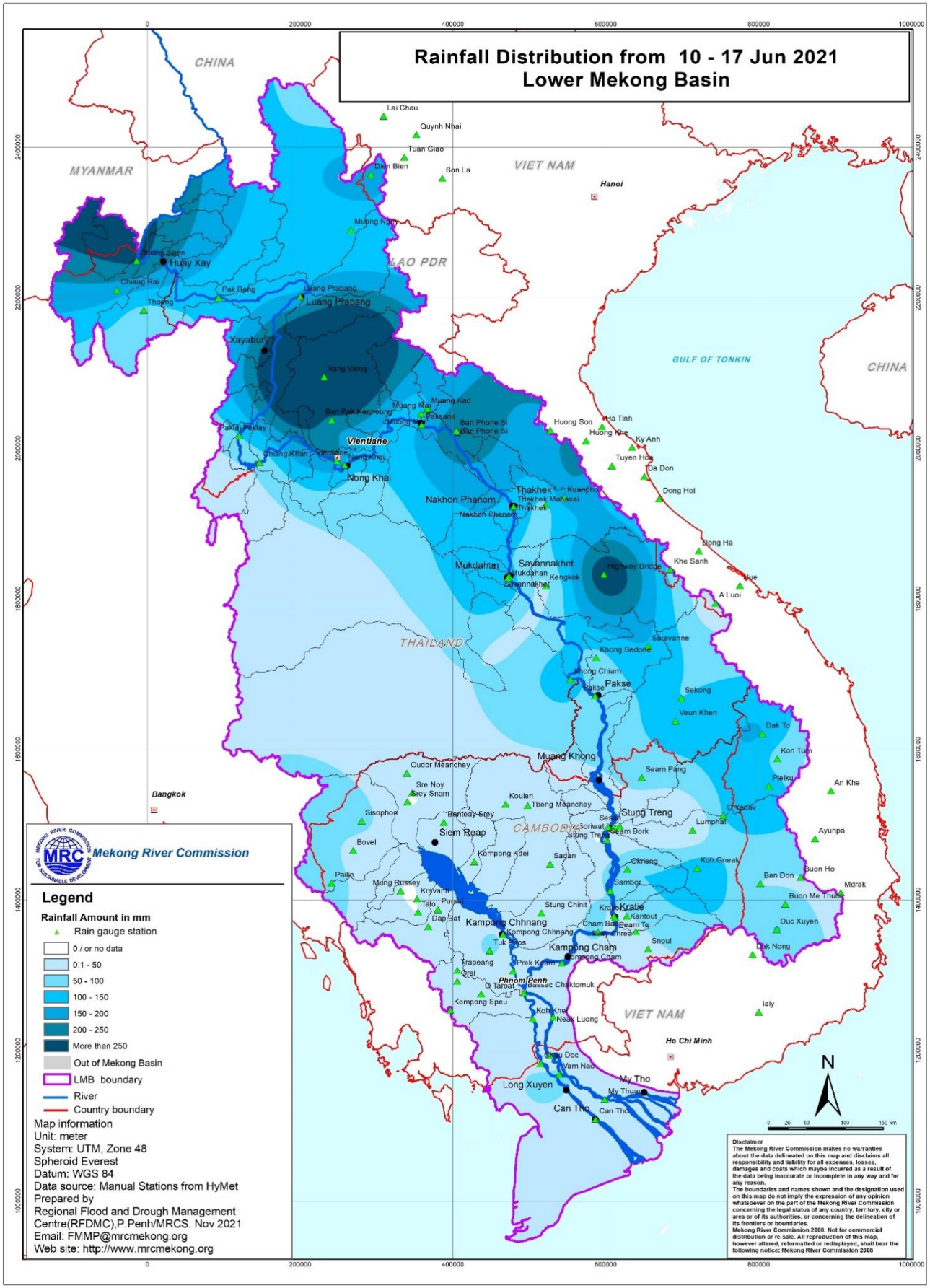

Figure 2-5: Rainfall distribution in the LMB from 10 -17 June 2021

2.3.3 Flash flood in Thailand, Lao PDR and Viet Nam on 13th June 2021.

Based on the MRC-FFGS' products, the satellite rainfall Mean Areal Precipitation (MAP24h) and the Average Soil Moisture (ASM), heavy rain occurred in some central parts of Lao PDR, north-central parts of Viet Nam, and north-eastern of Thailand (**Figure 2-6**). The comparison between MAP24h and the observed rainfall at some stations in the LMB during the period from 29th July to 05th August 2020 is shown in **Figure 2-7**.

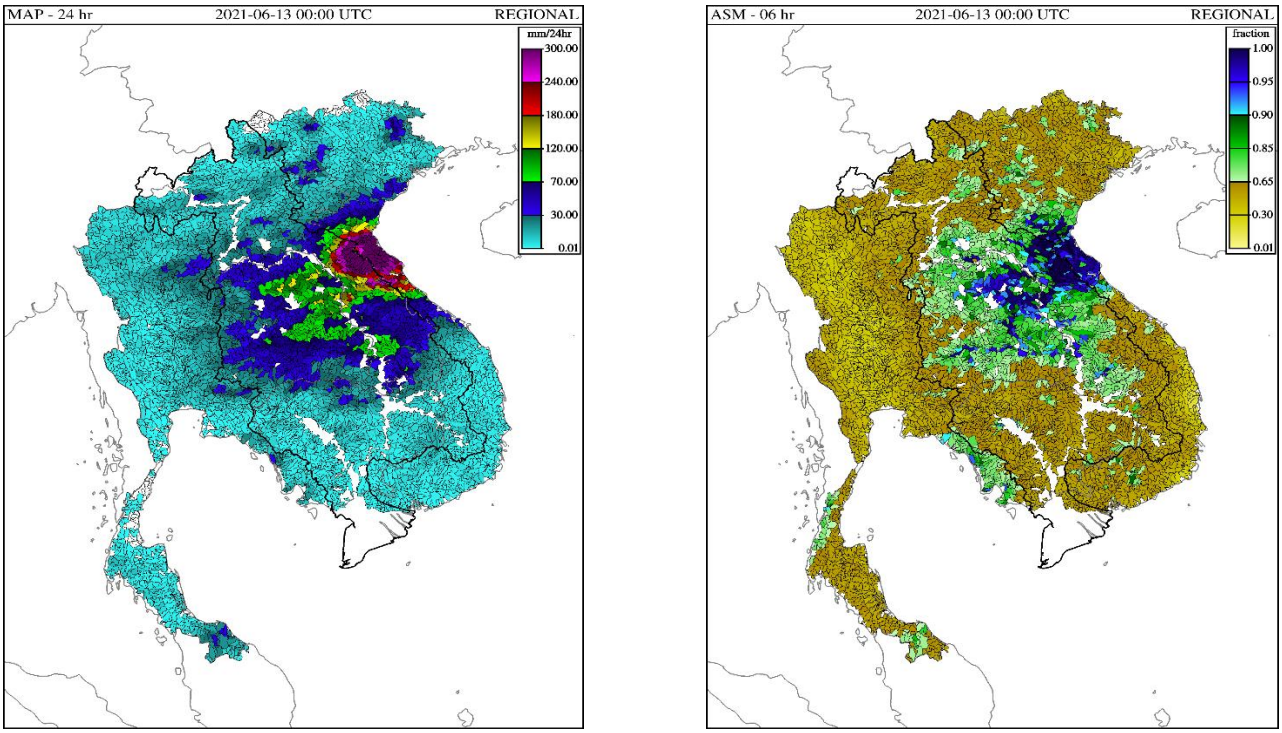

Figure 2-6: MAP24h and ASM on 13th June 2021 at 00:00 UTC (07: 00 local time)

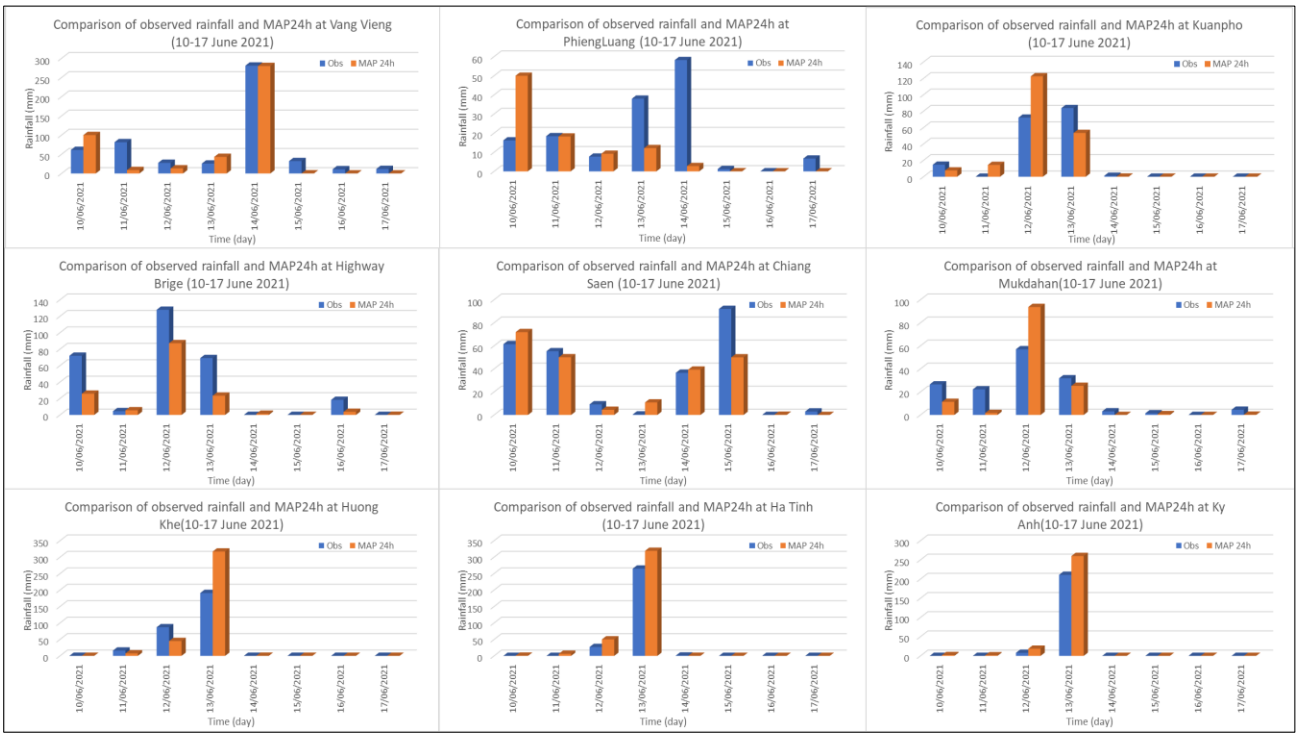

Figure 2-7: Comparison of observed rainfall and MAP at some stations in the LMB (June 10 -17)

Based on the analysis of the FFG from the MRC-FFGS (**Figure 2-8**) and on actual measurements available in RFDMC, the RFDMC made the decision to submit the warning of flash flood guidance for 1, 3, and 6 hours as shown in **Table 2-4**.

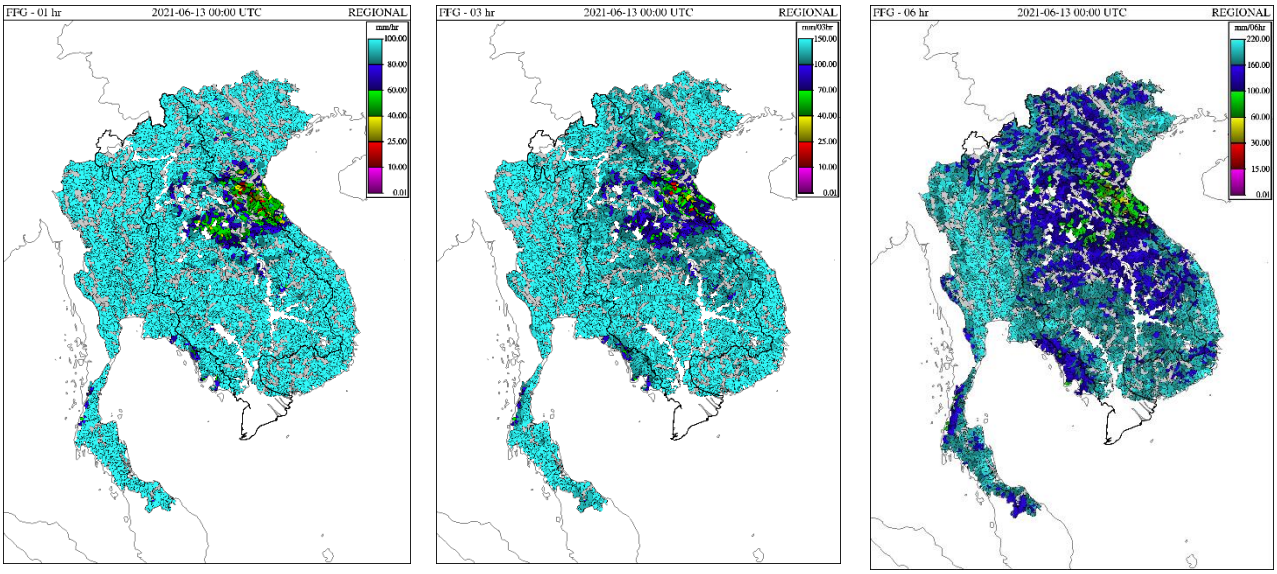

Figure 2-8: FFG 01, 03 and 06 on 13th June 2020 at 00:00 UTC (07: 00 local time)

Table 2-4: FFG detected by MRC-FFGS in (a) Lao PDR; (b) Thailand; and (c) Viet Nam; on 13th June 2020 at 00 UTC (07: 00 AM Local time)

(a)

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Lao PDR

Date of FFG products 13/06/2021 00:00 UTC time

01-Hour Flash Flood Risk and Location					03-Hour Flash Flood Risk and Location					06-Hour Flash Flood Risk and Location				
Provinces	Districts	Villages	Region	Level Risk	Provinces	Districts	Villages	Region	Level Risk	Provinces	Districts	Villages	Region	Level Risk
Xiengkhuang	Morkmay	KHANGVIENG	Northeast	Low-Risk	Xiengkhuang	Morkmay	KHANGVIENG	Northeast	Low-Risk	Xiengkhuang	Morkmay	KHANGVIENG	Northeast	Low-Risk
Bolikhamxay	Viengthon	PAHOK	Central Laos	Low-Risk	Bolikhamxay	Viengthon	PAHOK	Central Laos	Low-Risk	Xiengkhuang	Morkmay	NAMBUAK	Northeast	Low-Risk
Bolikhamxay	Viengthon	PHAPHIENG	Central Laos	Low-Risk	Bolikhamxay	Viengthon	PHAPHIENG	Central Laos	Low-Risk	Bolikhamxay	Viengthon	PAHOK	Central Laos	Low-Risk
Bolikhamxay	Viengthon	VANGPENE	Central Laos	Low-Risk	Bolikhamxay	Viengthon	VANGPENE	Central Laos	Low-Risk	Bolikhamxay	Viengthon	PHAPHIENG	Central Laos	Low-Risk
Bolikhamxay	Viengthon	HINDAM	Central Laos	Low-Risk	Bolikhamxay	Viengthon	KOKKIENG	Central Laos	Moderate-Risk	Bolikhamxay	Viengthon	VANGPENE	Central Laos	Low-Risk
Bolikhamxay	Viengthon	KOKKIENG	Central Laos	High-Risk	Bolikhamxay	Khamkheut	PHAPOUN	Central Laos	Low-Risk	Bolikhamxay	Viengthon	HINDAM	Central Laos	Low-Risk
Bolikhamxay	Khamkheut	PHAKHORT	Central Laos	Low-Risk	Bolikhamxay	Khamkheut	PHONESI	Central Laos	Low-Risk	Bolikhamxay	Viengthon	KOKKIENG	Central Laos	Moderate-Risk
Bolikhamxay	Khamkheut	PHAPOUN	Central Laos	Low-Risk	Bolikhamxay	Viengthon	YORTKAEB	Central Laos	Low-Risk	Bolikhamxay	Khamkheut	PHAKHORT	Central Laos	Low-Risk
Bolikhamxay	Khamkheut	PHONESI	Central Laos	Low-Risk	Bolikhamxay	Khamkheut	NAMSANGIN	Central Laos	High-Risk	Bolikhamxay	Khamkheut	PHAPOUN	Central Laos	Low-Risk
Bolikhamxay	Viengthon	YORTKAEB	Central Laos	Moderate-Risk	Khammuane	Nakai	THAM ONH	Center of Laos	Low-Risk	Bolikhamxay	Khamkheut	PHONESI	Central Laos	Low-Risk
Bolikhamxay	Khamkheut	NAMSANGIN	Central Laos	High-Risk	Bolikhamxay	Khamkheut	PAUNGLAN	Central Laos	Low-Risk	Bolikhamxay	Viengthon	YORTKAEB	Central Laos	Low-Risk
Khammuane	Nakai	MAI	Center of Laos	Low-Risk	Bolikhamxay	Khamkheut	NAPHOUANG	Central Laos	Moderate-Risk	Bolikhamxay	Khamkheut	NAMSANGIN	Central Laos	Moderate-Risk
Khammuane	Nakai	PUU	Center of Laos	Low-Risk	Bolikhamxay	Khamkheut	PAKHA	Central Laos	Low-Risk	Khammuane	Nakai	MAI	Center of Laos	Low-Risk
Khammuane	Nakai	THAM ONH	Center of Laos	Low-Risk	Khammuane	Hinboon	PHON XAI	Center of Laos	Low-Risk	Khammuane	Nakai	PUU	Center of Laos	Low-Risk
Bolikhamxay	Khamkheut	PAUNGLAN	Central Laos	Low-Risk	Khammuane	Hinboon	PHON MENH	Center of Laos	Low-Risk	Khammuane	Nakai	THAM ONH	Center of Laos	Low-Risk
Bolikhamxay	Khamkheut	NAPHOUANG	Central Laos	High-Risk	Khammuane	Hinboon	VANG TA KHONG	Center of Laos	Moderate-Risk	Bolikhamxay	Khamkheut	PAUNGLAN	Central Laos	Low-Risk
Bolikhamxay	Khamkheut	PHONESI	Central Laos	Low-Risk	Khammuane	Hinboon	PHON PHENG	Center of Laos	Low-Risk	Bolikhamxay	Khamkheut	NAPHOUANG	Central Laos	Moderate-Risk
Bolikhamxay	Khamkheut	PAKHA	Central Laos	Low-Risk	Khammuane	Hinboon	MOUANG NAM SANG	Center of Laos	Moderate-Risk	Bolikhamxay	Khamkheut	PAKHA	Central Laos	Low-Risk
Bolikhamxay	Pakkading	NABOY	Central Laos	Low-Risk	Khammuane	Hinboon	KA TAIB	Center of Laos	Low-Risk	Vientiane	Thoulakho	NAM ANG	Northwest	Low-Risk
Khammuane	Hinboon	PHON XAI	Center of Laos	Low-Risk	Khammuane	Nakai	HOUA PHOU ARK	Center of Laos	Low-Risk	Vientiane	Vangvieng	KEOKUANG	Northwest	Low-Risk
Khammuane	Hinboon	PHON MENH	Center of Laos	Low-Risk	Khammuane	Nhommalat	SANG	Center of Laos	Low-Risk	Vientiane	Vangvieng	NAMPAT NEUA	Northwest	Low-Risk
Khammuane	Hinboon	THONG KHA	Center of Laos	Low-Risk	Khammuane	Mahaxay	VANG POUN	Center of Laos	Low-Risk	Vientiane	Feuang	MOUANGFOUANG	Northwest	Low-Risk
Khammuane	Hinboon	VANG TA KHONG	Center of Laos	Moderate-Risk	Savannakhet	Xaybuly	NONGSAPHANG	Southern	Low-Risk	Bolikhamxay	Pakkading	NABOY	Central Laos	Low-Risk

(b)

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Thailand

Date of FFG product 13/06/2021 00:00 UTC time

01-Hour Flash Flood Risk and Location				03-Hour Flash Flood Risk and Location				06-Hour Flash Flood Risk and Location			
Provinces	Districts	Region	Level Risk	Provinces	Districts	Region	Level Risk	Provinces	Districts	Region	Level Risk
Nakhon Phanom	Nakae	Northeastern	Low-Risk	Udon Thani	Nong Han	Northeastern	Low-Risk	Nakhon Phanom	Nakae	Northeastern	Low-Risk
Nakhon Phanom	Nakae	Northeastern	Low-Risk	Sakon Nakhon	Song Dao	Northeastern	Low-Risk	Nakhon Phanom	Nakae	Northeastern	Low-Risk
Udon Thani	Prajak Silapakom	Northeastern	Low-Risk	Sakon Nakhon	Muang Sakon Nakhon	Northeastern	Low-Risk	Udon Thani	Na Yung	Northeastern	Low-Risk
Udon Thani	Nong Han	Northeastern	Moderate-Risk	Mukdahan	Kamchai	Northeastern	Low-Risk	Udon Thani	Prajak Silapakom	Northeastern	Low-Risk
Sakon Nakhon	Sawang Daen Din	Northeastern	Low-Risk	Mukdahan	Kamchai	Northeastern	Low-Risk	Udon Thani	Nong Han	Northeastern	Low-Risk
Udon Thani	Wang Sam Mo	Northeastern	Low-Risk	Mukdahan	Dong Luang	Northeastern	Low-Risk	Udon Thani	Wang Sam Mo	Northeastern	Low-Risk
Sakon Nakhon	Song Dao	Northeastern	Low-Risk	Kalasin	Sam Chai	Northeastern	Low-Risk	Sakon Nakhon	Song Dao	Northeastern	Low-Risk
Sakon Nakhon	Song Dao	Northeastern	Low-Risk	Kalasin	Sam Chai	Northeastern	Low-Risk	Sakon Nakhon	Song Dao	Northeastern	Low-Risk
Sakon Nakhon	Akat Amnuai	Northeastern	Low-Risk	Roi Et	Muaiwadi	Northeastern	Low-Risk	Sakon Nakhon	Akat Amnuai	Northeastern	Low-Risk
Sakon Nakhon	Phannanikhom	Northeastern	Low-Risk	Roi Et	Phon Thong	Northeastern	Low-Risk	Sakon Nakhon	Phannanikhom	Northeastern	Low-Risk
Nakhon Phanom	Na Wa	Northeastern	Low-Risk	Kalasin	Kuchi Narai	Northeastern	Low-Risk	Nakhon Phanom	Na Wa	Northeastern	Low-Risk
Sakon Nakhon	Muang Sakon Nakhon	Northeastern	Low-Risk	Kalasin	Khao Wong	Northeastern	Low-Risk	Sakon Nakhon	Muang Sakon Nakl	Northeastern	Low-Risk
Sakon Nakhon	Muang Sakon Nakhon	Northeastern	Low-Risk	Phangnga	Khura Buri	Southern-West Coast	Low-Risk	Sakon Nakhon	Muang Sakon Nakl	Northeastern	Low-Risk
Sakon Nakhon	Phang Khon	Northeastern	Low-Risk					Sakon Nakhon	Phang Khon	Northeastern	Low-Risk
Udon Thani	Wang Sam Mo	Northeastern	Low-Risk					Kalasin	Somdet	Northeastern	Low-Risk
Kalasin	Somdet	Northeastern	Low-Risk					Kalasin	Somdet	Northeastern	Low-Risk
Kalasin	Somdet	Northeastern	Low-Risk					Mukdahan	Kamchai	Northeastern	Low-Risk
Sakon Nakhon	Phannanikhom	Northeastern	Low-Risk					Kalasin	Na Khu	Northeastern	Low-Risk
Sakon Nakhon	Phon Na Kaeo	Northeastern	Low-Risk					Mukdahan	Kamchai	Northeastern	Low-Risk
Mukdahan	Kamchai	Northeastern	Low-Risk					Mukdahan	Dong Luang	Northeastern	Low-Risk

