EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

30 July 2018 16:00 UTC

Lao People's Democratic Republic
Flash Flood due to Dam Collapsing

Glide Number: **FF-2018-000118-LAO**
23 July - ongoing

UPDATE # 1 - Results of Dam Break Calculations

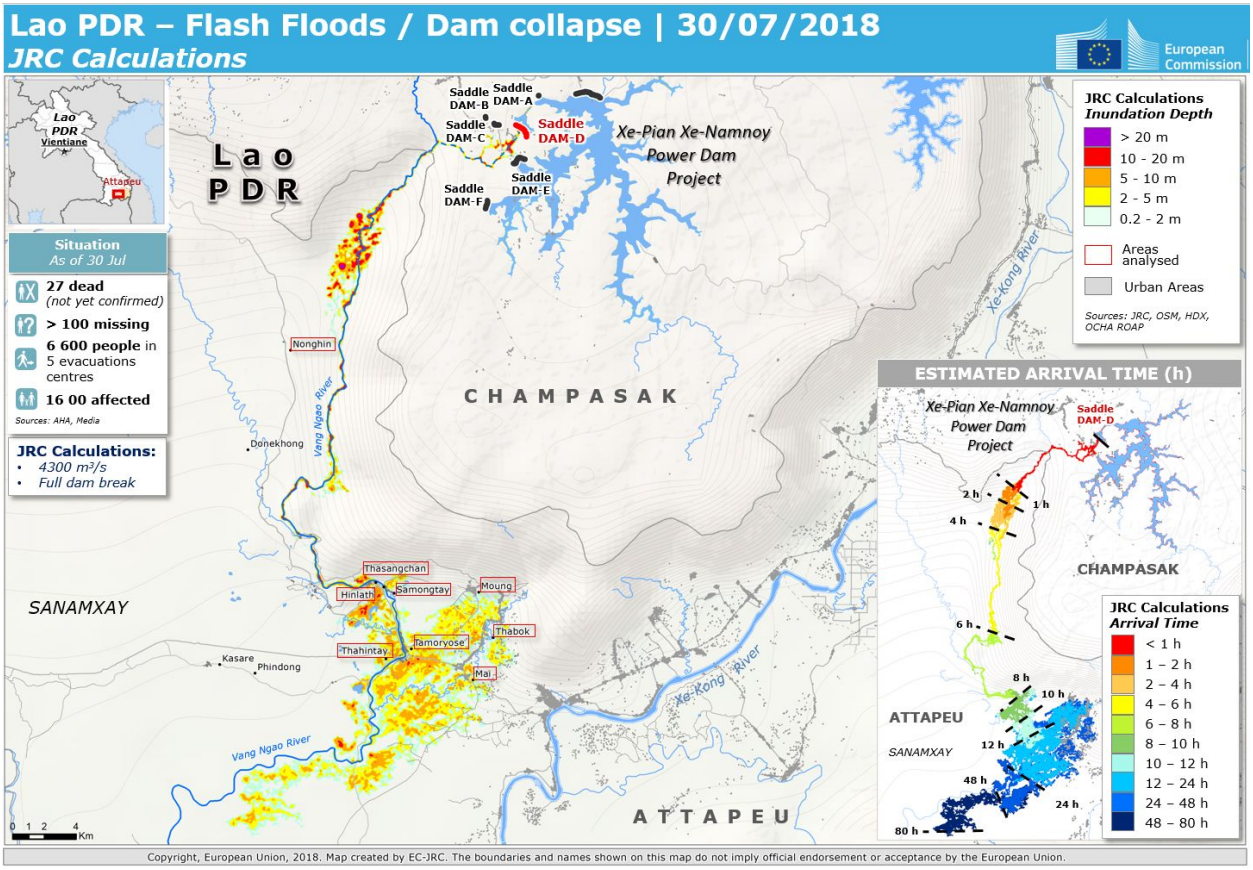


Fig 1 - Situation overview, JRC dam break calculations

1. Executive Summary

- Extensive flood occurred on **23 July**, downstream one of the dams of the **Xe-Pian Xe-Namnoy Power Project**, under-construction in southern Lao People's Democratic

Republic (Lao PDR); the flood was due to the partial failure of the dam as a result of the recent heavy rains that affected the area during the previous week.

- The event caused flash flooding in many villages of **Sanamxay district** (**Attapeu Province**), casualties and damage. According to media (as of 30 July), there were at least **27 dead (not yet confirmed)**, over **100 people** missing and **16,000 affected**. Search and rescue operations are still ongoing.
- Over the next 10 days more rain (accumulated amounts higher than 150 mm) may affect the area, which could further worsen the situation.
- The **dam break analysis**, performed by JRC, has identified the areas mostly affected and the extent is in good agreement with the analysis performed using radar satellite images although the distinction between monsoon/tropical storm rainfall contribution and dam break contribution is not easy.
- The analysis has shown that the most affected locations have been hit after **7 h** from the break and therefore ample time was available to alert the population; however the night conditions have been probably not favourable for a timely and effective alerting, if those mechanisms are implemented in the country.
- The estimated water height was about **5-10 m** and therefore consistent with the images of people at the top of the buildings.
- A first report on the event was published on 25th July[1]. This report will include only new or changed information respect to the 1st report. The two reports should be read together to have a full compound of the information.

2. Situation Assessment

2.1. Dam situation

- A partial failure of one of the dams of the **Xe-Pian Xe-Namnoy Power Project,** under-construction in southern Lao PDR, occurred on **23 July** evening, causing the release of about 5 billion cubic meters of water and causing flash flooding in many villages of **Sanamxay district** (**Attapeu Province**), casualties and damage (see Section 2.2).
- AHA center[2] reported on 30 Jul in VOSOCC: Based on latest satellite observation on Sanamxai District (29 July 2018), about 42.36 sqkm is still flooded, with 32.53 km2 agricultural area. Within the flooded area, 302 buildings and 31.5 km road length submerged in water. Should wet weather persist, flood waters may not recede as quickly as expected

[1] http://www.gdacs.org/Public/download.aspx?type=DC&id=28
[2] ASEAN Coordinating Centre for Humanitarian Assistance: http://adinet.ahacentre.org/

2.2. Humanitarian impact and response

The current situation is shown in the table below.

Lao PDR - Situation (as of 30 July, media)	
Dead / Missing	**27 dead, 123 still missing** *(numbers still under verification)*
Affected	**16,000 people affected**
Displaced	**6,600 people inside 5 evacuation centers**
Areas mostly Affected	**13 Villages in Sanamxay District (Attapeu province)**

Table 1 - Situation in Lao PDR (as of 30 July, media, AHA).

Fig 7- Floods due to the dam break (Source: https://www.nytimes.com/2018/07/26/world/asia/laos-dam-collapse.html)

2.3. Meteorological Forecast

Significant rainfall amounts, locally higher than 150 mm, are anticipated for the coming 10 days (from 30 July to 8 August 2018) over the greater area of interest based on the high-resolution (HIRES) forecast of the ECMWF as shown in Fig.8.