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Viet Nam (c)

Date of FFG products 13/06/2021 00:00 UTC time

01-Hour Flash Flood Risk and Location				3-Hour Flash Flood Risk and Location in Vietnam				6-Hour Flash Flood Risk and Location in Vietnam			
Provinces	Districts	Region	Level Risks	Provinces	Districts	Region	Level Risks	Provinces	Districts	Region	Level Risks
Nghe An	Tuong Duong	North Central	Low-Risk	Nghe An	Con Cuong	North Central	Low-Risk	Nghe An	Tuong Duong	North Central	Low-Risk
Nghe An	Con Cuong	North Central	Moderate-Risk	Nghe An	Thanh Chuong	North Central	High-Risk	Nghe An	Thanh Chuong	North Central	Moderate-Risk
Nghe An	Thanh Chuong	North Central	High-Risk	Quang Binh	Minh Hoa	North Central	High-Risk	Quang Binh	Minh Hoa	North Central	Moderate-Risk
Quang Binh	Minh Hoa	North Central	High-Risk	Quang Binh	Bo Trach	North Central	Moderate-Risk	Quang Binh	Bo Trach	North Central	Moderate-Risk
Quang Binh	Bo Trach	North Central	Moderate-Risk	Quang Binh	Quang Ninh	North Central	Low-Risk	Quang Binh	Quang Ninh	North Central	Low-Risk
Quang Binh	Quang Ninh	North Central	Low-Risk	Son La	Yen Chau	Northwest	Low-Risk	Lao Cai	Than Uyen	Northwest	Low-Risk
Son La	Yen Chau	Northwest	Low-Risk	Nghe An	Tuong Duong	North Central	Low-Risk	Son La	Yen Chau	Northwest	Low-Risk
Nghe An	Quynh Luu	North Central	Low-Risk	Ha Tinh	Duc Tho	North Central	Low-Risk	Nghe An	Quynh Luu	North Central	Low-Risk
Nghe An	Tan Ky	North Central	Low-Risk	Ha Tinh	Huong Son	North Central	Moderate-Risk	Nghe An	Con Cuong	North Central	Moderate-Risk
Ha Tinh	Duc Tho	North Central	Low-Risk	Ha Tinh	Huong Khe	North Central	Moderate-Risk	Hoa Binh	Ky Son	Northwest	Low-Risk
Ha Tinh	Huong Son	North Central	High-Risk	Nghe An	TX. Cua Lo	North Central	Low-Risk	Nghe An	Quy Chau	North Central	Low-Risk
Ha Tinh	Huong Khe	North Central	High-Risk	Ha Tinh	Nghi Xuan	North Central	Low-Risk	Nghe An	Que Phong	North Central	Low-Risk
Ha Tinh	Cam Xuyen	North Central	Low-Risk	Nghe An	Anh Son	North Central	High-Risk	Nghe An	Tan Ky	North Central	Low-Risk
Quang Binh	Tuyen Hoa	North Central	Low-Risk	Ha Tinh	TX. Ha Tinh	North Central	Low-Risk	Ha Tinh	Duc Tho	North Central	Low-Risk
Ha Tinh	Thach Ha	North Central	Low-Risk	Ha Tinh	Cam Xuyen	North Central	Low-Risk	Ha Tinh	Huong Son	North Central	Moderate-Risk
Ha Tinh	TX. Hong Linh	North Central	Low-Risk	Ha Tinh	Ky Anh	North Central	Low-Risk	Ha Tinh	Huong Khe	North Central	Moderate-Risk
Nghe An	TP. Vinh	North Central	Low-Risk	Quang Binh	Quang Trach	North Central	Low-Risk	Ha Tinh	Cam Xuyen	North Central	Low-Risk
Nghe An	TX. Cua Lo	North Central	Low-Risk					Quang Binh	Tuyen Hoa	North Central	Low-Risk
Ha Tinh	Nghi Xuan	North Central	Moderate-Risk					Quang Binh	Minh Hoa	North Central	Moderate-Risk
Nghe An	Anh Son	North Central	Low-Risk					Ha Tinh	TX. Hong Linh	North Central	Low-Risk
Nghe An	Anh Son	North Central	High-Risk					Nghe An	TP. Vinh	North Central	Low-Risk
Ha Tinh	TX. Ha Tinh	North Central	Low-Risk					Nghe An	TX. Cua Lo	North Central	Low-Risk
Ha Tinh	Cam Xuyen	North Central	Moderate-Risk					Ha Tinh	Nghi Xuan	North Central	Low-Risk
Ha Tinh	Ky Anh	North Central	Low-Risk					Nghe An	Anh Son	North Central	Moderate-Risk
Quang Binh	Quang Trach	North Central	Moderate-Risk					Ha Tinh	TX. Ha Tinh	North Central	Low-Risk
								Ha Tinh	Ky Anh	North Central	Low-Risk

2.3.4 Conclusions

- During the period 10 -17 June 2021, the main cause for heavy rain in the LMB was influenced by the tropical storm KOGUMA.
- Heavy rain brought flash floods at some areas in the central parts of Lao PDR, north central parts of Viet Nam, and north-eastern of Thailand which were detected by the MRC-FFGS.
- The comparison between rainfall observed and the MAP24h results shows that at some locations the rainfall was overestimated about 25 % by the FFGS.
- Flash flood risk areas detected by the MRC-FFGS on 13th June 2021 at 00:00 UTC were corresponded to the reported flash flood areas via newspaper or internet (see Annex A.1).

2.4 Flash flood events on 23rd July 2021 caused by typhoon CEMPAKA

2.4.1 Weather condition from 17 – 27 July 2021

The monsoon trough lay across Myanmar, Upper Thailand and Viet Nam during the first half of the week (19-25 July) towards the low-pressure cell over the coast of southern China. Then the mentioned low-pressure cell intensified into a tropical depression in the morning of 19 July, and in the afternoon into the tropical storm “CEMPAKA” . This severe tropical storm made landfall at Yangjiang City, Guangdong, China in the evening on the 20 July (**Figure 2-9**). It downgraded into a tropical storm at Maoming City, Guangdong, China in the morning of 21 July and downgraded into a tropical depression over Guangxi Zhuang Autonomous Region, China in the morning of 22 July. After that, it moved to cover Upper Viet Nam in the morning of 23 July and then it was downgraded into an active low-pressure cell over the coast of Upper Viet Nam and the Gulf of Tonkin on the next day. In addition, the active SW Monsoon prevailed over the Gulf of Thailand almost a week. These conditions caused heavy rainfall in upper parts almost the whole week; mainly during the second half of this week with heavy to very heavy rainfall in several areas and flooding in some areas.

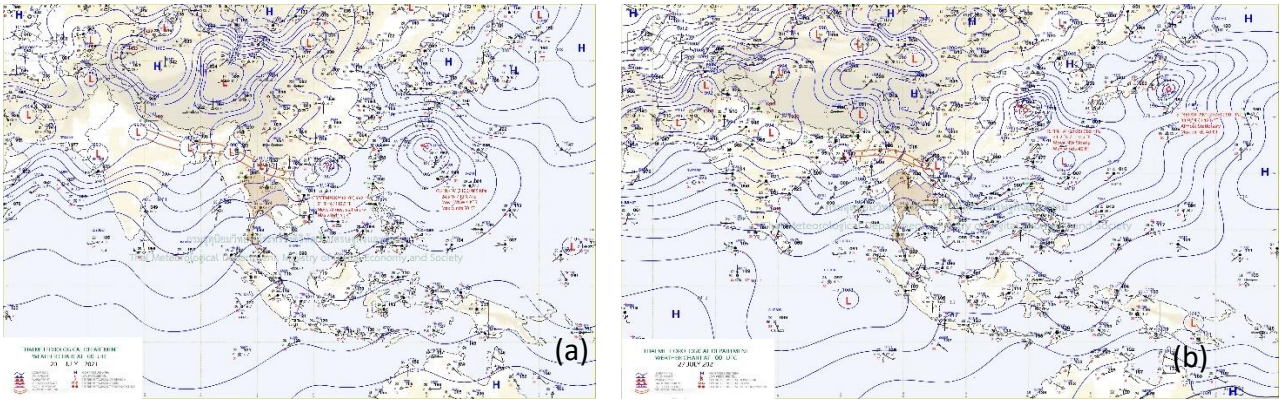

Figure 2-9: Weather map for (a) 20th July 2021 and (b) 27th July 2021 (Source: TMD)

Tropical Storm CEMKAPA (Source World Meteorological Organization (**WMO)):** On July 17, the JMA reported that a tropical depression had formed. The JTWC later issued a TCFA for the system, as the area of convection became more organized. By the next day, the JTWC upgraded the system to a tropical depression and designated it as 10W, with the storm possessing an improved convective structure and a defined low-level circulation. The JTWC upgraded the system to a tropical storm at 21:00 UTC as it had a defined low-level circulation centre with an improved banding structure.

At 00:00 UTC on July 19, the JMA upgraded the system to a tropical storm, assigning it the name CEMPAKA. At 21:00 UTC, the JTWC declared CEMPAKA to have strengthened into a Category 1 typhoon as it developed a ragged of 28 km wide eye. The JMA later upgraded it to a severe tropical storm at 00:00 UTC on the next day. JTWC assessed that it peaked as a typhoon with maximum 1-minute sustained wind of 150 km/h. CEMPAKA made landfall near Jiangcheng District, Yangjiang, Guangdong Province, China, and the JTWC downgraded it to a tropical storm at 18:00 UTC the same day as its low-level circulation center became obscure. The JMA also downgraded CEMPAKA to a tropical storm at 00:00 UTC the next day as it moved further inland, and its central dense overcast disappeared.

At 09:00 UTC, the JTWC further downgraded CEMPAKA to a tropical depression as its deep convection declined; however, it still retained a well-defined wind field. After moving inland, CAMPAKA started moving westward at 00:00 UTC on July 21 due to weak steering flow. On July 22, at 09:00 UTC, CEMPAKA then moved southwards towards the Gulf of Tonkin because of the influence of the monsoonal westerlies, while maintaining its tropical depression intensity inland. CEMPAKA moved southward, crossed Mong Cai , Quang Ninh Province in Viet Nam, and later entered the Gulf of Tonkin at 03:00.

However, CEMPAKA further weakened despite the presence of warm sea surface temperatures because of high monsoonal wind shear and land interaction. At 15:00 UTC, the JTWC issued its final warning on the system as it became a weakly defined system with an exposed low-level circulation center over Bach Long Vi Island. On July 26 at 00:00 UTC, the JMA issued its last advisory. The track of Tropical Storm CEMKAPA is shown in **Figure 2-10**.

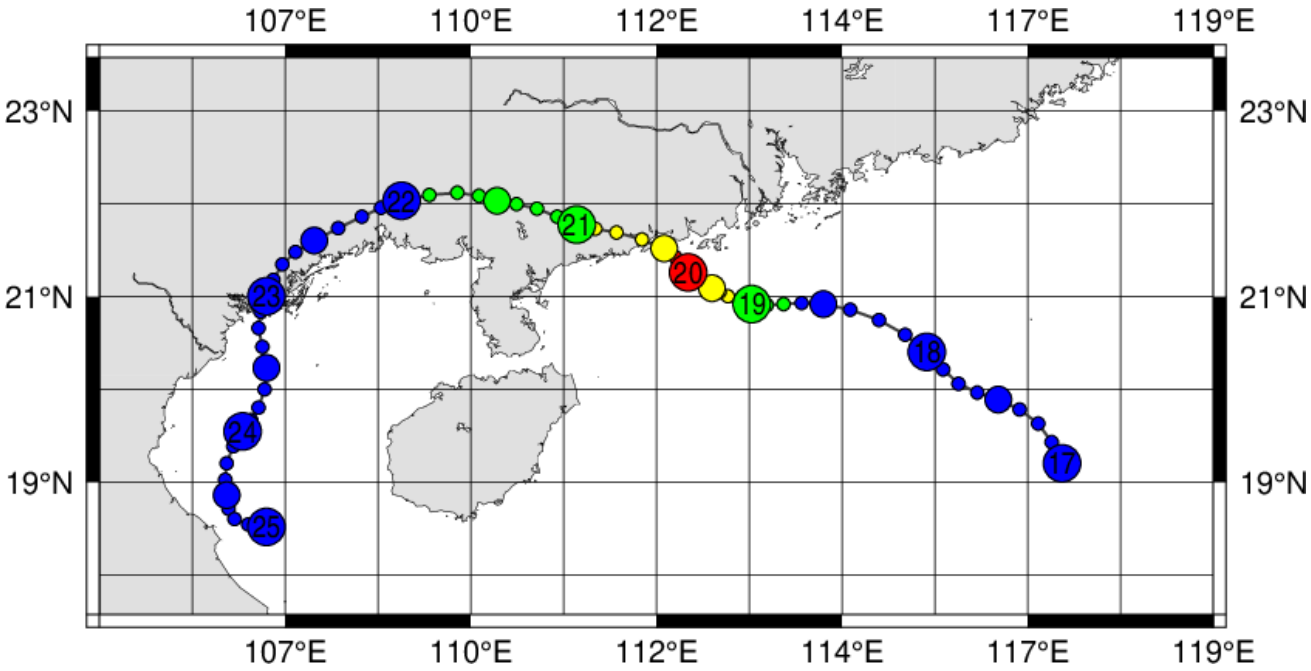

Figure 2-10: The track of tropical typhoon CEMKAPA (Source: JMA)

2.4.2 Heavy rainfall during 17 – 27 July 2021

In fact, the daily rainfall observed from the MCs shows that when the storm CEMKAPA's circulation combined other meteorology factors, causing heavy rain in some middle parts of the LMB including the eastern of Lao PDR and north central northwest of Viet Nam. The total rainfall measured during this period at some stations is very large such as at Vang Vieng, KuanPho and Highway Bridge (see **Table 2-5**) .The rainfall distribution over the LMB is depicted in **Figure 2-11**.

Table 2-5: Daily rainfall observed at some stations in the LMB (17 – 27 July 2021)

Unit:mm

Time	Paksane	Thakhek	Pakse	Ban Phone Si	Muang Kao	Mahaxai	Khong Sedone	Saravanne	Vang Vieng	Kuanpho	Highway Bridge	Tuyen Hoa
7/17/2021	60.4	0	0	2.8	13	0	0	0	0	0	9	4.2
7/18/2021	0.3	0	0	0	0	5.3	22.5	7.8	2.4	0	14.4	0
7/19/2021	47.8	3.8	123.6	21.6	5.9	7.5	69.4	35.4	141.6	0	0	0
7/20/2021	40.8	10.6	37.3	21.4	40	18.6	52.5	39.8	75.9	178.2	0	0
7/21/2021	23.3	19.5	8.8	36.4	20	37.5	11.2	2.9	25.5	11.6	30	0
7/22/2021	12.6	49	11.5	14.3	26	69.7	1.3	13.2	16.3	47.1	13.2	4
7/23/2021	3.2	81.1	7.2	10.4	0.3	0	16.4	32.8	0.4	81.4	86.6	1
7/24/2021	25.6	14.4	31	27.4	44.5	68.2	39	48.3	22.6	39	37.5	23
7/25/2021	17	87.7	58	37.4	14	73.4	69	41.2	0	59.8	148.4	67
7/26/2021	96.7	1.2	11.5	51.2	26	8.5	14.3	13	137.4	21.1	0	87
7/27/2021	0.2	0	4.4	0	3.5	5.8	0	1.8	43.3	0	0	1
Total	**327.9**	**267.3**	**293.3**	**222.9**	**193.2**	**294.5**	**295.6**	**236.2**	**465.4**	**438.2**	339.1	187.2

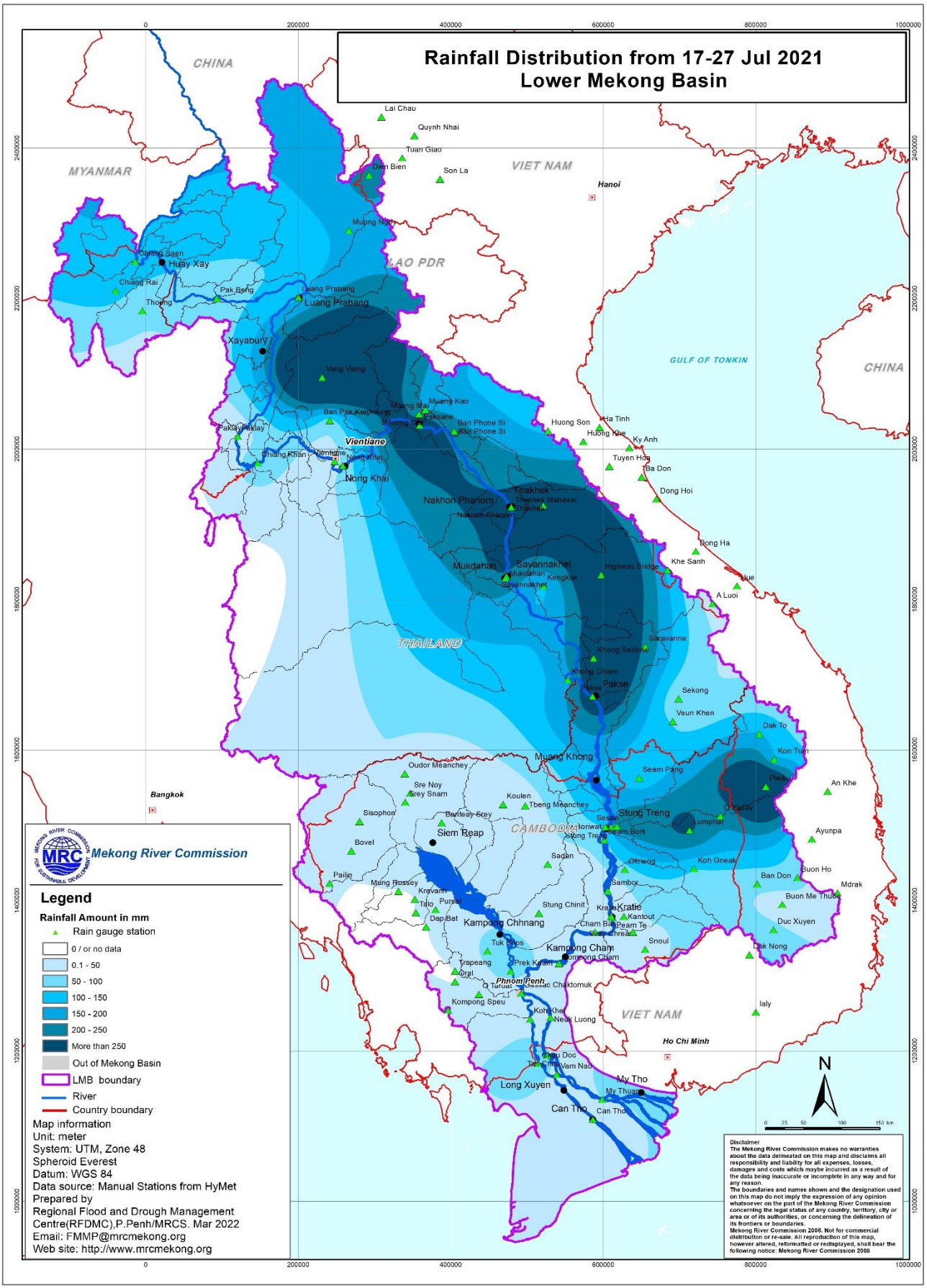
Rainfall Distribution from 17-27 Jul 2021
Lower Mekong Basin
CHINA
MYANMAR
LAO PDR
VIET NAM
THAILAND
CAMBODIA
GULF OF TONKIN
Hanoi
Vientiane
Bangkok
Ho Chi Minh
Phnom Penh
Mekong River Commission
Legend
Rainfall Amount in mm
Rain gauge station
0 / or no data
0.1 - 50
50 - 100
100 - 150
150 - 200
200 - 250
More than 250
Out of Mekong Basin
LMB boundary
River
Country boundary
Map information
Unit: meter
System: UTM, Zone 48
Spheroid Everest
Datum: WGS 84
Data source: Manual Stations from HyMet
Prepared by
Regional Flood and Drough Management Centre(RFDMC),P.Penh/MRCS. Mar 2022
Email: FMMP@mrcmekong.org
Web site: http://www.mrcmekong.org
N
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Figure 2-11: Rainfall distribution during 17-27 July 2021 in the LMB

2.4.3 Flash Flood in Lao PDR and Viet Nam on 23 July 2021

Based on the MRC-FFGS' products, MAP24h and ASM heavy rainfall was detected north-eastern of Lao PDR and northwest Viet Nam at 12:00 UTC (19:00 local time), (**Figure 2-12**). The comparison between MAP24h and the observed rainfall at some gauging stations during period from 17 – 27 July is shown in **Figure 2-13**.

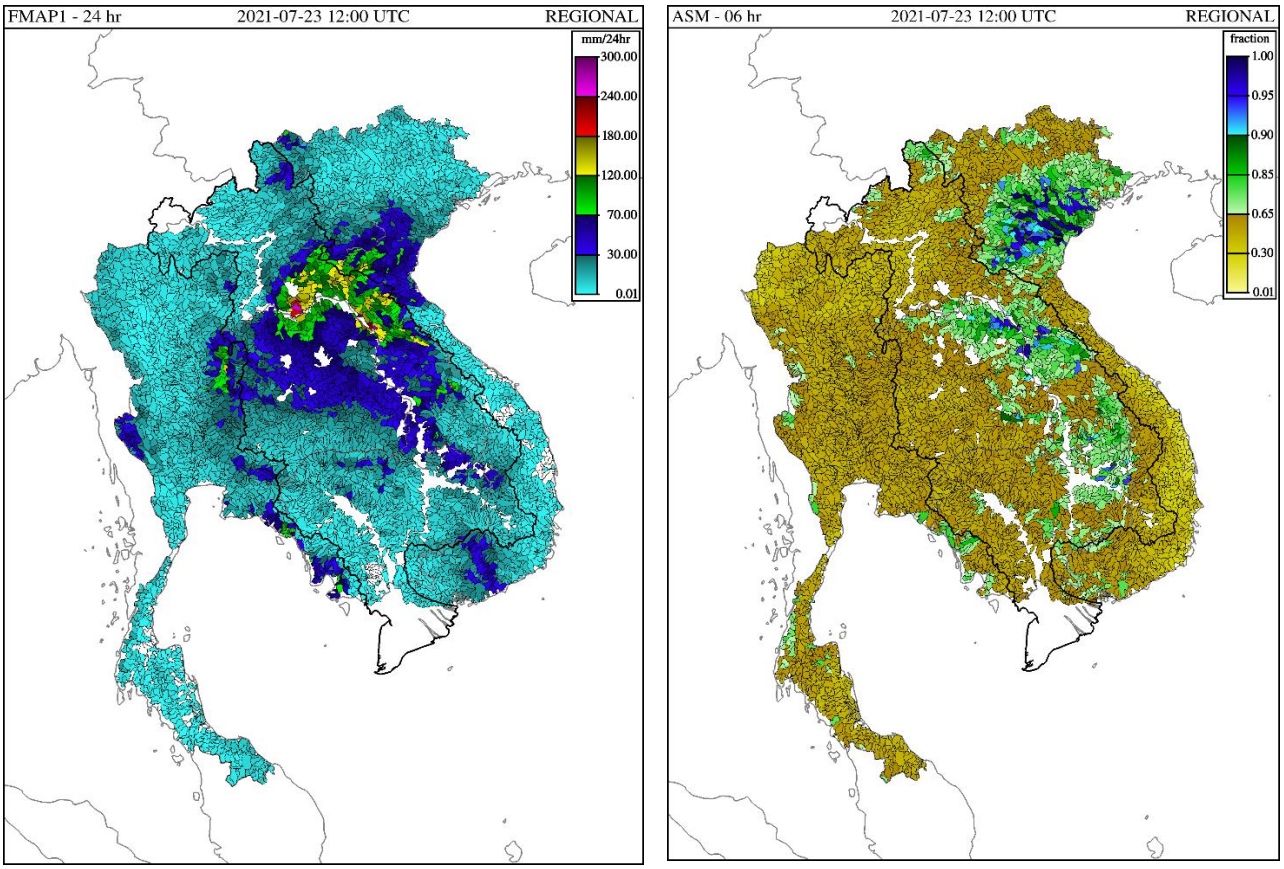

Figure 2-12: MAP24h and ASM on 23 July 2021 at 12:00 UTC (19: 00 local time)

Figure 2-13: Comparison observed rainfall and MAP24h at some station in LMB from 17-27 July

Based on the analysis of the FFG from the MRC-FFGS (**Figure 2-14**) and on actual measurements available in RFDMC, the RFDMC made the decision to submit the warning of flash flood guidance for 1, 3, and 6 hours as shown in Table 2-6.

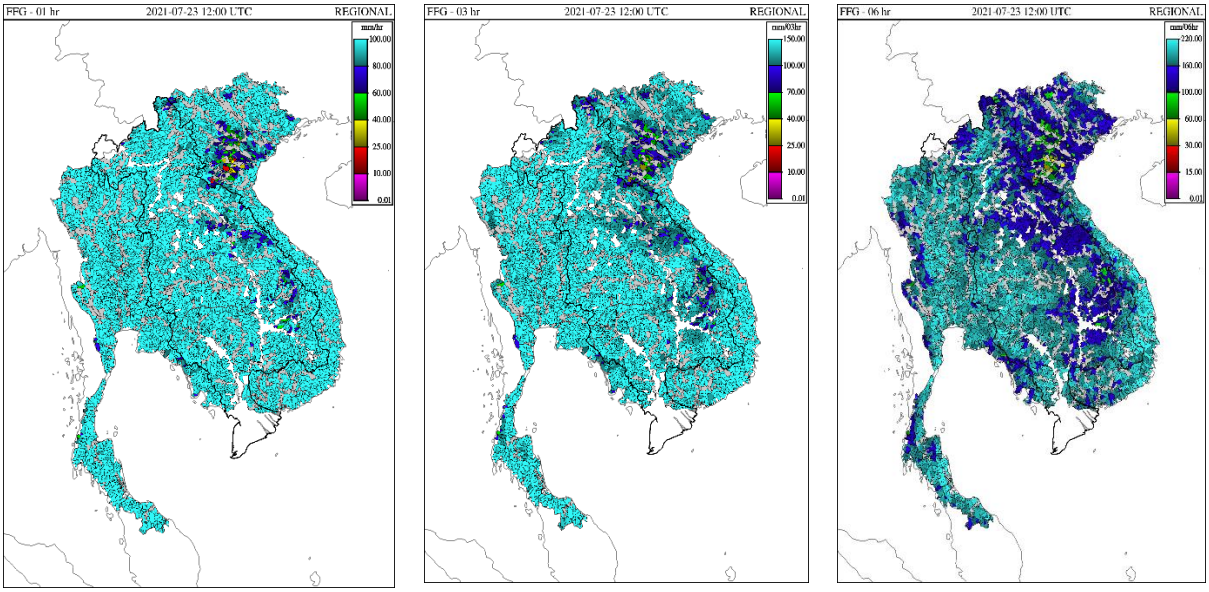

Figure 2-14: FFG 01, 03 and 06 on 23 July 2021 at 12:00 UTC (19: 00 local time)

Table 2-6: FFG detected by MRC-FFGS in (b) Lao PDR and (b) Viet Nam on 23 July 2021 at 12:00 UTC (19: 00 Local time)

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Lao PDR (a)

Date of FFG products 23/07/2021 12:00 UTC time

01-Hour Flash Flood Risk and Location					03-Hour Flash Flood Risk and Location					06-Hour Flash Flood Risk and Location				
Provinces	Districts	Villages	Region	Level Risk	Provinces	Districts	Villages	Region	Level Risk	Provinces	Districts	Villages	Region	Level Risk
Khammuane	Hinboon	MOUANG NAM SANG	Center of Laos	Low-Risk	Khammuane	Hinboon	MOUANG NAM SANG	Center of Laos	Low-Risk	Bolikhamxay	Khamkheut	NAPHOUANG	Central Laos	Low-Risk
Savannakhet	Xaybuly	NONGSAPHANG	Southern	Low-Risk	Sekong	Lamarm	KANONG MAI	Southeast	Low-Risk	Khammuane	Hinboon	PHON XAI	Center of Laos	Low-Risk
Sekong	Lamarm	KANONG MAI	Southeast	Low-Risk	Sekong	Lamarm	KADONE	Southeast	Low-Risk	Khammuane	Hinboon	MOUANG NAM SANG	Center of Laos	Low-Risk
Sekong	Lamarm	KADONE	Southeast	Low-Risk	Huaphanh	Xamtay	HINTANG	Eastern	Low-Risk	Savannakhet	Xaybuly	NONGSAPHANG	Southern	Low-Risk
Huaphanh	Xamtay	HINTANG	Eastern	Low-Risk	Huaphanh	Xamtay	HOUAYSAMONG	Eastern	Low-Risk	Sekong	Kaleum	AR-PEUANG	Southeast	Low-Risk
Huaphanh	Xamtay	NAMOUANG	Eastern	Low-Risk	Huaphanh	Xamtay	GNORT-INN	Eastern	Low-Risk	Sekong	Kaleum	TIN	Southeast	Low-Risk
Huaphanh	Xamtay	HOUAYSAMONG	Eastern	Low-Risk	Huaphanh	Xamtay	NAMMORN	Eastern	Moderate-Risk	Sekong	Kaleum	STTHORN	Southeast	Low-Risk
Huaphanh	Xamtay	GNORT-INN	Eastern	Moderate-Risk	Huaphanh	Xamtay	PHALOM	Eastern	Low-Risk	Sekong	Lamarm	KANONG MAI	Southeast	Low-Risk
Huaphanh	Xamtay	NAMMORN	Eastern	Moderate-Risk	Huaphanh	Xamtay	PHAKHAO	Eastern	Low-Risk	Sekong	Lamarm	KADONE	Southeast	Low-Risk
Huaphanh	Xamtay	PHALOM	Eastern	Low-Risk						Sekong	Dakcheung	DAKPORK	Southeast	Low-Risk
Huaphanh	Xamtay	PHAKHAO	Eastern	Moderate-Risk						Sekong	Dakcheung	DAKDEN	Southeast	Low-Risk
										Huaphanh	Xamtay	HINTANG	Eastern	Low-Risk
										Huaphanh	Xamtay	NAMOUANG	Eastern	Low-Risk
										Huaphanh	Xamtay	HOUAYSAMONG	Eastern	Low-Risk
										Huaphanh	Xamtay	GNORT-INN	Eastern	Moderate-Risk
										Huaphanh	Xamtay	NAMMORN	Eastern	Moderate-Risk
										Huaphanh	Xamtay	LONGKUANG	Eastern	Low-Risk
										Huaphanh	Xamneua	SATHORN	Eastern	Low-Risk
										Huaphanh	Viengxay	TA-AN	Eastern	Low-Risk
										Huaphanh	Viengxay	ONGKHATHIAM	Eastern	Low-Risk
										Huaphanh	Xamtay	PHALOM	Eastern	Low-Risk
										Huaphanh	Xamtay	PHAKHAO	Eastern	Moderate-Risk

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Viet Nam (b)

Date of FFG products 23/07/2021 12:00 UTC time

01-Hour Flash Flood Risk and Location				3-Hour Flash Flood Risk and Location in Vietnam				6-Hour Flash Flood Risk and Location in Vietnam			
Provinces	Districts	Region	Level Risks	Provinces	Districts	Region	Level Risks	Provinces	Districts	Region	Level Risks
Gia Lai	Duc Co	Central Highlands	Low-Risk	Gia Lai	Duc Co	Central Highlands	Low-Risk	Gia Lai	Duc Co	Central Highlands	Low-Risk
Hoa Binh	Da Bac	Northwest	Low-Risk	Hoa Binh	Da Bac	Northwest	Low-Risk	Ha Tinh	Huong Son	North Central	Low-Risk
Son La	Moc Chau	Northwest	Low-Risk	Son La	Moc Chau	Northwest	Low-Risk	Son La	Bac Yen	Northwest	Low-Risk
Son La	Phu yen	Northwest	Low-Risk	Son La	Phu yen	Northwest	Low-Risk	Hoa Binh	Da Bac	Northwest	Low-Risk
Hoa Binh	Mai Chau	Northwest	Low-Risk	Hoa Binh	Da Bac	Northwest	Low-Risk	Lai Chau	Muong Te	Northwest	Low-Risk
Thanh Hoa	Thuong Xuan	North Central	Low-Risk	Hoa Binh	Mai Chau	Northwest	Low-Risk	Son La	Bac Yen	Northwest	Low-Risk
Nghe An	Que Phong	North Central	Moderate-Risk	Nghe An	Que Phong	North Central	Low-Risk	Son La	Phu yen	Northwest	Low-Risk
Nghe An	Tuong Duong	North Central	High-Risk	Nghe An	Tuong Duong	North Central	Moderate-Risk	Son La	Moc Chau	Northwest	Low-Risk
Nghe An	Que Phong	North Central	Moderate-Risk	Nghe An	Quy Chau	North Central	Low-Risk	Hoa Binh	Mai Chau	Northwest	Low-Risk
Nghe An	Quy Chau	North Central	Moderate-Risk	Thanh Hoa	Quan Hoa	North Central	Low-Risk	Ha Giang	Bac Quang	Northeast	Low-Risk
Thanh Hoa	Thach Thanh	North Central	Low-Risk	Thanh Hoa	Ba Thuoc	North Central	Low-Risk	Lao Cai	Bao Yen	Northwest	Low-Risk
Thanh Hoa	Muong Lat	North Central	Low-Risk	Thanh Hoa	Quan Son	North Central	Low-Risk	Hoa Binh	Lac Son	Northwest	Low-Risk
Son La	Moc Chau	Northwest	Low-Risk	Thanh Hoa	Muong Lat	North Central	Low-Risk	Thanh Hoa	Thuong Xuan	North Central	Low-Risk
Thanh Hoa	Quan Hoa	North Central	Low-Risk	Thanh Hoa	Quan Son	North Central	Low-Risk	Nghe An	Que Phong	North Central	Moderate-Risk
Thanh Hoa	Ba Thuoc	North Central	Moderate-Risk	Nghe An	Que Phong	North Central	Moderate-Risk	Nghe An	Tuong Duong	North Central	Moderate-Risk
Thanh Hoa	Muong Lat	North Central	Low-Risk	Nghe An	Tuong Duong	North Central	Low-Risk	Nghe An	Quy Chau	North Central	Moderate-Risk
Thanh Hoa	Quan Son	North Central	Low-Risk	Nghe An	Con Cuong	North Central	Low-Risk	Thanh Hoa	Thach Thanh	North Central	Low-Risk
Nghe An	Que Phong	North Central	High-Risk	Hoa Binh	Ky Son	Northwest	Moderate-Risk	Son La	Yen Chau	Northwest	Low-Risk
Nghe An	Tuong Duong	North Central	Low-Risk					Thanh Hoa	Muong Lat	North Central	Low-Risk
Nghe An	Con Cuong	North Central	Low-Risk					Thanh Hoa	Quan Hoa	North Central	Low-Risk
Nghe An	Tuong Duong	North Central	Low-Risk					Thanh Hoa	Ba Thuoc	North Central	Moderate-Risk
Hoa Binh	Ky Son	Northwest	High-Risk					Thanh Hoa	Quan Son	North Central	Low-Risk
Nghe An	Quy Chau	North Central	Moderate-Risk					Thanh Hoa	Muong Lat	North Central	Low-Risk

2.4.4 Conclusions

- The circulation after tropical storm CEMPAKA is the cause of heavy rain in some areas in the north-eastern parts of Lao PDR and northwestern Viet Nam in the period 17 -27 July. Due to saturated soil combined with heavy rain at the same time, flash flood events took place in these areas.
- The MRC-FFGS detected heavy rain quite good; based on a comparison result at some stations in the LMB, the system's result at peak values has a difference of about 5-15 % (over and under estimates). For example at Vang Vieng (Lao PDR) with the total rainfall from 17-27 July of MAP24h was 462 mm and the observed rainfall was 465.4 mm. So the FFGS overestimated it about 0.5 %; at Kuanpho (Lao PDR) MAP24h estimated 319.97 mm with overserved rainfall 339.1 mm, overestimated about 5.6 %, and at Tuyen Hoa (Viet Nam) with MAP24h calculated 187.2 mm compared to observed rainfall 195.54 mm, it underestimated 4.5 %.
- The MRC-FFGS correctly detected several locations that flash floods were likely to occur, corresponded with the reported flash flood areas via newspaper or internet (see Annex A.2).

2.5 Flash flood event during 13-19 August 2021 caused by Intertropical Convergence Zone (ICTZ)

2.5.1 Weather condition during 13 – 19 August 2021

For 13 -19 August, a low-pressure cell covered Upper Viet Nam, associated with the southeasterly wind which prevailed over the Gulf of Thailand during the mentioned time. In addition, the SW Monsoon which prevailed over the Gulf of Thailand was weakened during the second half of the period. Moreover, the low-pressure cell covered lower southern part of Thailand and Malaysia during late period. These conditions caused heavy rainfall in upper parts of the LMB during the first half of the period and then decreased in amount and distribution (Figure 2-15).

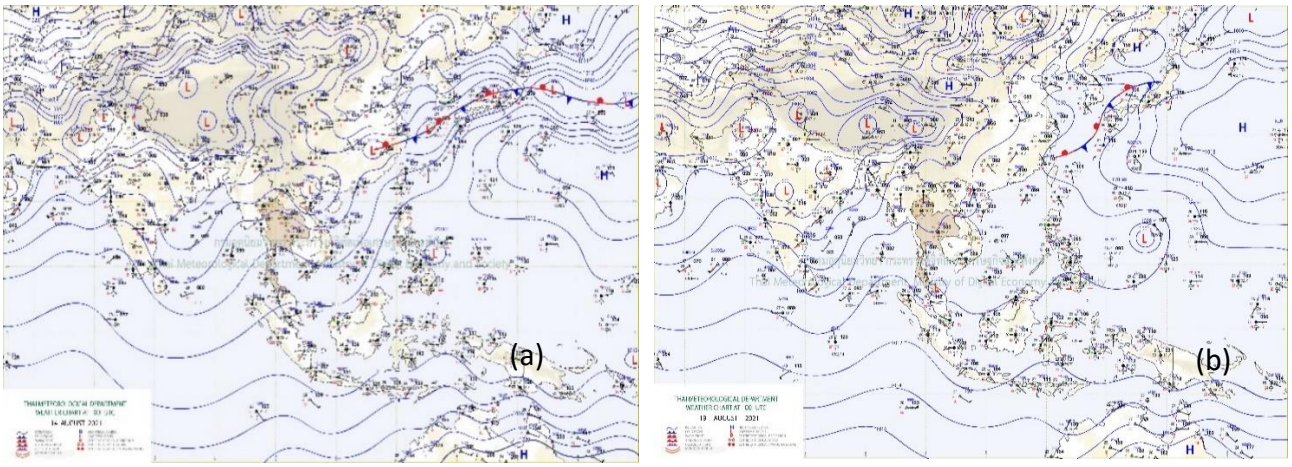

Figure 2-16: Weather map for (a) 14 August 2021 and (b) 19 August 2021 (Source: TMD)

2.5.2 Heavy rainfall for 13 -19 August

During period 13–19 August 2021, the daily rainfall observed shows that influenced by the ITCZ very heavy rainfall occurred, in fact it was concentrated from 14 – 16 August in some areas in the LMB. **Table 2-7** shows the daily rainfall observed on 15 August in the Lao PDR at Muong Mai (113 mm), Muang Kao (108 mm), Vang Vieng (155 mm), in Thailand at Khong Chiam (129.5 mm) and in Cambodia at Sambor (81 mm) on 13 August. The rainfall distribution during 13-19 August 2021 in the LMB is shown in the **Figure 2-21**.

Table 2-7: Daily rainfall observed at some stations in the LMB (13-19 August 2021)

Time	Paksane	Muong Mai	Muang Kao	Tam Duong	Sin Ho	Vang Vieng	Khong Chiam	Sambor	Kantout
8/13/2021	13.1	48.2	6.5	13	17	33.2	16.5	81	46.7
8/14/2021	90.8	17	17	3	5	50.3	129.5	16.9	57.4
8/15/2021	27	113	108	74	59	155	10.6	40.5	3.5
8/16/2021	37.2	59.5	24	59	45	107.7	5.6	4	0
8/17/2021	46.3	0	4.5	56	35	29	0	0	0
8/18/2021	0	5	10	47	49	0	0	1	0
8/19/2021	11.5	0	7.5	11.1	4.6	0	34.8	0	0
Total	**225.9**	**242.7**	**177.5**	**263.1**	**214.6**	**375.2**	**197**	**143.4**	**107.6**

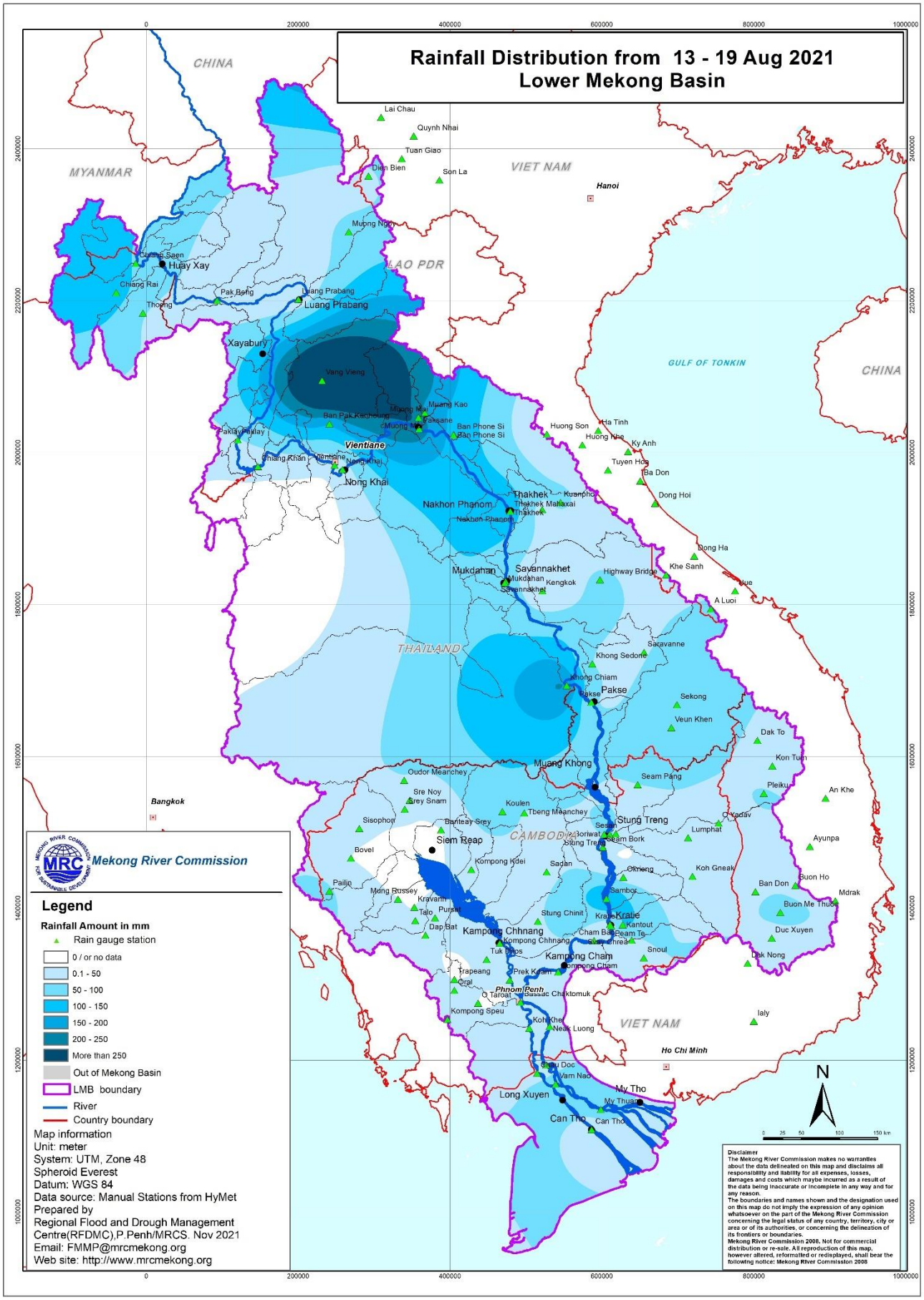

Figure 2-17: Rainfall distribution during 13-19 August 2021 in the LBM

2.5.3 Flash flood event on 15 August 2021

Based on the MRC-FFGS' products, MAP24h and ASM, very heavy rain was detected in some areas in the of northwest part of Lao PDR and in the northwest part of Viet Nam at 00:00 UTC (00:00 local time). Those results show that the rainfall in many areas was more than 100 mm/24h and that the resulted soil moisture in those areas was also very wet, saturated in a wide range (**Figure 2-18**).

The comparison between MAP24h and rainfall observed at some gauging stations during the period from 13-19 August is shown in **Figure 2-19**. From the comparison it is shown that satellite data and measured data (24-hour time step) are good in terms of time and space, however, the value of rainfall at each location shows that the system value is smaller than the actual value.

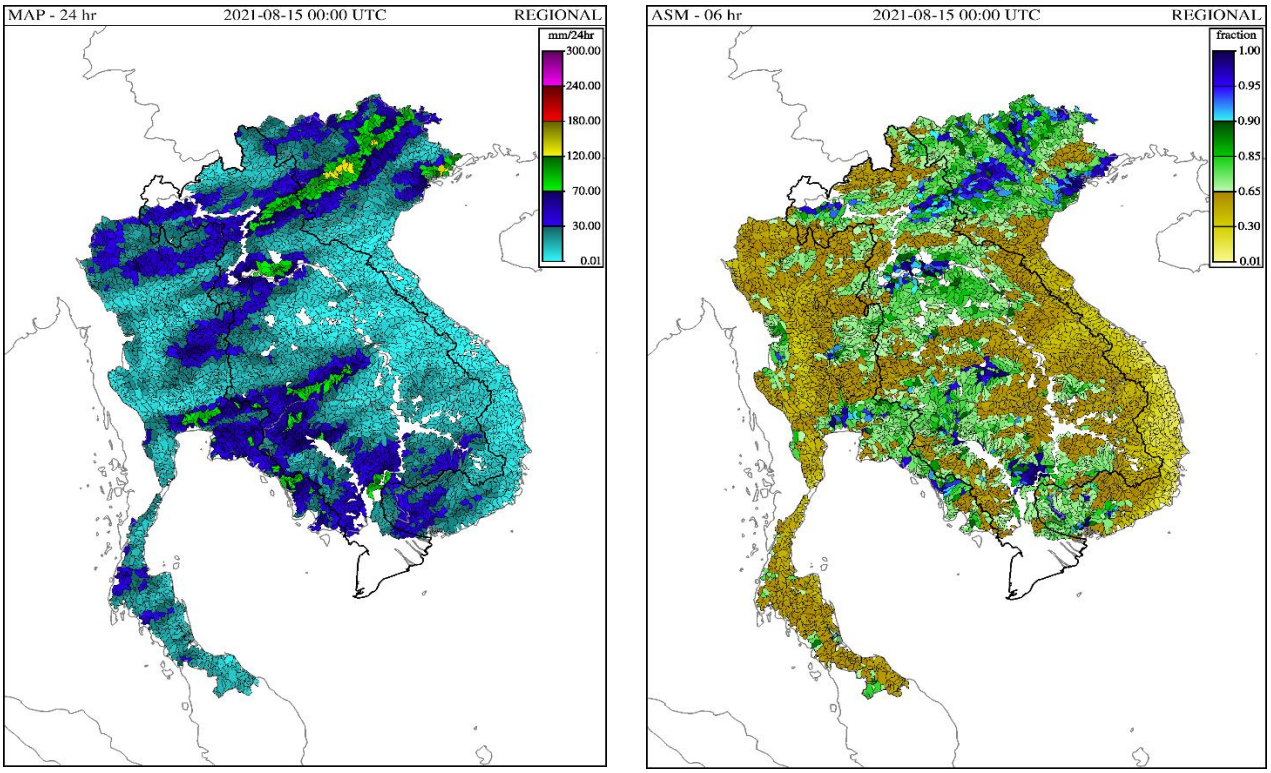

Figure 2-18: MAP24h and ASM on 15 August 2021 at 00:00 UTC (07: 00 local time)

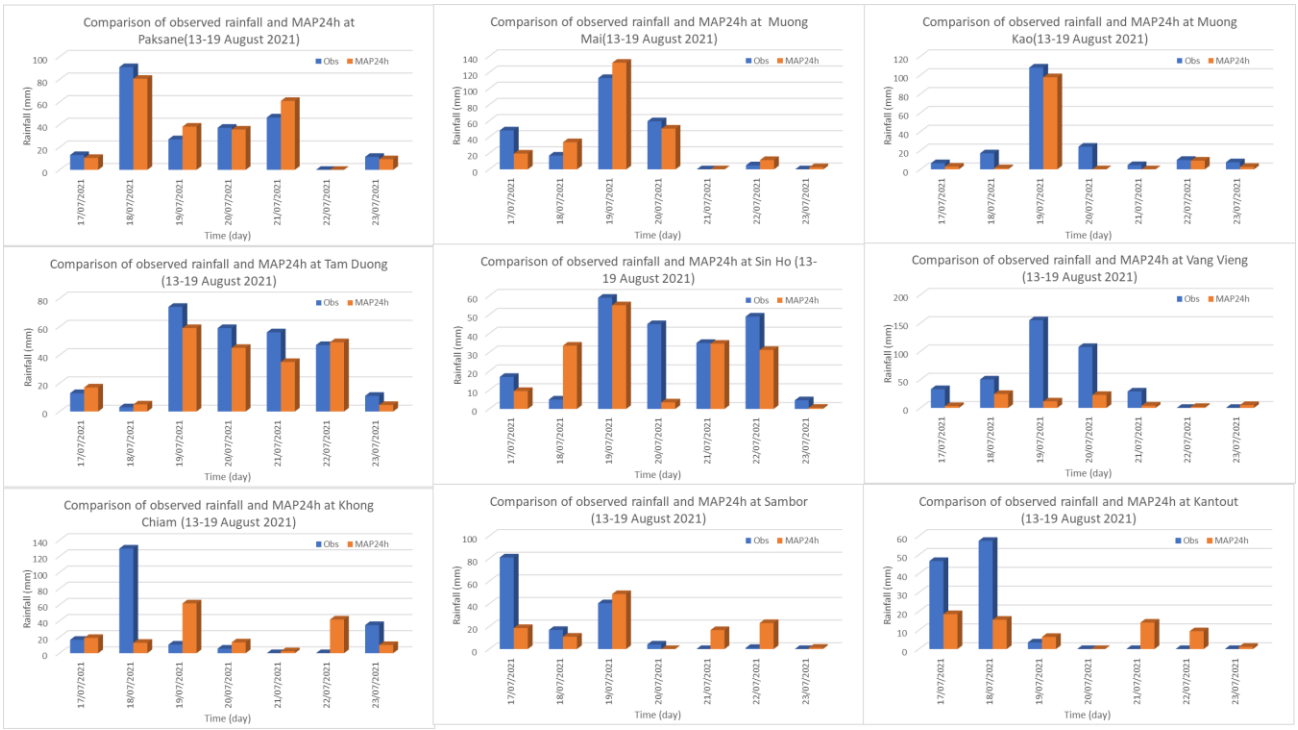

Figure 2-19: Comparison rainfall observed and MAP24h at some stations in LMB from 13-19 August 2021

The RFDMC submitted the warning with flash flood guidance for 1, 3, and 6 hours on 00:00 UTC 15 August 2021. Some areas in Viet Nam and Lao PDR were predicted from low to high-risk of flash flood as shown in the

Table 2-8 and **Figure 2-20**.

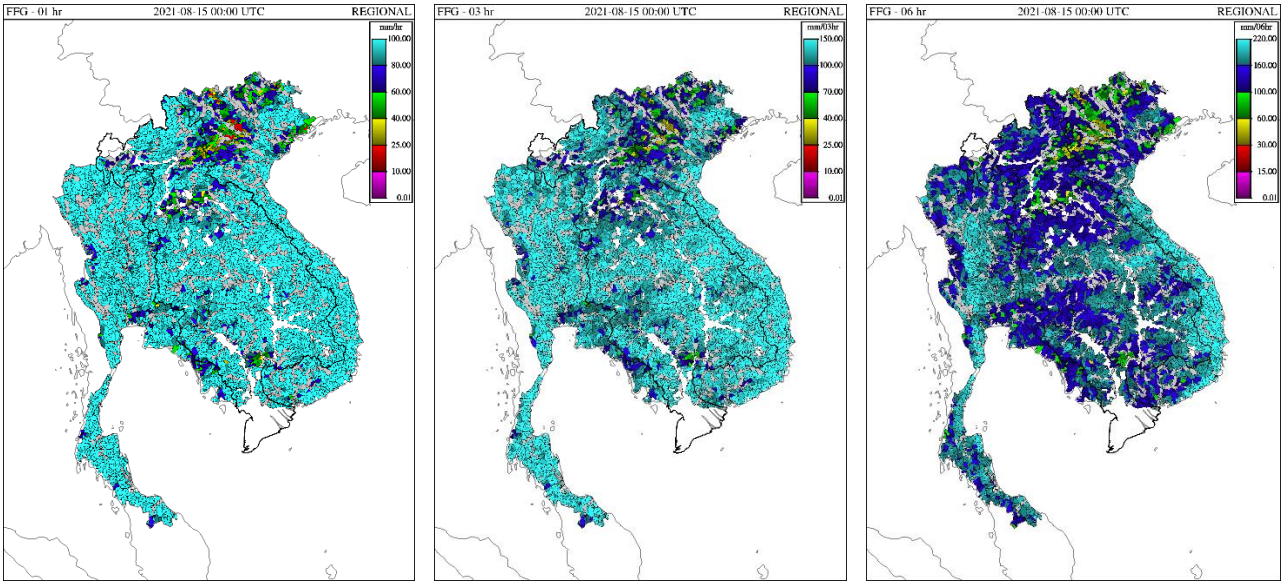

Figure 2-20: FFG 01, 03 and 06 on 15 August 2021 at 00:00 UTC (07: 00 local time)

Table 2-8: FFG detected by MRC-FFGS (a) Viet Nam; (b) Lao PDR on 15 August 2021 at 00:00 UTC (07: 00 Local time)

(a)

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Viet Nam

Date of FFG products 15/08/2021 00:00 UTC time

01-Hour Flash Flood Risk and Location				3-Hour Flash Flood Risk and Location in Vietnam				6-Hour Flash Flood Risk and Location in Vietnam			
Provinces	Districts	Region	Level Risks	Provinces	Districts	Region	Level Risks	Provinces	Districts	Region	Level Risks
Son La	Phu yen	Northwest	High-Risk	Lai Chau	Muong Te	Northwest	Low-Risk	Lai Chau	Muong Te	Northwest	Low-Risk
Lai Chau	Muong Te	Northwest	Low-Risk	Dong Nai	Xuan Loc	Southeast	Low-Risk	Lai Chau	Dien Bien	Northwest	Low-Risk
Lai Chau	Dien Bien	Northwest	Low-Risk	Cao Bang	Hoa An	Northeast	Moderate-Risk	Long An	Can Giuoc	Southewest-Meko	Low-Risk
Long An	Can Giuoc	Southewest-Mekong	Low-Risk	Cao Bang	Ha Quang	Northeast	Low-Risk	Binh Thuan	Tanh Linh	South Central Coa	Low-Risk
Dong Nai	Xuan Loc	Southeast	Low-Risk	Cao Bang	Nguyen Binh	Northeast	Moderate-Risk	Dong Nai	Xuan Loc	Southeast	Low-Risk
Cao Bang	Hoa An	Northeast	Moderate-Risk	Quang Ninh	Hoanh Bo	Northeast	Low-Risk	Cao Bang	Hoa An	Northeast	Moderate-Risk
Cao Bang	Ha Quang	Northeast	Low-Risk	Quang Ninh	TX. Cam Pha	Northeast	Moderate-Risk	Cao Bang	Ha Quang	Northeast	Low-Risk
Cao Bang	Nguyen Binh	Northeast	Moderate-Risk	Hai Phong	An Hai	Red River Delta	Low-Risk	Cao Bang	Nguyen Binh	Northeast	Moderate-Risk
Cao Bang	TX. Cao Bang	Northeast	Low-Risk	Hai Phong	Thuy Nguyen	Red River Delta	Low-Risk	Cao Bang	TX. Cao Bang	Northeast	Low-Risk
Quang Ninh	Ba Che	Northeast	Low-Risk	Thai Binh	Dong Hung	Red River Delta	Low-Risk	Bac Kan	Ngan Son	Northeast	Low-Risk
Quang Ninh	Tien Yen	Northeast	Low-Risk	Bac Kan	Cho Don	Northeast	Low-Risk	Quang Ninh	Tien Yen	Northeast	Low-Risk
Quang Ninh	Hoanh Bo	Northeast	Low-Risk	Lao Cai	Van Ban	Northwest	Low-Risk	Quang Ninh	Hoanh Bo	Northeast	Low-Risk
Quang Ninh	TX. Cam Pha	Northeast	High-Risk	Yen Bai	Mu Cang Chai	Northwest	Low-Risk	Quang Ninh	TX. Cam Pha	Northeast	Moderate-Risk
Yen Bai	Mu Cang Chai	Northwest	Low-Risk	Hoa Binh	Da Bac	Northwest	Moderate-Risk	Quang Ninh	TP. Ha Long	Northeast	Low-Risk
Son La	Bac Yen	Northwest	High-Risk	Lao Cai	Sa Pa	Northwest	Low-Risk	Hai Phong	An Hai	Red River Delta	Low-Risk
Hoa Binh	Da Bac	Northwest	Moderate-Risk	Lao Cai	Than Uyen	Northwest	Moderate-Risk	Hai Phong	Thuy Nguyen	Red River Delta	Low-Risk
Lao Cai	Sa Pa	Northwest	Moderate-Risk	Son La	Muong La	Northwest	Low-Risk	Quang Ninh	Yen Hung	Northeast	Low-Risk
Lao Cai	Than Uyen	Northwest	High-Risk	Lai Chau	Phong Tho	Northwest	Low-Risk	Thai Binh	Thai Thuy	Red River Delta	Low-Risk
Son La	Muong La	Northwest	Low-Risk	Lao Cai	Bat Xat	Northwest	Moderate-Risk	Thai Binh	Dong Hung	Red River Delta	Low-Risk
Lai Chau	Phong Tho	Northwest	Low-Risk	Son La	Mai Son	Northwest	Low-Risk	Bac Kan	Cho Don	Northeast	Low-Risk
Lao Cai	Bat Xat	Northwest	High-Risk	Son La	Bac Yen	Northwest	Moderate-Risk	Yen Bai	Tram Tau	Northwest	Low-Risk
Son La	Mai Son	Northwest	Moderate-Risk	Son La	Moc Chau	Northwest	Moderate-Risk	Lao Cai	Bat Xat	Northwest	Moderate-Risk
Son La	Moc Chau	Northwest	High-Risk	Son La	Phu yen	Northwest	Moderate-Risk	Lao Cai	Than Uyen	Northwest	Moderate-Risk
Son La	Phu yen	Northwest	High-Risk	Ha Giang	Xin Man	Northeast	Low-Risk	Lao Cai	Van Ban	Northwest	Low-Risk
Ha Giang	Xin Man	Northeast	Low-Risk	Tuyen Quang	Chiem Hoa	Northeast	Low-Risk	Yen Bai	Mu Cang Chai	Northwest	Low-Risk
Tuyen Quang	Na Hang	Northeast	Moderate-Risk	Tuyen Quang	Na Hang	Northeast	Low-Risk	Yen Bai	TX. Nghia Lo	Northwest	Low-Risk
Bac Kan	Ba Be	Northeast	Low-Risk	Bac Kan	Bach Thong	Northeast	Low-Risk	Son La	Bac Yen	Northwest	Moderate-Risk
Bac Kan	Bach Thong	Northeast	Low-Risk	Ha Giang	Hoang Su Phi	Northeast	Low-Risk	Phu Tho	Thanh Son	Northeast	Low-Risk
Ha Giang	Bac Quang	Northeast	Low-Risk	Ha Giang	Vi Xuyen	Northeast	Low-Risk	Phu Tho	Thanh Son	Northeast	Low-Risk

(b)

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Lao PDR

Date of FFG products 15/08/2021 00:00 UTC time

01-Hour Flash Flood Risk and Location					03-Hour Flash Flood Risk and Location					06-Hour Flash Flood Risk and Location				
Provinces	Districts	Villages	Region	Level Risk	Provinces	Districts	Villages	Region	Level Risk	Provinces	Districts	Villages	Region	Level Risk
Bolikhamxay	Paksanh	XAYSAVANG	Central Laos	Low-Risk	Bolikhamxay	Paksanh	XAYSAVANG	Central Laos	Low-Risk	Xiengkhuang	Morkmay	KHANGVIENG	Northeast	Low-Risk
Bolikhamxay	Thaphabat	HOUAYGNAI	Central Laos	Low-Risk	Bolikhamxay	Thaphabat	HOUAYGNAI	Central Laos	Low-Risk	Xaysomboun	Hom	VIENGKEO	province is mountainous Northeast	Low-Risk
Bolikhamxay	Thaphabat	HATKHAY	Central Laos	Low-Risk	Bolikhamxay	Thaphabat	HATKHAY	Central Laos	Low-Risk	Xiengkhuang	Khoune	MEUANG	Northeast	Low-Risk
Xaysomboun	Hom	KORMI	province is mountainous Northeast	Moderate-Risk	Xaysomboun	Hom	KORMI	province is mountainous Northeast	Low-Risk	Bolikhamxay	Paksanh	XAYSAVANG	Central Laos	Low-Risk
Xaysomboun	Hom	MUANGSOUM	province is mountainous Northeast	Low-Risk	Xaysomboun	Hom	MUANGSOUM	province is mountainous Northeast	Low-Risk	Bolikhamxay	Thaphabat	HOUAYGNAI	Central Laos	Low-Risk
Bolikhamxay	Thaphabat	GNANGKHEUA	Central Laos	Low-Risk	Vientiane	Thoulakho	NAM ANG	Northwest	Moderate-Risk	Bolikhamxay	Thaphabat	HATKHAY	Central Laos	Low-Risk
Bolikhamxay	Thaphabat	SOMSA-ATH	Central Laos	Low-Risk	Vientiane	Thoulakho	NAWA	Northwest	Low-Risk	Xaysomboun	Hom	KORMI	province is mountainous Northeast	Moderate-Risk
Vientiane	Thoulakho	NAM ANG	Northwest	Moderate-Risk	Vientiane	Feuang	NAMOUANG	Northwest	Low-Risk	Xaysomboun	Hom	MUANGSOUM	province is mountainous Northeast	Low-Risk
Vientiane	Thoulakho	NAWA	Northwest	Low-Risk	Luangprabang	Pak xeng	NAMAI	North	Low-Risk	Bolikhamxay	Thaphabat	GNANGKHEUA	Central Laos	Low-Risk
Vientiane	Feuang	MOUANGFOUANG	Northwest	Low-Risk	Luangprabang	Viengkham	PHOUHING	North	Low-Risk	Bolikhamxay	Thaphabat	SOMSA-ATH	Central Laos	Low-Risk
Vientiane Municipality	Sangthong	MAIPAKSANG	Northwest	Low-Risk	Luangprabang	Viengkham	HUAYKOU	North	Low-Risk	Vientiane	Thoulakho	NAM ANG	Northwest	Moderate-Risk
Vientiane	Feuang	NAMOUANG	Northwest	Low-Risk	Luangprabang	Viengkham	HATKAI	North	Low-Risk	Vientiane	Thoulakho	NAWA	Northwest	Low-Risk
Vientiane	Xanakham	NASAK	Northwest	Low-Risk	Luangprabang	Phonxay	PHOUNGONG	North	Low-Risk	Xiengkhuang	Pek	PHOUVIENG	Northeast	Low-Risk
Vientiane	Xanakham	NAMKUAN	Northwest	Low-Risk	Luangprabang	Viengkham	PAPHAI	North	Low-Risk	Vientiane	Feuang	MOUANGFOUANG	Northwest	Low-Risk
Luangprabang	Pak xeng	NAMAI	North	Low-Risk	Luangprabang	Viengkham	PHONEXAI	North	Low-Risk	Vientiane Municipality	Sangthong	MAIPAKSANG	Northwest	Low-Risk
Luangprabang	Viengkham	PHOUHING	North	Low-Risk	Luangprabang	Viengkham	VANGMAAT	North	Low-Risk	Vientiane	Feuang	NAMOUANG	Northwest	Low-Risk
Luangprabang	Viengkham	HUAYKOU	North	Low-Risk	Luangprabang	Viengkham	NAVAEN	North	Low-Risk	Vientiane	Xanakham	NASAK	Northwest	Low-Risk
Luangprabang	Viengkham	HATKAI	North	Low-Risk	Luangprabang	Viengkham	NAMXAI	North	Low-Risk	Vientiane	Xanakham	NAMKUAN	Northwest	Low-Risk
Luangprabang	Phonxay	PHOUNGONG	North	Moderate-Risk	Luangprabang	Viengkham	NONGKHAM	North	Moderate-Risk	Phongsaly	Phongsaly	HOUAYLOU	North	Low-Risk
Luangprabang	Pak xeng	HUAYSOK	North	Low-Risk	Luangprabang	Phonxay	HUAYKHING	North	Low-Risk	Luangprabang	Ngoi	DONLORMI	North	Low-Risk
Luangprabang	Viengkham	PARKTHEU	North	Low-Risk	Luangprabang	Phonxay	LONGYOMNOI	North	Low-Risk	Luangprabang	Ngoi	NAMTAN	North	Low-Risk
Luangprabang	Viengkham	PAPHAI	North	Low-Risk	Luangprabang	Phonxay	NONG ON	North	Low-Risk	Luangprabang	Nambak	KIOUCHADI	North	Low-Risk
Luangprabang	Viengkham	PHONEXAI	North	Low-Risk	Luangprabang	Phonxay	HUAYPOTE	North	Low-Risk	Luangprabang	Ngoi	SIBVAN	North	Low-Risk
Luangprabang	Viengkham	VANGMAAT	North	Low-Risk	Luangprabang	Phonxay	MOKCHONG	North	Low-Risk	Luangprabang	Pak xeng	NAMAI	North	Low-Risk
Luangprabang	Viengkham	NAVAEN	North	Moderate-Risk	Luangprabang	Luangprab	LONGWAY KAO	North	Low-Risk	Luangprabang	Park Ou	HOUAYLERN	North	Low-Risk
Luangprabang	Viengkham	NAMXAI	North	Moderate-Risk	Luangprabang	Phonxay	HEUADOI	North	Low-Risk	Luangprabang	Viengkham	PHOUHING	North	Low-Risk
Luangprabang	Viengkham	HATKHOUN	North	Low-Risk	Luangprabang	Phonxay	HUAYCHANG	North	Low-Risk	Luangprabang	Viengkham	HUAYKOU	North	Low-Risk
Luangprabang	Viengkham	NONGKHAM	North	Moderate-Risk	Huaphanh	Viengthon	HUAYSA	Eastern	Low-Risk	Luangprabang	Viengkham	HATKAI	North	Low-Risk
Luangprabang	Phonxay	HUAYKHING	North	Low-Risk	Huaphanh	Viengthon	NAPHONE	Eastern	Low-Risk	Luangprabang	Viengkham	PHONEVIENG	North	Low-Risk

2.5.4 Conclusions

- The influence of the ICTZ caused heavy rain and very heavy rain in some areas in the northeast parts of Viet Nam and some provinces of Lao PDR.
- The comparison between real and satellite rainfall data from the system shows that there is a significant difference between these two values. For example, in Vang Vieng (Lao PDR), observed rainfall and MAP24h from the FFGS (satellite data) on August 16 are 107.7 mm and 22.89 mm, at Khong Chiam (Thailand) on August 14, observed rainfall was 129.50 mm and MAP24h 12.84 mm. In the meanwhile, at some other locations, it shows that the rainfall determination system is quite good, for example, at Muong Mai (Lao PDR) on August 15 (observed:113 mm, MAP24h: 131 mm), at Muang Kao (Lao PDR) (observed: 108 mm and MAP24h: 97.73 mm). From this analysis and through the operation of the system, the accuracy in determining the amount of precipitation caused by the ICTZ elements of the MRC-FFGS system is not better than amount of precipitation caused by storm circulation.
- During this time of intense heavy rainfall, the MRC-FFGS has correctly detected almost all serious

flash flood events in the northwest provinces of Viet Nam. Some of them are corresponded with the reported flash flood areas via newspaper or internet (see **Annex A.3**)

2.6 Flash flood event during 10-14 September caused by tropical storm CONSON

2.6.1 Weather condition during 10-14 September 2021

The monsoon trough lay across the lower northern, central, and north-eastern parts of the LMB in this period. It lay toward the tropical depression "CONSON" on 12 - 13 September which made landfall at Quang Ngai, Viet Nam in the early morning of 12 September, and weakened into an active low-pressure cell covering the coast of Viet Nam in the morning of 13 September. In addition, the active SW Monsoon which prevailed over the Gulf of Thailand was weakened to the moderate SW Monsoon during the period (see **Figure 2-21**).

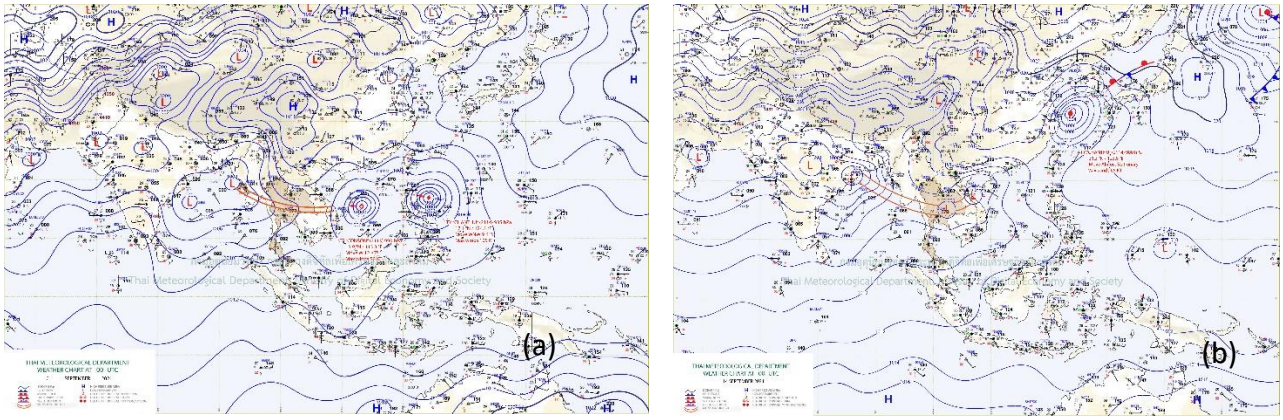

Figure 2-21: Weather map for (a) 10 September and (b) 14 September (Source: TMD)

Tropical storm CONSON: At 06:00 UTC of September 5, the United States JTWC started to monitor a tropical disturbance in the Philippine Sea. At 18:00 UTC that day, the JMA upgraded the system to a tropical depression, followed simultaneously with the Philippine Atmospheric, Geophysical and Astronomical Services Administration's (PAGASA) designation of the storm as Tropical Depression **Jolina** as it was under the agency's area of responsibility.

The JTWC issued a Tropical Cyclone Formation Alert (TCFA) at 23:30 UTC as a circulation was now evident along the system and an organizing convective band to its south-southeast. The same agency further upgraded the storm to a tropical depression on the next day as it further consolidated, with a persistent area of thunderstorms over an obscured Low Level Circulation Center (LLCC). Moving north-westward under the periphery of a subtropical ridge to the northeast, its organization continued to improve with an eye feature developing and at 06:00 UTC that day, the depression strengthened to a tropical storm according to the estimates of JMA and PAGASA, with the former naming it **CONSON** and the JTWC did the same, three hours later.

At 09:00 UTC (17:00 PHT), the PAGASA reported that the system further intensified to a severe tropical storm while nearing Samar Island of Philippine. Over the next hours, its convection further expanded to the east from the southeast and as a result the JMA upgraded the system as well, two hours later.

In brief, from August 6 to 9, CONSON made landfall and became active in the Philippines area, then the storm passed into the East Sea, and it continued tracking westward on September 10, however, high vertical wind shear exposed its LLCC, weakening the storm. CONSON later regained some of its strength as it organized and regained a defined LLCC in the early hours of September 11, however this was short-lived as it had later become exposed again due to wind shear. As a result of this, the JMA downgraded the system to a tropical storm at 12:00 UTC on that day and further, with the JTWC reporting that CONSON further degraded to a tropical depression at 18:00 UTC and 02:00 UTC that day and on September 12. Remaining weak and exposed, the storm stalled near **Quang Ngai Province** in South-central Viet Nam under a weak steering pattern of three ridges. At 21:00 UTC, the JTWC issued its final bulletin on the storm, indicating that CONSON already made landfall near **Da Nang** and it rapidly weakened overland. Meanwhile, the JMA tracked the system until it fully dissipated on September 13 at 18:00 UTC. The track of tropical storm CONSON is shown in **Figure 2-22**.

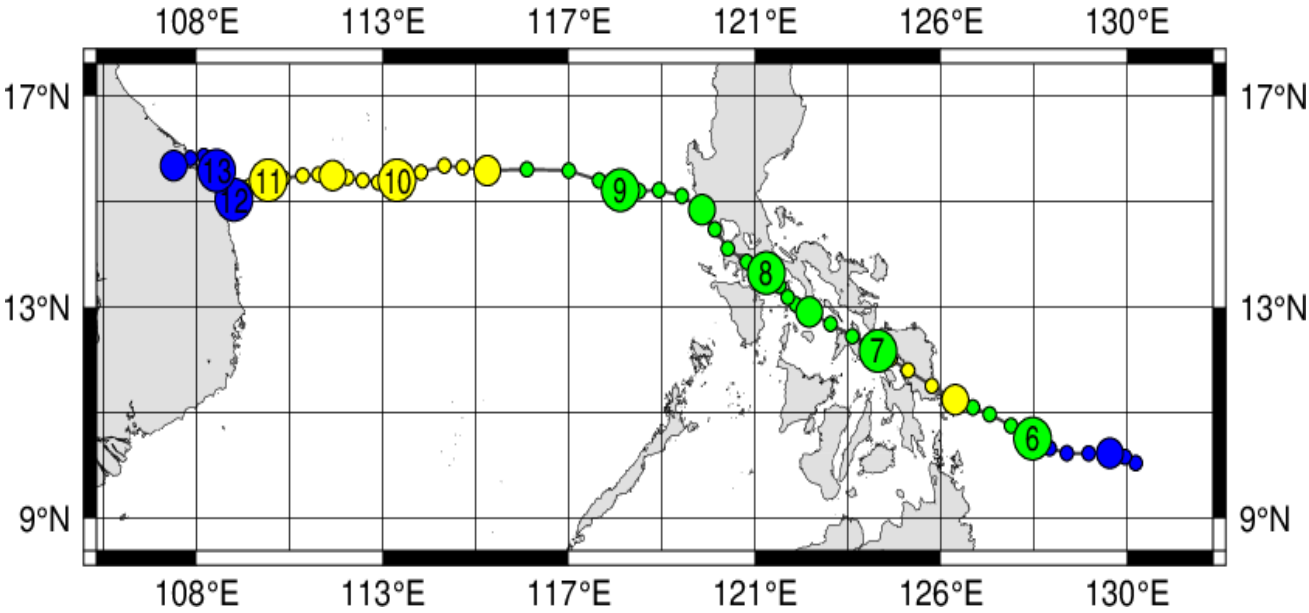

Figure 2-22: The track of tropical storm CONSON (Source: JMA)

2.6.2 Heavy rainfall during 10-14 September 2021

During period of 10-14 September 2021, regarding to the daily rainfall observed from the MCs the storm CONSON's circulation caused very heavy rainfall in some areas in the LMB on September 12, such as in Viet Nam at Dong Hoi (152 mm), at Dong Ha (150 mm), at A Luoi (220 mm), in Lao PDR at Saravanne (156 mm) and at Pakse (141 mm). The map of rainfall distribution during 10 -14 September 2021 in the LBM is shown in the **Figure 2-23** and daily rainfall observed at some stations in the LMB is shown in the

Table 2-9.

Table 2-9: Daily rainfall observed at some stations in the LMB (10-14 September 2021)

Unit: mm

Time	Dong Hoi	Dong Ha	A Luoi	Khe Sanh	Khong Sedone	Saravanne	Pakse
9/10/2021	53.20	15.40	2.10	4.30	6.00	0.00	27.40
9/11/2021	1.80	14.60	34.90	8.00	93.90	18.40	15.60
9/12/2021	152.00	150.00	220.00	83.00	33.60	156.20	141.30
9/13/2021	63.00	139.00	84.00	102.00	31.10	62.40	43.60
9/14/2021	83.00	29.00	49.00	23.00	1.30	3.40	2.20
Sum	**353.00**	**348.00**	**390.00**	**220.30**	**165.90**	**240.40**	**230.10**

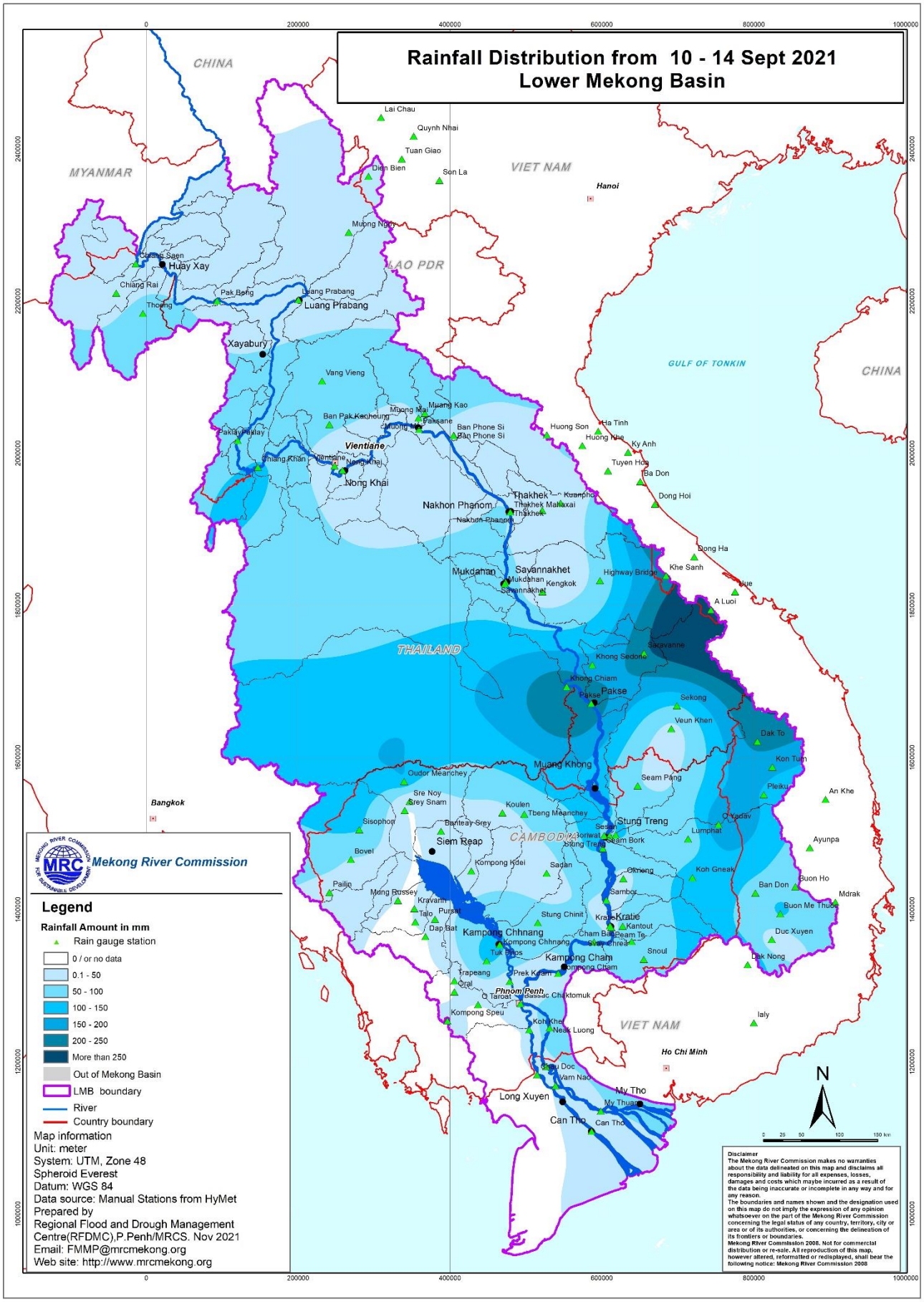

Figure 2-23 Rainfall distribution during 10 -14 September 2021 in the LMB

2.6.3 Flash flood event on 12 September 2021

Based on the MRC-FFGS products, the satellite rainfall MAP24h and the ASM, very heavy rainfall was detected in the central highlands and south-central coat areas of Viet Nam, south and southeast areas of Lao PDR at 00:00 UTC (00:00 local time) on September 12. Those results show that the rainfall in many areas was more than 120 mm/24h and the soil moisture in those areas was also very wet, saturated in a wide range of the areas where heavy rainfall is described above (**Figure 2-24**).

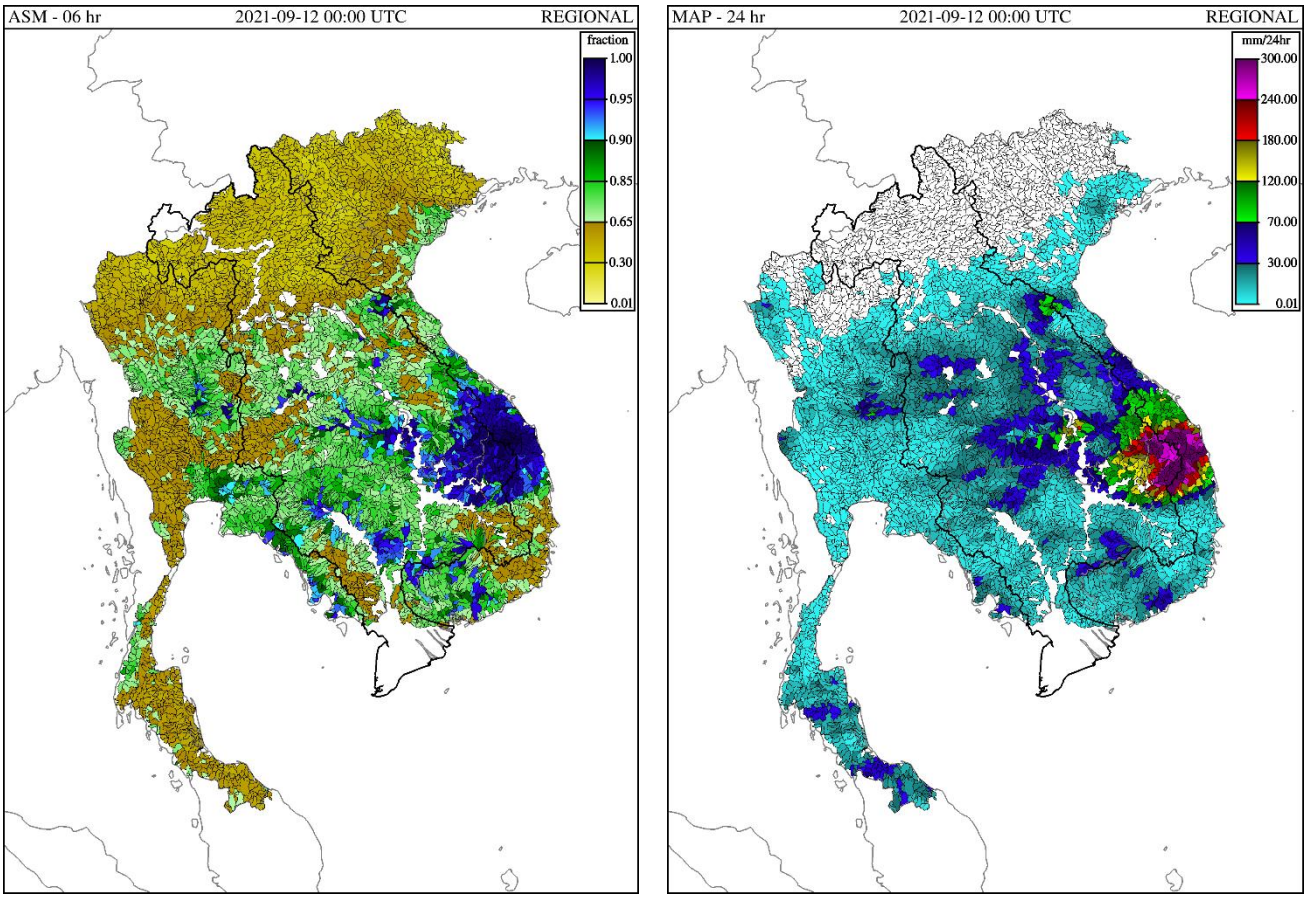

Figure 2-24: MAP24h and ASM on 18th October 2020 at 00:00 UTC (07: 00 local time)

The comparison between MAP24h and rainfall observed at some gauging stations during the period from 7 – 14 October is shown in Error! Reference source not found.. It is shown that rainfall satellite d ata and measured data (24hrs) are good in terms of time and space.

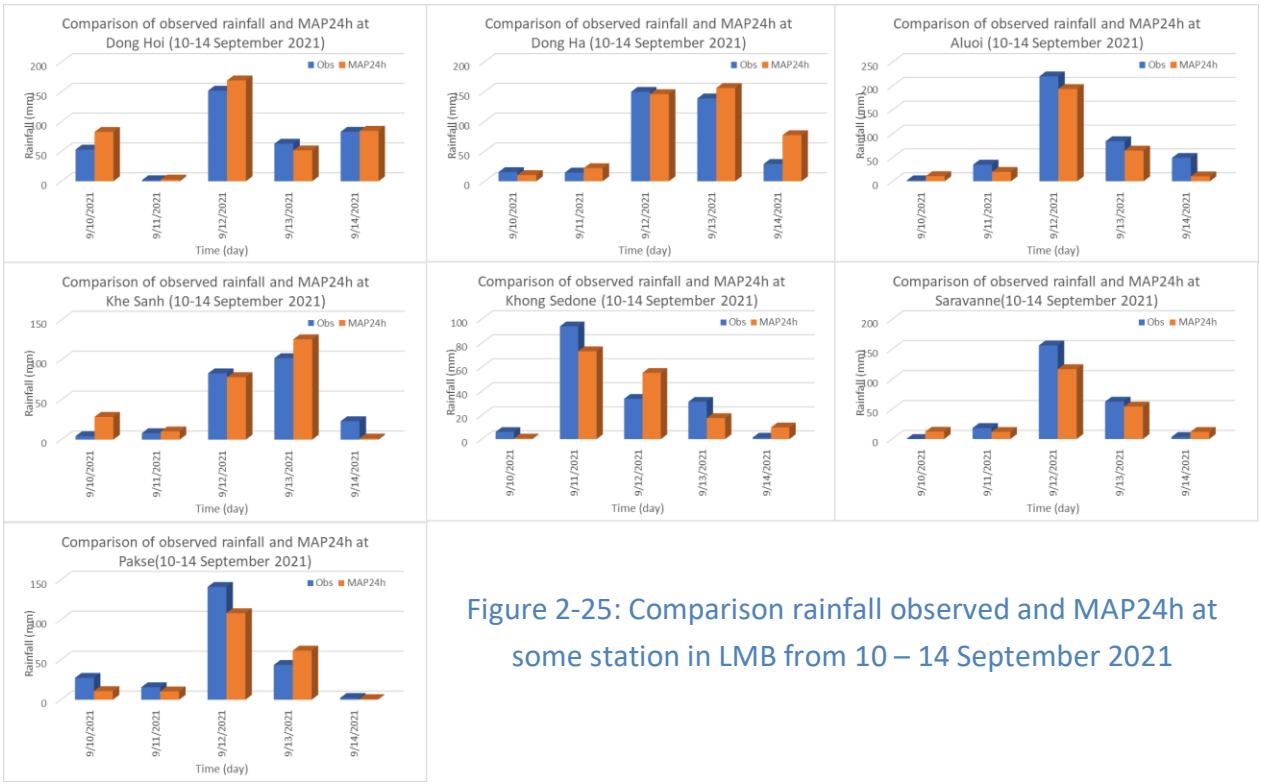

Figure 2-25: Comparison rainfall observed and MAP24h at some station in LMB from 10 – 14 September 2021

RFDMC's forecaster submitted the flash flood warning for 1, 3, and 6 hours on 00:00 UTC 18th October 2020. Some areas in Viet Nam and Lao PDR were predicted with high risk of flash flood as shown in the **Figure 2-26** and

Table 2-10.

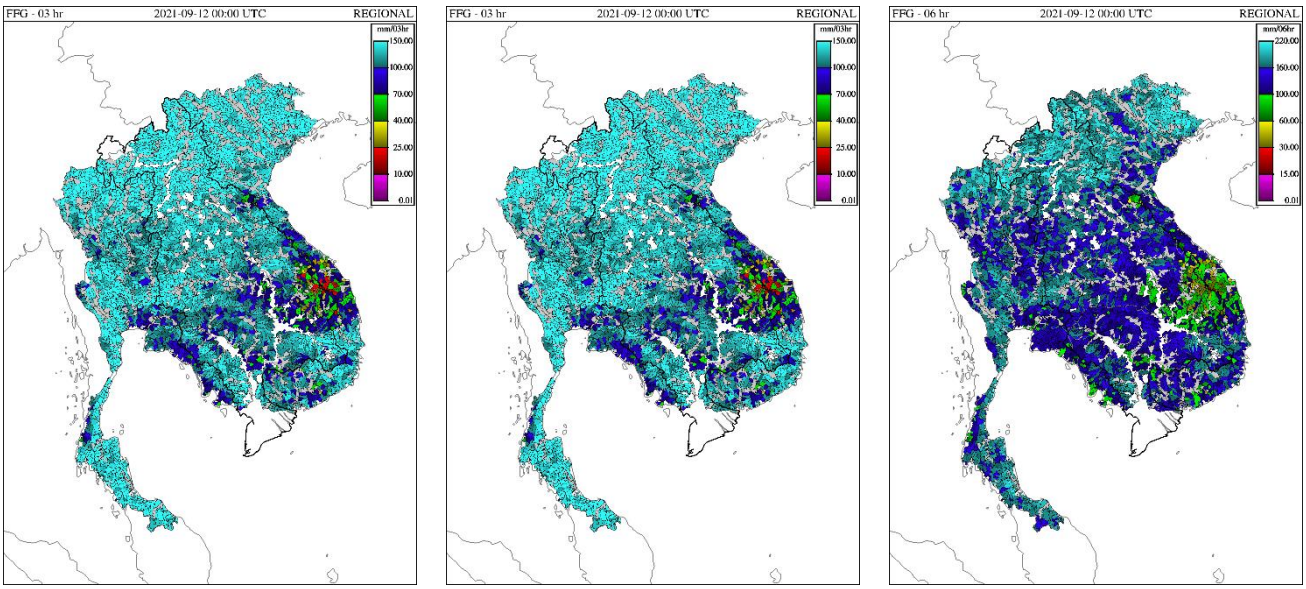

Figure 2-26: FFG 01, 03 and 06-hour on 12 September 2021 at 00:00 UTC (07: 00 local time)

Table 2-10: FFG detected by the MRC-FFGS in (a) Viet Nam, (b) Lao PDR, on 12 September 2021 at 00:00 UTC (07: 00 Local time)

(a)

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Viet Nam

Date of FFG products 9/12/2021 0:00 UTC time

01-Hour Flash Flood Risk and Location				3-Hour Flash Flood Risk and Location in Vietnam				6-Hour Flash Flood Risk and Location in Vietnam			
Provinces	Districts	Region	Level Risks	Provinces	Districts	Region	Level Risks	Provinces	Districts	Region	Level Risks
Kon Tum	Sa Thay	Central Highlands	High-Risk	Kon Tum	Sa Thay	Central Highlands	Moderate-Risk	Gia Lai	Ia Grai	Central Highlands	Moderate-Risk
Gia Lai	Ia Grai	Central Highlands	High-Risk	Gia Lai	Ia Grai	Central Highlands	Moderate-Risk	Gia Lai	Duc Co	Central Highlands	Low-Risk
Gia Lai	Chu Prong	Central Highlands	Low-Risk	Gia Lai	Chu Se	Central Highlands	Low-Risk	Gia Lai	Chu Prong	Central Highlands	Low-Risk
	Dak To	Central Highlands	Extreme-Risk	Quang Ngai	Ba To	South Central Coast	High-Risk	Gia Lai	Ayun Pa	Central Highlands	Low-Risk
Gia Lai	Chu Se	Central Highlands	Low-Risk	Dak Lak	Ea Sup	Central Highlands	Low-Risk	Gia Lai	Chu Se	Central Highlands	Low-Risk
Dak Lak	Ea Sup	Central Highlands	Low-Risk	Dak Lak	TX. Buon Ma Thuot	Central Highlands	Low-Risk	Quang Tri	Huong Hoa	North Central	Moderate-Risk
Dak Lak	Ea Sup	Central Highlands	Low-Risk	Nghe An	Thanh Chuong	North Central	Low-Risk	Dak Lak	Ea Sup	Central Highlands	Low-Risk
Dak Lak	Cu Jut	Central Highlands	Low-Risk	Quang Tri	Huong Hoa	North Central	Moderate-Risk	Dak Lak	Cu Jut	Central Highlands	Low-Risk
Dak Lak	TX. Buon Ma Thuot	Central Highlands	Low-Risk	Ha Tinh	Huong Son	North Central	Moderate-Risk	Dak Lak	TX. Buon Ma Thuot	Central Highlands	Low-Risk
Dak Lak	Dak Mil	Central Highlands	Low-Risk	Gia Lai	Duc Co	Central Highlands		Dak Lak	Dak Mil	Central Highlands	Low-Risk
Dak Lak	Ea Sup	Central Highlands	Low-Risk	Thua Thien Hue	A Luoi	North Central		Nghe An	Thanh Chuong	North Central	Low-Risk
Dak Lak	Ea Sup	Central Highlands	Low-Risk	Quang Nam	Nam Giang	South Central Coast		Thua Thien Hue	A Luoi	North Central	Moderate-Risk
Gia Lai	Duc Co	Central Highlands	Moderate-Risk	Quang Nam	Nam Giang	South Central Coast		Quang Binh	Bo Trach	North Central	Low-Risk
Quang Nam	Nam Giang	South Central Coast	High-Risk	Quang Binh	Bo Trach	North Central	Moderate-Risk	Quang Nam	Nam Giang	South Central Coast	Moderate-Risk
Quang Binh	Quang Ninh	North Central	Moderate-Risk	Quang Binh	Quang Ninh	North Central	Moderate-Risk	Quang Binh	Quang Ninh	North Central	Moderate-Risk
Quang Binh	Le Thuy	North Central	Moderate-Risk	Quang Binh	Le Thuy	North Central	High-Risk	Quang Binh	Le Thuy	North Central	Moderate-Risk
Quang Tri	Da Krong	North Central	High-Risk	Quang Tri	Da Krong	North Central	Moderate-Risk	Quang Tri	Da Krong	North Central	Moderate-Risk
Quang Binh	Bo Trach	North Central	Low-Risk	Thua Thien Hue	Phong Dien	North Central	Moderate-Risk	Thua Thien Hue	Phong Dien	North Central	Moderate-Risk
Quang Tri	Vinh Linh	North Central	Low-Risk	Quang Nam	Hien	South Central Coast	High-Risk	Thua Thien Hue	Nam Dong	North Central	Moderate-Risk
Ha Tinh	Huong Son	North Central	High-Risk	Thua Thien Hue	Nam Dong	North Central	Moderate-Risk	Quang Nam	Que Son	South Central Coast	Moderate-Risk
Thua Thien Hue	A Luoi	North Central	High-Risk	Da Nang	Hoa Vang	South Central Coast	Low-Risk	Da Nang	Lien Chieu	South Central Coast	Low-Risk
Nghe An	Thanh Chuong	North Central	Low-Risk	Da Nang	Hoa Vang	South Central Coast	Moderate-Risk	Kon Tum	Dak Glei	Central Highlands	High-Risk
Quang Tri	Huong Hoa	North Central	Moderate-Risk	Da Nang	Hoa vang	South Central Coast	Moderate-Risk	Quang Nam	Hien	South Central Coast	Moderate-Risk
Thua Thien Hue	Phong Dien	North Central	High-Risk	Quang Nam	Dai Loc	South Central Coast	High-Risk	Da Nang	Hoa vang	South Central Coast	Moderate-Risk
Quang Nam	Hien	South Central Coast	High-Risk	Quang Nam	Tra My	South Central Coast	Moderate-Risk	Quang Nam	Dai Loc	South Central Coast	Moderate-Risk
Thua Thien Hue	Nam Dong	North Central	Moderate-Risk	Quang Nam	Tra My	South Central Coast	High-Risk	Quang Nam	Phuoc Son	South Central Coast	Moderate-Risk
Da Nang	Lien Chieu	South Central Coast	Low-Risk	Kon Tum	Dak Glei	Central Highlands	High-Risk	Quang Nam	Tien Phuoc	South Central Coast	Low-Risk
Da Nang	Hoa vang	South Central Coast	High-Risk	Quang Nam	Que Son	South Central Coast	Moderate-Risk	Quang Nam	Tra My	South Central Coast	Moderate-Risk
Quang Nam	Dai Loc	South Central Coast	High-Risk	Quang Ngai	Son Tay	South Central Coast	High-Risk	Kon Tum	Dak To	Central Highlands	High-Risk

(b)

Rate-risk and location of the flash flood may occur in the next 1, 3, and 6 hours in Lao PDR

Date of FFG products 9/12/2021 0:00 UTC time

01-Hour Flash Flood Risk and Location					03-Hour Flash Flood Risk and Location					06-Hour Flash Flood Risk and Location				
Provinces	Districts	Villages	Region	Level Risk	Provinces	Districts	Villages	Region	Level Risk	Provinces	Districts	Villages	Region	Level Risk
Champasak	Khong	THAHIN TAI	Southwestern	Low-Risk	Savannakhet	Nong	TALING	Southern	Low-Risk	Champasak	Khong	THAHIN TAI	Southwestern	Low-Risk
Savannakhet	Sepone	THAKHONG	Southern	Low-Risk	Savannakhet	Nong	GNANG	Southern	Low-Risk	Savannakhet	Sepone	THAKHONG	Southern	Low-Risk
Savannakhet	Sepone	SALOUNG	Southern	Low-Risk	Savannakhet	Nong	LAGNENG KHOK	Southern	Low-Risk	Savannakhet	Sepone	SALOUNG	Southern	Low-Risk
Sekong	Kaleum	TIN	Southeast	High-Risk	Saravane	Ta oi	TUMLEKHAO	South	Low-Risk	Saravane	Samuoi	ATUK	South	Low-Risk
Sekong	Kaleum	STTHORN	Southeast	High-Risk	Saravane	Ta oi	PHOR SANH	South	High-Risk	Savannakhet	Nong	TALING	Southern	Low-Risk
Savannakhet	Nong	GNANG	Southern	Low-Risk	Bolikhamxay	Khamkheut	PHAPOUN	Central Laos	Low-Risk	Savannakhet	Nong	GNANG	Southern	Low-Risk
Savannakhet	Nong	LAGNENG KHOK	Southern	Low-Risk	Bolikhamxay	Khamkheut	PHONESI	Central Laos	Low-Risk	Savannakhet	Nong	LAGNENG KHOK	Southern	Low-Risk
Savannakhet	Nong	PASANEIR TAI	Southern	Low-Risk	Bolikhamxay	Khamkheut	NAMSANGIN	Central Laos	Low-Risk	Savannakhet	Nong	PASANEIR TAI	Southern	Low-Risk
Saravane	Ta oi	TUMLEKHAO	South	Low-Risk	Bolikhamxay	Khamkheut	NAPHOUANG	Central Laos	Low-Risk	Saravane	Ta oi	TUMLEKHAO	South	Low-Risk
Saravane	Ta oi	PHOBEUI	South	Low-Risk	Khammuane	Hinboon	MOUANG NAM SANG	Center of Laos	Low-Risk	Saravane	Ta oi	PHOBEUI	South	Low-Risk
Saravane	Ta oi	PHOR SANH	South	High-Risk	Champasak	Pathoomph	NAMPHAAK	Southwestern	Low-Risk	Saravane	Ta oi	PHOR SANH	South	High-Risk
Saravane	Ta oi	TUMLE KAO	South	Low-Risk	Attapeu	Xaysetha	XENOI	Sotheast	Low-Risk	Saravane	Ta oi	TUMLE KAO	South	Low-Risk
Bolikhamxay	Khamkheut	PHAPOUN	Central Laos	Low-Risk	Champasak	Paksong	THONGYAO	Southwestern	Low-Risk	Saravane	Ta oi	KANG	South	Low-Risk
Bolikhamxay	Khamkheut	PHONESI	Central Laos	Low-Risk	Sekong	Kaleum	PRO	Southeast	Moderate-Risk	Savannakhet	Phine	PHAY	Southern	Low-Risk
Bolikhamxay	Khamkheut	NAMSANGIN	Central Laos	Moderate-Risk	Sekong	Kaleum	AR-HOR NEUA	Southeast	Low-Risk	Bolikhamxay	Viengthon	KOKKIENG	Central Laos	Low-Risk
Khammuane	Nakai	PUU	Center of Laos	Low-Risk	Sekong	Kaleum	KA-OUANG	Southeast	Moderate-Risk	Bolikhamxay	Khamkheut	PHAPOUN	Central Laos	Low-Risk
Bolikhamxay	Khamkheut	NAPHOUANG	Central Laos	Moderate-Risk	Sekong	Kaleum	PANORM	Southeast	Low-Risk	Bolikhamxay	Khamkheut	PHONESI	Central Laos	Low-Risk
Khammuane	Hinboon	MOUANG NAM SANG	Center of Laos	Low-Risk	Sekong	Kaleum	AR-PEUANG	Southeast	Low-Risk	Bolikhamxay	Khamkheut	NAMSANGIN	Central Laos	Moderate-Risk
Khammuane	Bualapha	SENE PHANH	Center of Laos	Low-Risk	Sekong	Kaleum	PALAENG	Southeast	Moderate-Risk	Khammuane	Nakai	PUU	Center of Laos	Low-Risk
Khammuane	Bualapha	VANG KHON	Center of Laos	Low-Risk	Sekong	Kaleum	VAK TAI	Southeast	Low-Risk	Bolikhamxay	Khamkheut	PAUNGLAN	Central Laos	Low-Risk
Khammuane	Bualapha	MAI VANG KOUAN	Center of Laos	Low-Risk	Sekong	Kaleum	TIN	Southeast	Moderate-Risk	Bolikhamxay	Khamkheut	NAPHOUANG	Central Laos	Moderate-Risk
Champasak	Pathoomph	NAMPHAAK	Southwestern	Moderate-Risk	Sekong	Kaleum	STTHORN	Southeast	Moderate-Risk	Bolikhamxay	Khamkheut	PAKHA	Central Laos	Low-Risk
Attapeu	Xaysetha	XENOI	Sotheast	Low-Risk	Sekong	Lamarm	KANONG MAI	Southeast	Moderate-Risk	Khammuane	Hinboon	VANG TA KHONG	Center of Laos	Low-Risk

2.6.4 Conclusions

- Due to the influence of the consecutive tropical storm CONSON, its circulation caused heavy rain in some areas in the highland central and south-central coast provinces of Viet Nam and border provinces of Lao PDR.
- During the time, the MRC-FFGS has detected most observed rainfall by space and time. However, compared with the observed rainfall data it was over/underestimate about 10-20 %.
- During this time of intense heavy rain, the MRC-FFGS has correctly detected the flash flood events in Viet Nam and in Lao PDR.The time of flash flood occurring was detected quite good. MRC-FFGS has correctly detected them according to the reported flash flood areas via newspaper or the internet (see Annex A.3).

3 Evaluation of the MRC-FFGS

3.1 Methodology to evaluate the MRC-FFGS

Many verification studies rely on a categorical approach that considers a range of values to be classified into a prescribed category. The categorical approach often refers to the occurrence or non-occurrence of a specific meteorological or hydrological event. The exact nature of the event must be clearly identified with respect to the event characteristics, spatial extent, and time span. For instance, the forecast and observed time series pertaining to the occurrence of a flash flood event can be converted to a categorical time series that contain values of 1 and 0, with the former indicating occurrence and the later indicating non-occurrence in both observed and forecast/simulated time series.

Probability of Detection (PoD) or Hit Rate (HR): $\boldsymbol{PoD} = \boldsymbol{HR} = \frac{a}{a+c}$

Where:

a Hits: Number of observed flash floods that were correctly forecast to be flash floods.

c Misses: Number of observed flash floods that were forecasted to be non – flash flood, or misses.

The HR has a range of 0 to 1 with 1 representing a perfect forecast. It uses only observed events in the contingency table which is sensitive only to missed events and not to false alarm. Therefore, the HR can generally be improved by systematically over-forecasting the occurrence of the event. HR also is incomplete by itself and should be used in conjunction with either the false alarm ratio or the false alarm rate.

To estimate the **a** and **c** numbers above, the methodology for evaluation of flash flood guidance products used in this flash flood report is based on two concepts:

(i) The first concept evaluates the feedback from the MRC-FFGS detected risk areas. As no direct link between the RFDMC and the local population is established, the feed-back information on flash flood areas was mainly collected from the national media, such as online newspapers, and from LAs' forecasters of MCs via communication with RFDMC's forecasters.

(ii) The second concept evaluates the MRC-FFGS results through the recorded water levels that are available in the operational database of RFDMC. If MRC-FFGS detected flash flood warnings in the sub-areas where a gauging station is available, the MRC-FFGS results can be evaluated by comparing with the water level data of the gauging station located in the downstream part of the sub-catchment.

The recorded daily rainfall available at the flash flood risk areas was also used to evaluate if a flash flood really occurred. However, occasionally it is difficult to evaluate the MRC-FFGS results using the media information because flash floods occur in areas that are difficult to access and reporting of

flash floods is lacking. Although the MRC-FFGS often successfully had indicated a flash flood risk in the flooded areas, the information of the occurred flash flood was not accurate or incomplete, which makes the validation of the system difficult. Unfortunately, during the wet season 2020 there were numerous periods in which "missing data" were reported, especially at Phongsaly, Muong Namtha, Oudomxay, Ban Mixay, Vang Vieng, Muong Techpon, Xieng Khoang, and Sayaboury and Moung Ngoy stations located within the northern province of Lao PDR. Limiting the "missing data" in these areas is highly necessary in order to improve the verification of flash floods and getting 'grip' on the accuracy of the system in these areas.

Detailed assessment of PoD is found in **Annex B.**

3.2 Flash flood operation at the RFDMC during wet season 2021

Analysing the flash flood situation in the wet season 2021 and the operation of the MRC-FFGS, the following has been observed:

- The total number of flash flood events across the Mekong region was about 46 events, which is more than the LTA and more than 2020 (34 events). The **Table 3-1** shows the total number and distribution in space and time of flash flood events in the wet season 2021 in the LBM.

Table 3-1: Distribution of flash flood events in the LMB in 2021

Month	FF events	Lao PDR	Thailand	Cambodia	Viet Nam
June	5	1	1	1	2
July	10	2	2	2	4
August	11	3	3	2	3
September	8	2	2	2	2
October	10	2	2	2	4
November	2	0	1	0	1
Total	**46**	**10**	**11**	**9**	**16**

- Most high-intensity flash floods are concentrated in the months of July, August, and October due to the extreme climatic conditions with tropical storms from the Pacific Ocean causing heavy rainfall in the LMB. Besides, some flash food events occurred due to the impact of the ICTZ and Low Pressure.
- Unusual weather in this wet season: Although the wet season is over in November still the ICTZ occurred and caused heavy rainfall leading to several flash floods in the central highlands part of Viet Nam and the middle-part of Lao PDR.

Table 3-2: Calendar date of flash flood recorded in the LMB during wet season 2021

2021 June

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
31	01	02	03	04	05	06
07	08	09	10	11	12	13 L,T,C,V
14	15	16	17	18	19	20
21	22	23	24 V	25	26	27
28	29	30	01	02	03	04
05	06					

2021 July

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
28	29	30	01	02	03	04
05 V	06	07	08	09	10	11
12	13	14	15	16	17	18
19 T,C,V	20	21	22	23 V,L	24	25
26	27	28	29	30	31 L,T,C,V	01
02	03					

2021 August

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
26	27	28	29	30	31	01
02 L,T,V	03	04	05	06	07	08
09	10	11 L	12	13	14	15 L,T,C,V
16	17 T,V	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

2021 September

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
30	31	01	02	03	04	05
06	07	08	09	10	11	12 L,T,C,V
13	14	15	16	17	18	19
20	21	22	23	24 L,T,C,V	25	26
27	28	29	30	01	02	03
04	05					

2021 October

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
27	28	29	30	01	02	03
04	05	06	07	08	09 L,T,C,V	10
11	12	13	14	15	16	17
18 L,T,C,V	19	20	21	22	23	24
25 V	26 V	27	28	29	30	31
01	02					

2021 November

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
01	02	03	04	05	06	07
08	09	10	11	12 T,V	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	01	02	03	04	05
06	07					

Note: :Inter Tropical Convergence Zone (ITCZ) and Low Pressure
: Tropical Storm
V: Viet Nam L: Lao PDR
C: Cambodia T: Thailand

- In general, during wet season 2021 the MRC-FFGS operated very smoothly during the whole wet season. There were a few times some minor errors on server connection, but the RFDMC was technically supported from the HRC (see **Annex C1** for correspondence).
- There was a total of 310 flash flood bulletins uploaded on the RFDMC's website. In general, the MRC-FFGS detected flash flood events during the wet season 2021 with a PoD of around 70 %. False rate was…

  Please see **Annex B** for the evaluation of the MRC-FFGS in each country of the LMB.

4 Conclusions and recommendations

4.1 Conclusions

Flash floods in the LMB are recurrent events which have the potential to adversely affect economic, human, livelihoods, properties, and infrastructures. Moreover, the wet season in 2021 has been affected by unusual climatic factors (e.g. rain appeared late, heavy rain due to storms is concentrated in July, August and October). It makes the MCs increasingly more concerned about flash floods and they are looking for ways to improve flood preparedness to limit the extent of damage. According to the media reported flash floods and landslides occur very often in mountainous areas in the upper and central part of Mekong region.

During wet season 2021, there were 23 tropical storms which developed over the Pacific Ocean and or over the East Sea. There were eighth tropical storms, namely (1) CHOI-WAN, (2) KOGUMA, (3) CEMPAKA, (4) LUPIT, (5) CONSON, (6) DIAMU, (7) LIONROCK, and (8) KOMPASU which caused serious flash floods affecting the LMB. The other causes of flash floods in the LMB is the ITCZ, low pressure and tropical depression which also led to flash flood occurrence at some areas in the Mekong mainstream and its tributaries. Most of the flash flood risk areas in the Mekong region that were detected by the MRC-FFGS occurred in the provinces of Viet Nam (from north to norther-central part), in the northern and south-central part of Lao PDR, and northern part of Thailand.

During the wet season 2021, we found that there were numerous periods in which “missing data” were reported, especially at Phongsaly, Muong Namtha, Oudomxay, Ban Mixay, Vang Vieng, Muong Techpon, Xieng Khoang, and Sayaboury and Moung Ngoy stations located within the northern province of Lao PDR. Limiting the “missing data” in these areas is highly necessary in order to improve the verification of flash floods and getting ‘grip’ on the accuracy of the system in these areas.

The MRC-FFGS has been operating successfully during wet season 2021. The RFDMC provides products to support the development of warning and estimate the risk of flash flooding from rainfall events in the sub-basins of the MRC MCs. The average percentage of accuracy for the correct detection of flash floods is about **71 %** (higher than 2020, which was 65%). See **Annex B** for more detail.

The main aim of this report is to evaluate the performance of the MRC-FFGS in areas of the MRC MCs for the detection of the risk areas of potential flash floods during the wet season 2021 from June until the late of November. The report does not cover all the flash flooding that occurred in 2021 wet season, it is based on the available flash flood information that was collected from the media and information from the MCs. However, it is difficult to evaluate the MRCFFG results using media information because flash floods occurred in areas which are difficult to access and there are no reports available. The MRC-FFGS often indicated a flash flood risk in the flooded areas, but it is lacking an accurate and complete database of flash flood events. This makes it difficult to put a number on the success rate.

Finally, it can be stated that the MRC-FFGS performance during wet season 2021 could predict

expected rainfall amounts with reasonable accuracy; the system is potentially a very effective tool for flash flood forecasting in the LMB.

4.2 Recommendations

The recommendations for further development of the MRC-FFGS for enhancing the accuracy of flash flood forecasting, and to reduce damage, the risk of lives and properties caused by flash floods are listed below:

1. Based on the results of the MRC-FFGS there are still many missing detections of flash flood risk areas by the MRC-FFGS . It is recommended that to improve the MAP product for reliable rainfall measurement the bias correction factor needs to be reviewed. Once the bias correction factor is updated, the MRC-FFGS should be re-run to review and verify the results.
2. In order to develop, implement and operate the MRC-FFGS, data and information such as climatological data (hourly, daily, monthly), precipitation data (hourly, daily, monthly), air temperature (hourly, daily, monthly), soil moisture data, the updated land use/ land cover map, streamflow discharge data for tributary streams to the Mekong River or upstream (hourly, daily, monthly), stream stage data for tributaries (hourly, daily, monthly), radiation data for computation of evapotranspiration (daily, monthly), wind and humidity data for computation of potential evapotranspiration (daily, monthly), etc. are needed for system operations and bias correction. Especially, the data from the MCs should be available to support the operational task and valuation of the MRC-FFGS
3. For the more effective evaluation of the MRC-FFGS and to improve the accuracy of the system, it is recommended to build in the system a more orderly way to collect the information of flash floods. National flood relief authorities should build up a data base on the exact location of flash floods and the damage occurrences, and report to the RFDMC. Then the effectiveness of the system can be properly evaluated, and weaknesses of the system identified and rectified.
4. GIS database of village, district and province information is a significant input to address the high-risk area of flash floods. Since 2010 until present, the RFDMC still lack on the information about the village database in GIS format (ArcGIS point file) of Thailand and Viet Nam for the GIS database. This information would help to improve the capability of the MRC-FFGS to issue a warning on possible flash floods occurrence in Thailand and Viet Nam. It is recommended to figure out how to coordinate with the respective LAs to provide and support village database of Thailand and Viet Nam (GIS point file).
5. The current GIS database with the village, district and province name and boundary was received from national LAs in 2003. This information may not be consistent and out of date compared to the current GIS database of each country. The updated GIS database is a significant input to issue the warnings on possible flash floods occurrences.
6. The RFDMC can further contribute by offering training courses in the use of the MRC-FFGS

and by urging the countries to alert flash flood warnings. It is recommended to conduct refreshment training courses of the MRC-FFGS operation to improve FFG operation, and to exchange the knowledge and experiences on FFG operation between the national centres and the RFDMC.

7. It is recommended to strengthen capacity of the staff at all levels to be able to handle flash flood forecasting and warnings.
8. For effective disaster flash flood risk reduction community awareness of flash floods is essential.

5 References

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Annex A. Newspaper/ Internet/ Media of flash flood events in 2021 in the LBM

5.1 A.1. Flash flood event caused by tropical storm KOGUMA

Source: Vientiane Times

LAO PRESS
IN FOREIGN LANGUAGES

Vientiane Times

www.vientianetimes.org.la www.vientianetimes.la

Villages inundated as heavy rain lashes provinces

Thousands of people in many provinces are suffering from flash floods after heavy rain in recent days has inundated their communities.

Xayaboury, Bokeo, Xieng Khuang and Vientiane provinces have all been affected by varying degrees of flooding since June 13 and 14. In northwestern Xayaboury province, the swollen Houng River overflowed its banks, swamping riverside villages and partially submerging houses.

Local authorities have been battling to move people to higher ground, the province's Deputy Governor Mr Phetthixay Sounvilay told *Vientiane Times* on Monday.

Flooding in Xayaboury province.
--Photo Bay Saysavanh

Xayaboury district has been the hardest hit and more than 10 villages are affected. Roads, water and electricity supply in flooded areas have been cut off, making it hard to move people and their belongings from flooded houses to higher ground.

"As roads are cut off, we are having to use boats to evacuate people, but we have only a limited number," Mr Phetthixay said. Villagers have been evacuated to places on higher ground, such as schools and other public facilities, while others are staying with relatives in unaffected areas.

The number of people left homeless has not yet been assessed because local authorities are busy evacuating people and providing emergency relief, the deputy governor said.

Many people are now in need of shelter, food and drinking water and some need boats to move around.

In Bokeo province, authorities are preparing safe places where people whose homes have been flooded can take shelter, head of the province's Information, Culture and Tourism Department, Dr Somkhit Vongpanya, said.

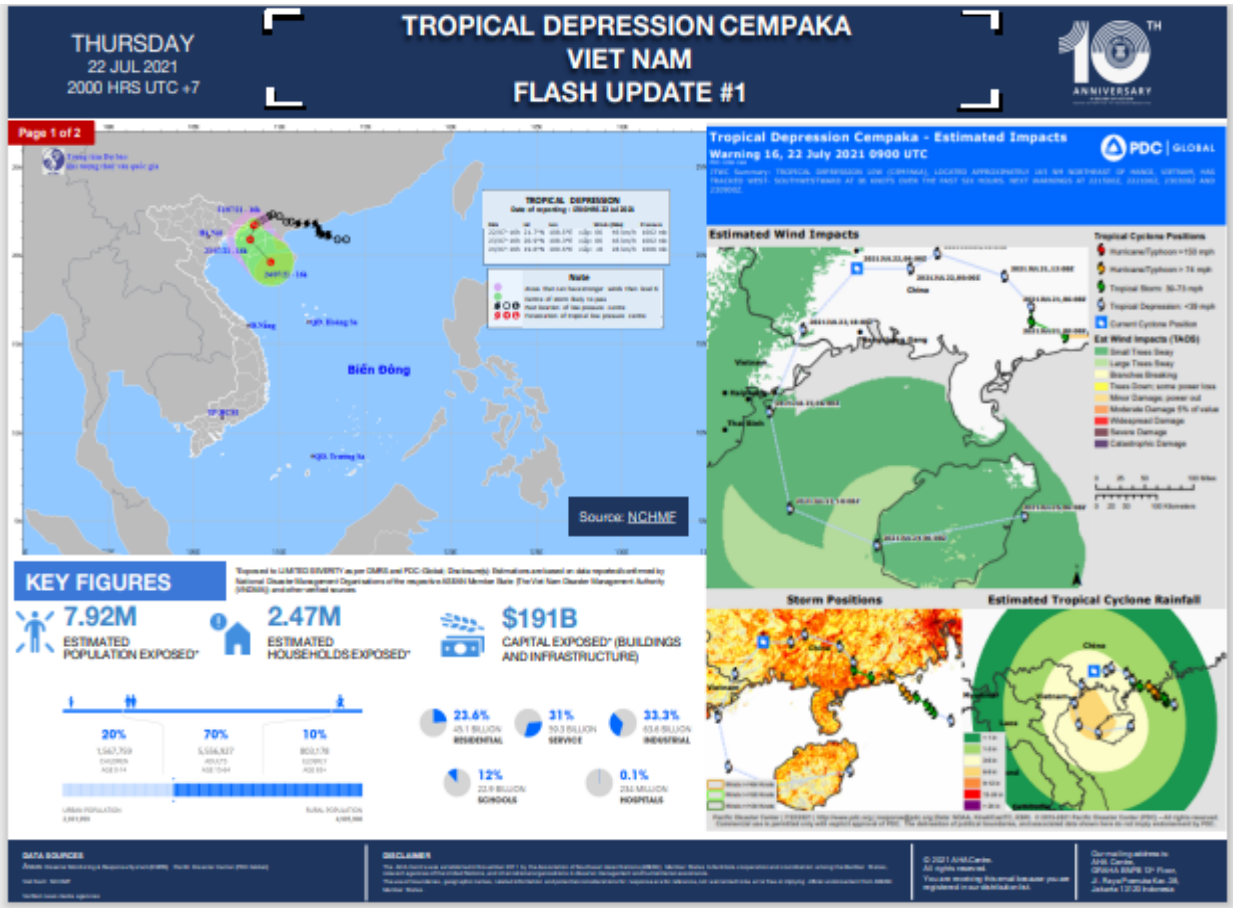
As a result of the floods, people need clothing, food and drinking water, while authorities are assessing the extent of the flooding and collecting information about the number of people affected.

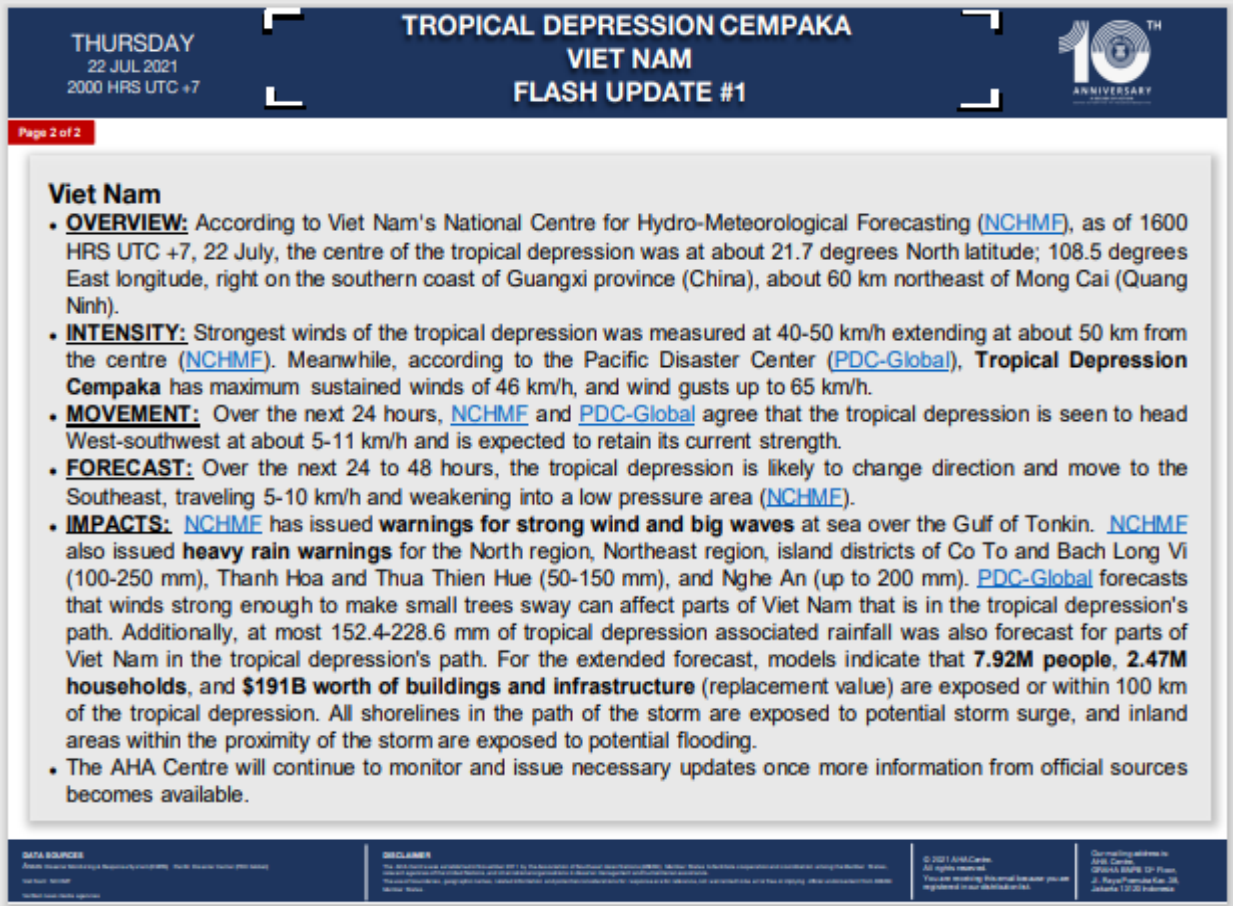
Vangvieng district in Vientiane province has also been affected after the Song River overflowed its banks, inundating local communities and resorts in the tourist hotspot. A well-known orange bridge that crosses the river on the way to Chang Cave has been broken.

Parts of Xieng Khuang province are also flooded and local authorities will report details of the situation as more information becomes available, according to Lao Youth Radio. Photos and video clips posted on social media by official mainstream news channels and local people showed how villagers in the provinces were struggling to move their belongings and vehicles.

The Meteorology and Hydrology Department warned that heavy rain and wind gusts would occur throughout the country until June 14, with flooding and landslides possible in many areas. The department says there will be no storms from June 15-18 but there will be more rain in some parts of the country. Authorities warn everyone to be prepared for weather extremes and to follow forecasts regularly in order to mitigate the effects of severe conditions.

5.2 A.2. Flash flood event caused by tropical storm CAMPAKA





5.3 A.3. Flash flood event caused by ICTZ in Viet Nam

Tin tức thời tiết hôm nay 15.8.2021, các tỉnh vùng núi Bắc bộ có nguy cơ cao xảy ra lũ quét, sạt lở đất sau nhiều ngày mưa lớn.

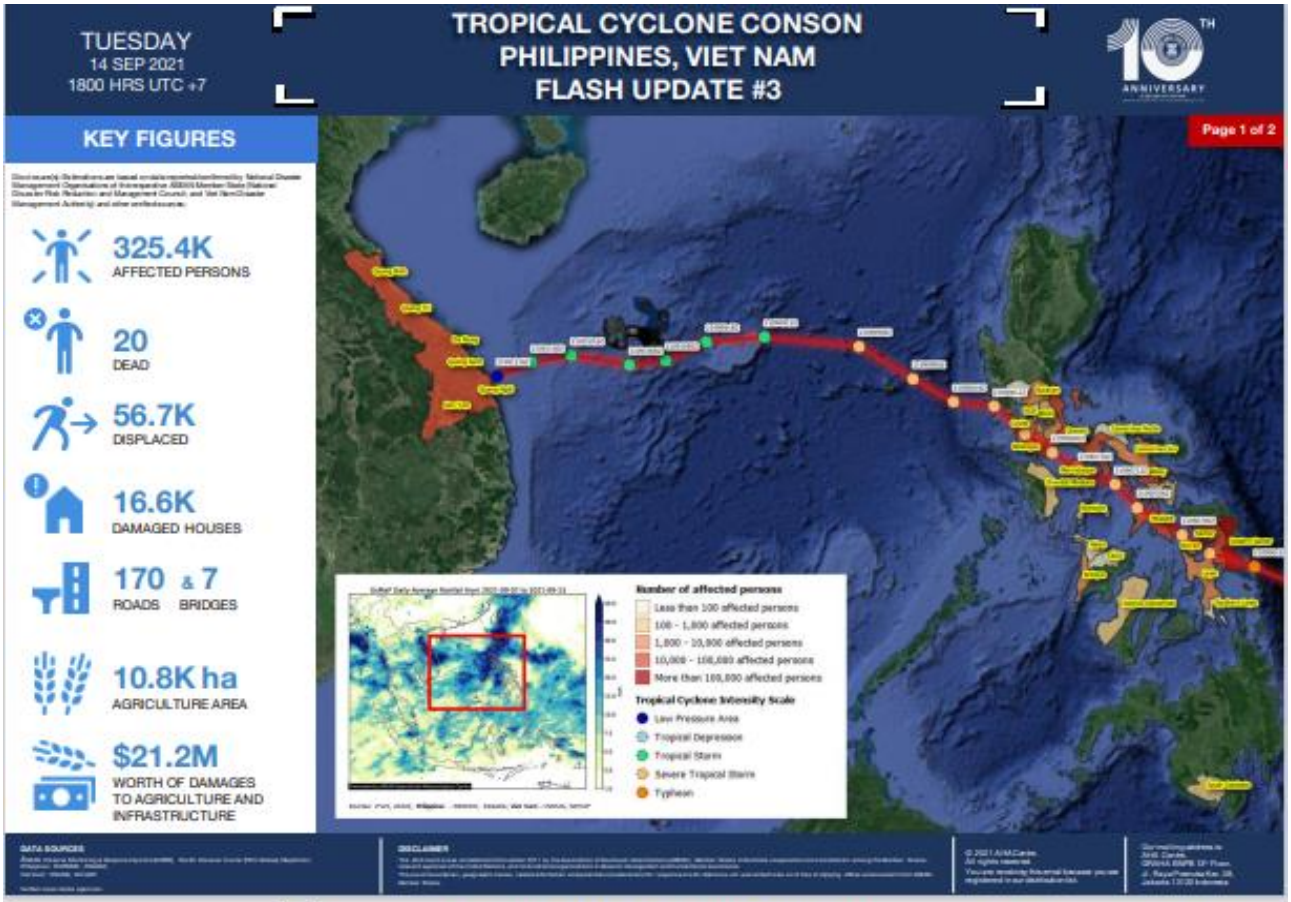
Các tỉnh vùng núi phía Bắc có nguy cơ cao xảy ra lũ quét, sạt lở đất sau nhiều ngày mưa lớn
ẢNH: HOÀNG PHAN

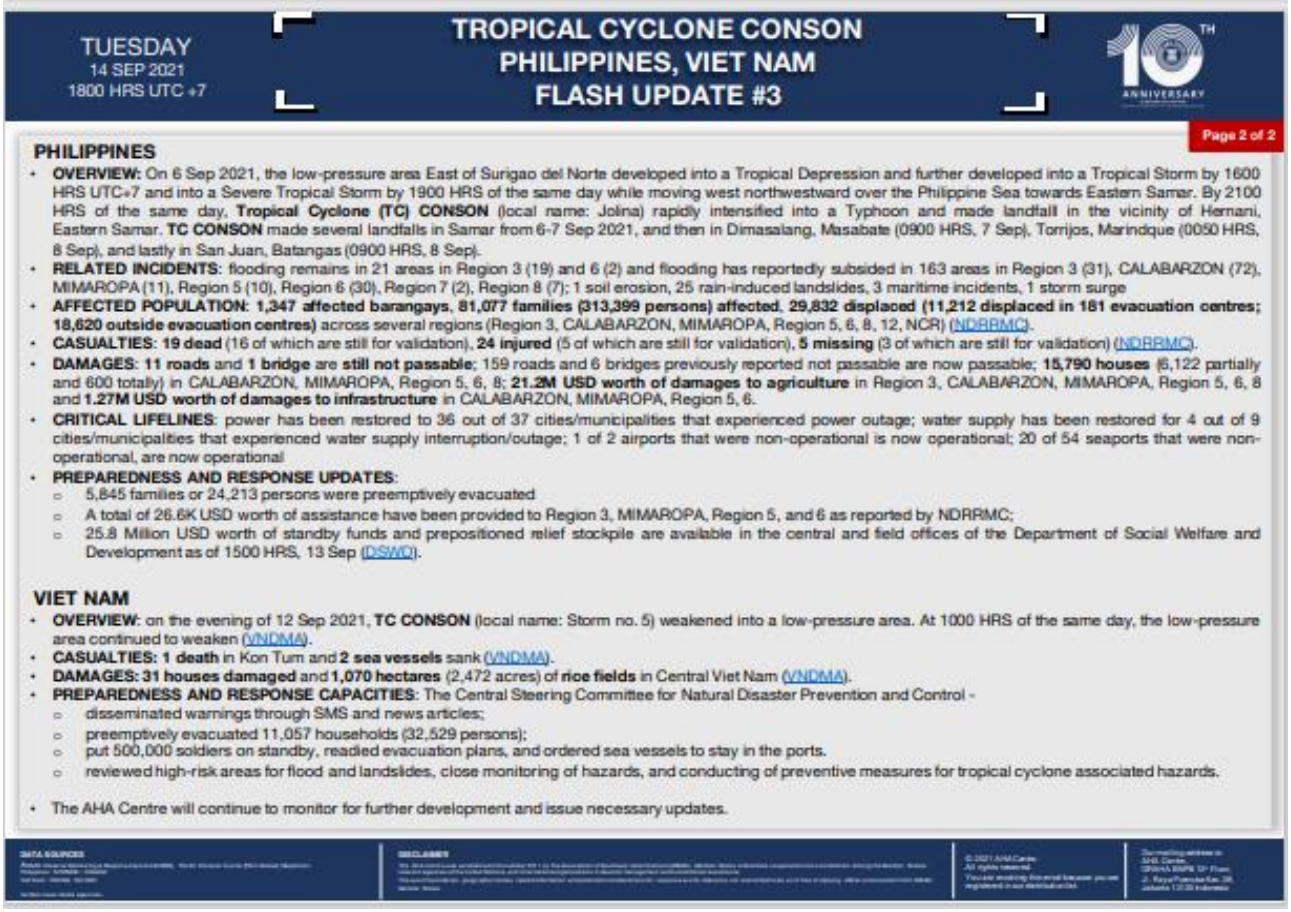
Tin tức thời tiết hôm nay 15.8.2021, Trung tâm Dự báo khí tượng thủy văn quốc gia cho biết, do ảnh hưởng của rãnh áp thấp có trục ở khoảng 21 - 24 độ vĩ bắc kết hợp với hội tụ gió lên đến 5.000 m.

Trong đêm qua 15.8, vùng núi và trung du Bắc bộ tiếp tục có mưa vừa, mưa to, có nơi mưa rất to và rải rác có giông.

Một số nơi có lượng mưa lớn (lượng mưa tính từ 19 giờ ngày 15.8 đến 1 giờ ngày 16.8) tại Vĩnh Tường (Vĩnh Phúc) là 112,6 mm; Chợ Đồn (Bắc Kạn) là 103,4 mm; tại Đại Từ (Thái Nguyên) là 72 mm; tại Lục Yên (Yên Bái) là 70,6 mm; tại Bảo Yên (Lào Cai) là 63,6 mm...

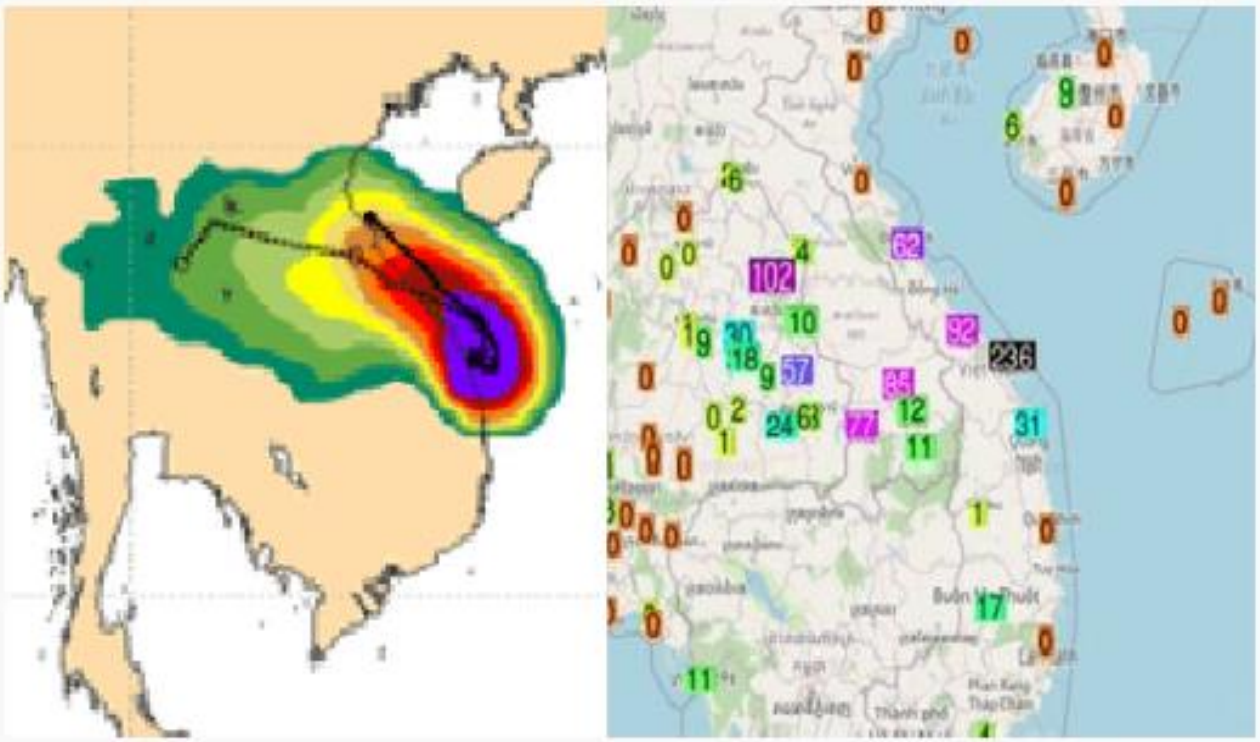
5.4 A.4. Flash flood event caused by by tropical storm CONSON





Tropical storm Conson hit Vietnam, Thailand, Laos, and Cambodia, unbelievable 908 mm of rainfall and 20 dead!

MK September 15, 2021 5 min read



After **Tropical storm Conson hit Philippines** /https://mkweather.com/tropical-storm-conson-hit-the-philippines-vietnam-and-se-china-floods-are-reported-from-thailand-myanmar-cambodia-indonesia-and-east-timor-se-asia//, it aimed directly towards **Vietnam, Thailand, Laos, Cambodia, Myanmar, and southeastern China!**

Together 20 dead **is reported, the most in the Philippines, 2 in Vietnam**.

In Vietnam however, the stronger rainfall event appeared **between 10.-13. September** 2021, with 908 mm rainfall **in Binh Tan, Quang Ngai Province** /https://floodlist.com/asia/vietnam-storm-conson-september-2021/. **In Tra Hiep in Quang Ngai, 807 mm, in Thuong Lo in Thua Thien Hue, 772 mm; in Tam Tra in Quang Nam, 772mm; and in Tra Kot in Quang Nam, 685 mm** was measured.

Severe impact with floods was reported from some parts of **Thailand or Laos**, minor impact was reported in Cambodia, Myanmar, or southeastern China.

All near only 10-minute sustained winds **up to 100 km/h and 985 hPa** in the middle of the system during a maximum of development.

ANNEX B. Accuracy of detected flash floods in the Countries by the MRC-FFGS 2021

THAILAND				
a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	11	3	14
	No	4	4	8
	Total	15	7	310
	Hit rate (POD)	0.73		

LAO PDR				
a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	10	10	20
	No	4	5	9
	Total	14	15	310
	Hit rate (POD)	0.71		

CAMBODIA				
a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	9	2	11
	No	4	4	8
	Total	13	6	310
	Hit rate (POD)	0.69		

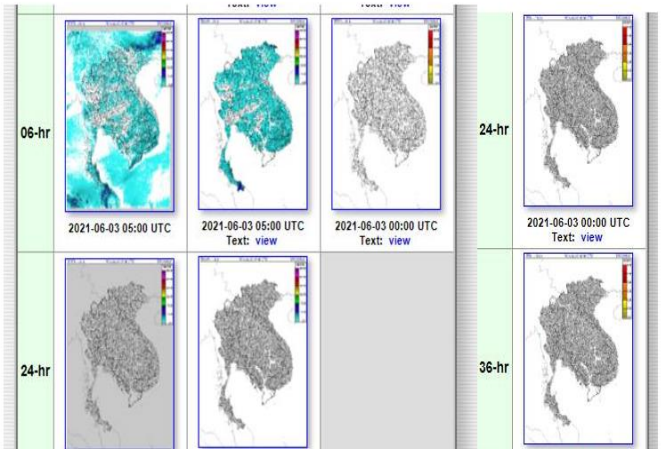
VIETNAM				
a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	16	5	21
	No	7	17	24
	Total	23	22	310
	Hit rate (POD)	0.70		

ANNEX C. MRC-FFGS Operation and Output Product Descriptions

5.5 C.1. Technical communication between HRC and RFDMC

From: Nguyen Quoc Anh [mailto:Anh@mrcmekong.org]
Sent: Thursday, June 3, 2021 12:30 AM
To: Cristopher Spencer <cspencer@hrcwater.org>
Cc: Konstantine Georgakakos <kgeorgakakos@hrcwater.org>; Son Lam Hung <son@mrcmekong.org>; Winai Wangpimool <winai@mrcmekong.org>; Sokong Ann <sokong@mrcmekong.org>
Subject: MRCFFGS error

Dear Cris,
I hope this email finds you are well.
We have just found errors in process export MRCFFGS' products (MAP 24h and FFR 24, 36) as figures below:



RE: MRCFFGS error

Cristopher Spencer <cspencer@hrcwater.org>
To Nguyen Quoc Anh
Cc 'Konstantine Georgakakos'; Son Lam Hung; Winai Wangpimool; Sokong Ann; Jason Sperfslage; tmodrick@hrcwater.org; Randall Banks

Reply | Reply All | Forward
Fri 6/4/2021 4:33 AM

You replied to this message on 6/4/2021 9:01 AM.

Dear Anh,

It is good to hear from you and thank you for bringing this to our attention. I looked into the nature of the interruption and found evidence to suggest that there were intermittent data errors when downloading the GFS data files from the NOMADS server at NCEP. These intermittent issues (reported by NOMADS as "Error 500: Internal Server Error.") meant there was a failure to sufficiently download the GFS input required by MRCWRF to successfully process. The result of this failure was that the WRF did not produce output for 00 and 12 UTC on 2 June 2021. While the original cause of the server errors at NOMADS is not clear, the issues appear to have resolved automatically starting with the 00 UTC model run on 3 June 2021. At this time, file downloads have returned to normal operational status and the forecast products are now available in MRCFFG from 00 UTC on 3 June.

Since we do not yet know the cause of the failure on 2 June, my colleagues and I will continue to monitor the status of MRCWRF in the coming days and investigate the symptoms as needed. We will share any conclusions that we find but for now we believe that the MRCFFG System should be operating normally with MRCWRF forecast products being generated as normal. If you observe any further interruptions or symptoms, please let us know.

Best regards,

Cristopher Spencer
Hydrologic Research Center
11440 West Bernardo Court, Suite 375
San Diego, CA 92127
Tel (Direct): +1-619-485-0765
Tel (Main): +1-858-798-9440
cspencer@hrcwater.org
https://www.hrcwater.org

RE: MRCFFGS error

Cristopher Spencer <cspencer@hrcwater.org>
To Nguyen Quoc Anh
Cc 'Konstantine Georgakakos'; Son Lam Hung; Winai Wangpimool; Sokong Ann; 'Jason Sperfslage'; tmodrick@hrcwater.org; 'Randall Banks'

Reply | Reply All | Forward
Tue 6/8/2021 3:53 AM

You replied to this message on 6/8/2021 10:17 AM.

Dear Anh,

HRC has periodically been monitoring the status of data acquisitions from the NOMADS server at NCEP. Since our last email correspondence, we have not observed any further interruptions in the data transfers. While it is still unclear what was causing the error, the evidence still seems to suggest that the problem was localized at NCEP and that it has now been resolved. At this time, the system data acquisition and processing appears to be operationally stable.

Thanks again for reaching out about the issue.

Best regards,

Cristopher Spencer
Hydrologic Research Center
11440 West Bernardo Court, Suite 375
San Diego, CA 92127
Tel (Direct): +1-619-485-0765
Tel (Main): +1-858-798-9440
cspencer@hrcwater.org
https://www.hrcwater.org

RE: GHE's error

Cristopher Spencer <cspencer@hrcwater.org>
To Nguyen Quoc Anh
Cc 'Konstantine Georgakakos'; Son Lam Hung; 'Jason Sperfslage'; Sokong Ann; 'Queen Tran'

Reply | Reply All | Forward
Wed 7/7/2021 3:35 AM

You replied to this message on 7/7/2021 3:16 PM.

Thank you for your email bringing this to our attention. HRC has reviewed the status of the system and found that the issue appears to have been resolved. At the time that we logged in to the server around 19:00 UTC, all MWGHE and GHE data products had been downloaded to the server and processed normally.

As you know, HRC gets the GHE data from NESDIS to generate the MWGHE product and then makes both products available on a FTP account at HRC for download by the FFGS. In reviewing the processing log files, we found that the server had difficulty downloading the MWGHE and GHE data files between 03:00 UTC and 17:00 UTC on 6 July 2021.

You can see the logs where this time-out issue started occurring in the following links (near the top of each page) ...

https://ffg.mrcmekong.org/MRCFFG_CONSOLE/LOGS/2021/07/06//20210706-032201_99999_mrcffg-cs_process_sequence_ghe_precip_cron_log.txt
https://ffg.mrcmekong.org/MRCFFG_CONSOLE/LOGS/2021/07/06//20210706-034501_99999_mrcffg-cs_process_sequence_mwghe_precip_cron_log.txt

Similar log messages to what you can see in these links occurred in all MWGHE and GHE processing log files in all hours between 03:00 UTC and 17:00 UTC when the data starts to download normally again.

It appears that the MRCFFG System operating at MRC was able to reach the server at HRC to download the data but that the data transfers were interrupting before completing due to the time-out functionality for FFGS data downloads. This time-out functionality on input data downloads is currently configured for 5 minutes for each download attempt before it decides that a failure has occurred and moves on with additional processing tasks.

The purpose of this functionality is to ensure that the system output products are not delayed too long in the case of an intermittent communication issue when downloading data. What this means in the context of this issue is that every attempt to download a file from HRC took more than 5 minutes to complete so the system abandoned the download and moved on for real-time processing contingency-handling.

This is an unusual operational situation as the download of data from HRC to the center usually takes less than a minute per file. We compared the symptoms occurring on MRCFFG hosted in Phnom Penh to other FFGS installations hosted elsewhere globally and found that the issue was isolated to MRCFFG. These details lead us to conclude that there was some external issue or interruption causing a slowdown in transfer speeds or reduced bandwidth between HRC and MRC.

In any event, the system now appears to be processing at normal operational capacity with all input data feeds restored to normal. Since the interruption was shorter than the 48-hour "self-healing" processing window, no manual intervention was required to restore the system to normal operational status. As you can see from the below screen capture of the MRCFFG Dashboard Interface, the missing data was automatically downloaded and applied to system processing when the external transfer/bandwidth issue was resolved.

5.6 C.2. MRC-FFGS Products descriptions

MRCFFG Operational Output Product Descriptions				
Label	**Definition**	**Format**	**Updated**	**Description**
HE Sat	Hydroestimator Satellite Precipitation	Images	Hourly	The images display gridded hourly, 3-hourly, 6-hourly and 24-hourly totals of precipitation (mm) ending on the current hour as estimated in real-time from geostationary satellites using the Hydroestimator algorithm. The satellite rainfall estimates are provided on a grid having approximately 10x10 km resolution which is displayed over a background of MRCFFG sub-basin boundaries. The HE Sat data products are updated every hour and reflect rainfall accumulations ending on the current product hour.
				SAT 01-hr: Total of precipitation as estimated by the Hydroestimator over the last hour ending on the current product hour. (mm/1hr)
				SAT 03-hr: Total of precipitation as estimated by the Hydroestimator over the last 3 hours ending on the current product hour. (mm/3hr)
				SAT 06-hr: Total of precipitation as estimated by the Hydroestimator over the last 6 hours ending on the current product hour. (mm/6hr)
				SAT 24-hr: Total of precipitation as estimated by the Hydroestimator over the last 24 hours ending on the current product hour. (mm/24hr)
.	.	.	.	.

Merged MAP	Mean Areal Precipitation	Text & Images	Hourly	Text tables and images of hourly, 3-hourly, 6-hourly and 24-hourly totals of mean areal precipitation (mm) for each MRCFFG catchment. It includes real-time or climatological bias adjustment of the real-time satellite rainfall and substitution of interpolated precipitation of 6-hourly raingauge data for sub-basins with no available satellite information (either by unavailability or masking). The Merged MAP data products are updated every hour and reflect accumulations of basin-average precipitation of a given duration ending on the current product hour.
				MAP 01-hr: Total mean areal precipitation estimated over the last hour ending on the current product hour. (mm/1hr)
				MAP 03-hr: Total mean areal precipitation estimated over the last 3 hours ending on the current product hour. (mm/3hr)
				MAP 06-hr: Total mean areal precipitation estimated over the last 6 hours ending on the current product hour. (mm/6hr)
				MAP 24-hr: Total mean areal precipitation estimated over the last 24 hours ending on the current product hour. (mm/24hr)
.	.	.	.	.
ASM	Average Soil Moisture	Text & Images	00, 06, 12 & 18 UTC	Text tables and images provide soil water saturation fraction (dimensionless ratio of contents over capacity) for the upper zone (down to 20-30 cm depth) of the

				Sacramento Soil Moisture Accounting Model for each of the MRCFFG sub-basins. The products are updated every 6 hours at the model processing hour (i.e. 00, 06, 12 and 18 UTC).
				ASM 06-hr: Average soil water saturation at most recent model processing hour. (fraction of soil capacity in the upper zone)
.	.	.	.	.
FFG	Flash Flood Guidance	Text & Images	00, 06, 12 & 18 UTC	Text tables and images of hourly, 3-hourly and 6-hourly flash flood guidance (mm) for each MRCFFG sub-basin are provided. The FFG value indicates the total volume of rainfall over the given duration which is just enough to cause bankfull flow in the draining stream outlet. Consequently, rainfall volumes of the same duration that are greater than the FFG value indicate a likelihood of overbank flows at the draining stream outlet. Each of the FFG products is updated at every model processing hour (00, 06, 12 and 18 UTC). **This product is appropriate to use in real time with nowcasts or forecasts of rainfall and other local information to estimate the risk of flash flooding in the MRCFFG sub-basins.**
				FFG 01-hr: Required precipitation over the next hour following the most recent (current) model processing hour to cause bankfull flow. (mm/1hr)

				FFG 03-hr: Required precipitation over the next 3 hours following the most recent (current) model processing hour to cause bankfull flow. (mm/3hr)
				FFG 06-hr: Required precipitation over the next 6 hours following the most recent (current) model processing hour to cause bankfull flow. (mm/6hr)
				Prev FFG 01-hr: Required precipitation over the hour following the previous model processing hour to cause bankfull flow. (mm/1hr)
				Prev FFG 03-hr: Required precipitation over the 3 hours following the previous model processing hour to cause bankfull flow. (mm/3hr)
				Prev FFG 06-hr: Required precipitation over the 6 hours following the previous model processing hour to cause bankfull flow. (mm/6hr)
.	.	.	.	.
PFFT	Persistence Flash Flood Threat	Text & Images	00, 06, 12 & 18 UTC	PFFT products include text tables and images of hourly, 3-hourly and 6-hourly flash flood threat (mm) for each MRCFFG catchment. The values indicate the difference of recent persisted merged estimates of mean areal rainfall of the given duration and the corresponding current FFG of the same duration for a given MRCFFG sub-basin. The last 1-hour, 3-hour and 6-hour durations of MAP are persisted and considered with current

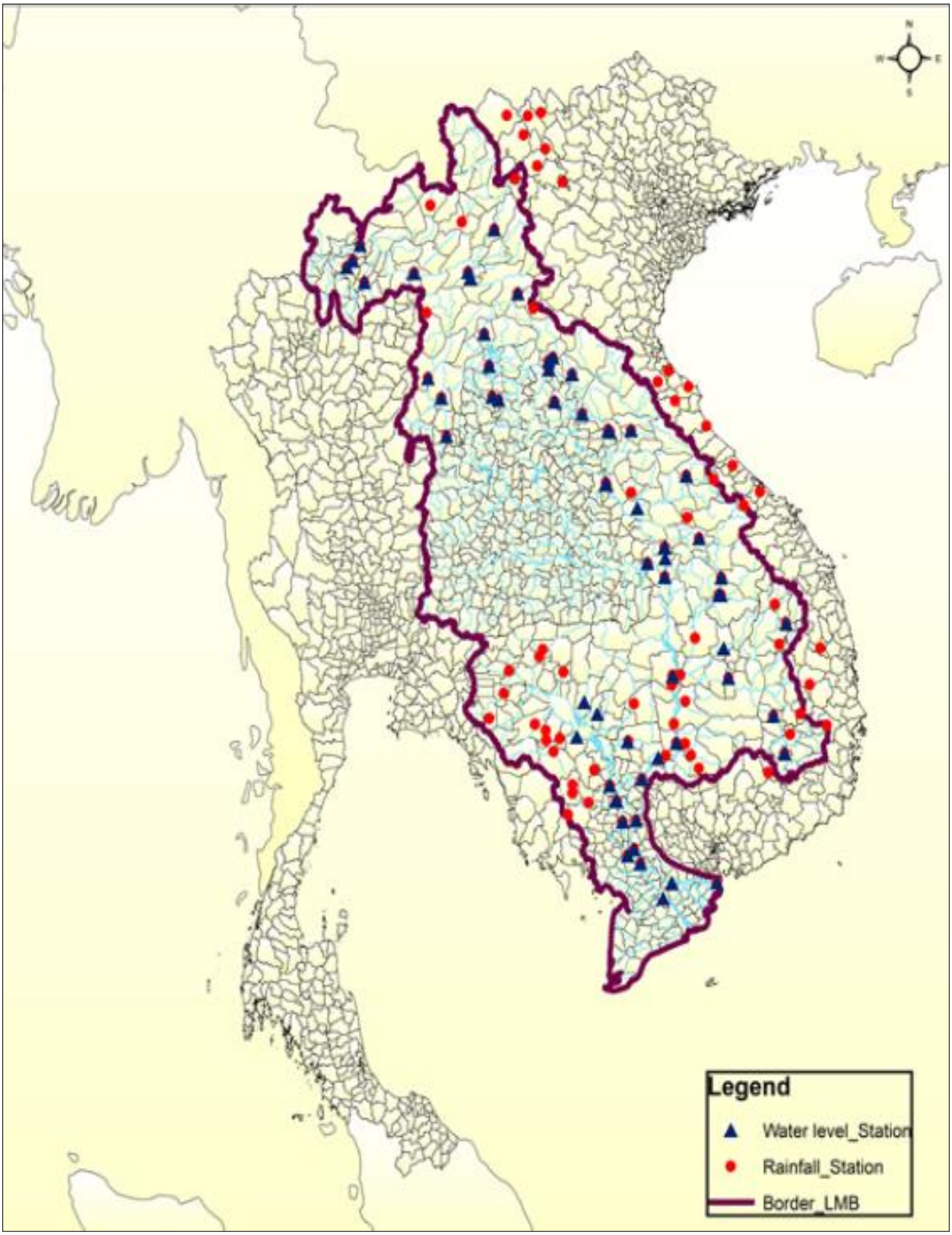
				corresponding FFG in the computation of PFFT.
				For example, the 6-hr PFFT at 12:00 UTC = 06-hr MAP from 12:00 UTC - 06-hr FFG from 12:00 UTC
				In the images, an approximate measure of uncertainty in the PFFT estimates is indicated by the ranges in the color scale (with yellow indicating the range of values that are unlikely to be of concern for flash flooding and with orange and red indicating progressively higher risk of flooding for the sub-basin of interest). The hourly, 3-hourly and 6-hourly PFFT products are updated at model processing hours (00, 06, 12, 18 UTC). **Note that this set of products uses a crude rainfall forecast and probably contains large uncertainties. PFFT is offered as a baseline product that must be carefully evaluated by the forecaster in real-time.**
				PFFT 01-hr: Difference of 01-hr FFG for current model processing hour and current 01-hr MAP persisted for the next 1 hour. (mm/1hr)
				PFFT 03-hr: Difference of 03-hr FFG for current model processing hour and current 03-hr MAP

				persisted for the next 3 hours. (mm/3hr)
				PFFT 06-hr: Difference of 06-hr FFG for current model processing hour and current 06-hr MAP persisted for the next 6 hours. (mm/6hr)
.	.	.	.	.
FFT	Flash Flood Threat	Text & Images	1, 3 and 6 hours after previous model processing hour	FFT products include text tables and images of hourly, 3-hourly and 6-hourly flash flood threat (mm) for each MRCFFG catchment. The values indicate the difference of the observed mean areal rainfall of the given duration and the corresponding past FFG of the same duration for a given MRCFFG sub-basin. The last 1-hour, 3-hour and 6-hour durations of FFG are considered with current corresponding MAP in the computation of FFT.
				For example, the 06-hr FFT at 12:00 UTC = 06-hr MAP from 12:00 UTC - 06-hr FFG from 6:00 UTC
				The most recent FFT product for each time-scale is provided in the Baseline Threat Product table and displayed with the MAP and FFG products that were used in the respective calculation. In the images, an approximate measure of uncertainty in the FFT estimates is indicated by the ranges in the color scale (with yellow indicating the range of values that are unlikely to

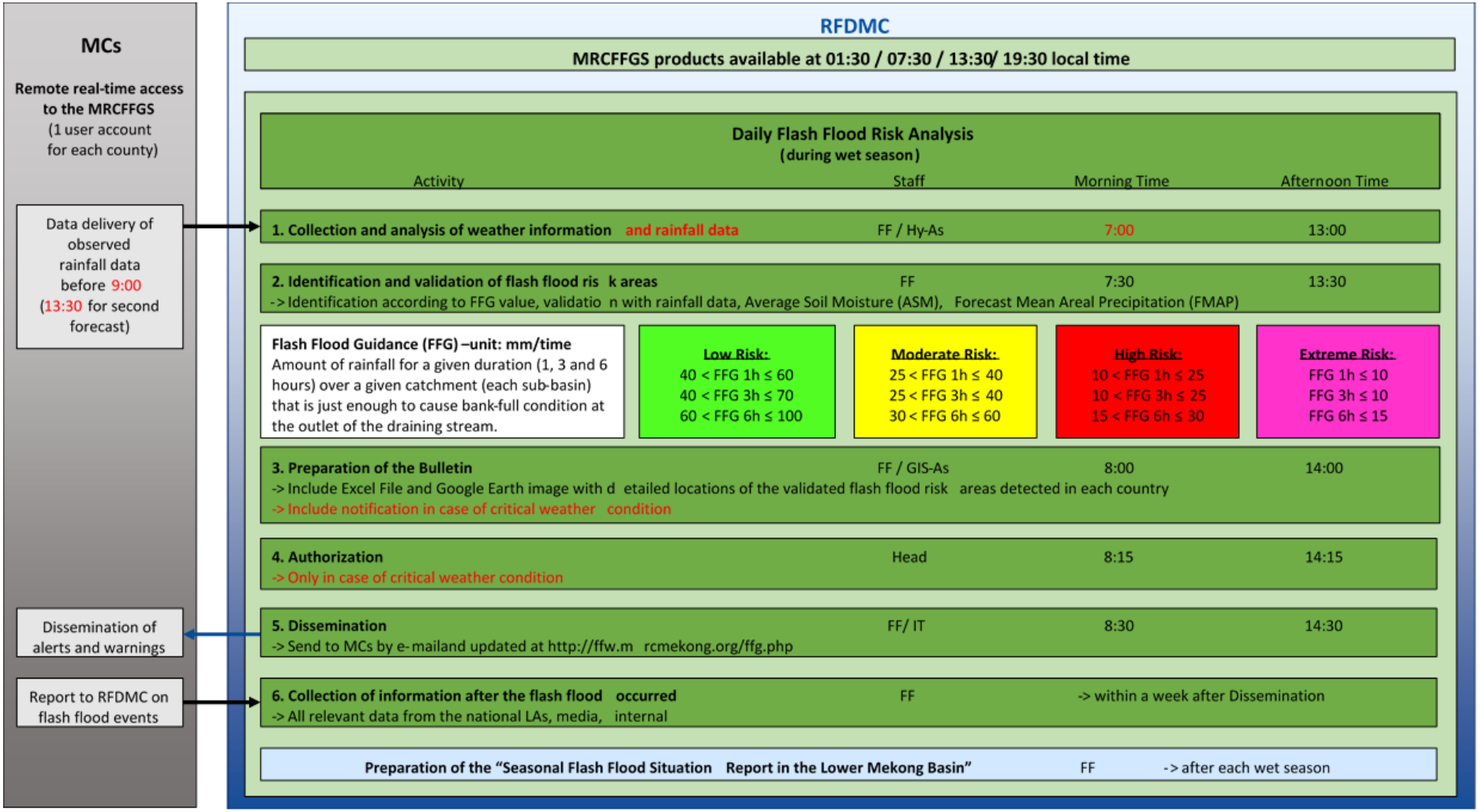
				be of concern for flash flooding and with orange and red indicating progressively higher risk of flooding for the sub-basin of interest). The hourly, 3-hourly and 6-hourly FFT products are respectively updated at 1, 3, and 6 hours after the preceding model processing hour. FFT provides the forecaster with an idea of likely regions of imminent flash flood threats. **Note that this set of products concerns the past and may not be appropriate to use for real-time warning. FFT is offered as a baseline product that must be carefully evaluated by the forecaster in real-time.**
				FFT 01-hr: Difference of 01-hr FFG from a previous model processing hour and 01-hr MAP observed over the following 1 hour. (mm/1hr)
				FFT 03-hr: Difference of 03-hr FFG from a previous model processing hour and 03-hr MAP observed over the following 3 hours. (mm/3hr)
				FFT 06-hr: Difference of 06-hr FFG from a previous model processing hour and 06-hr MAP observed over the following 6 hours. (mm/6hr)

ANNEX D. Hydmet database and daily operation of MRC-FFGS

5.7 D.1. The map of rainfall and water level stations of the Hydmet database network



5.8 D.2. Daily Operation of the MRC-FFGS



Abbreviations :

FF	Flood Forecaster	Head	Head of the RFDMC	MCs	Member Countries (Cambodia, Lao PDR, Thailand, Viet Nam)
FFGS	Flash Flood Guidance System	Hy-As	Hydrology Assistant	MRC	Mekong River Commission
GIS-As	GIS/ Mapping Assistant	IT	IT Assistant	RFDMC	Regional Flood and Drought Management Centre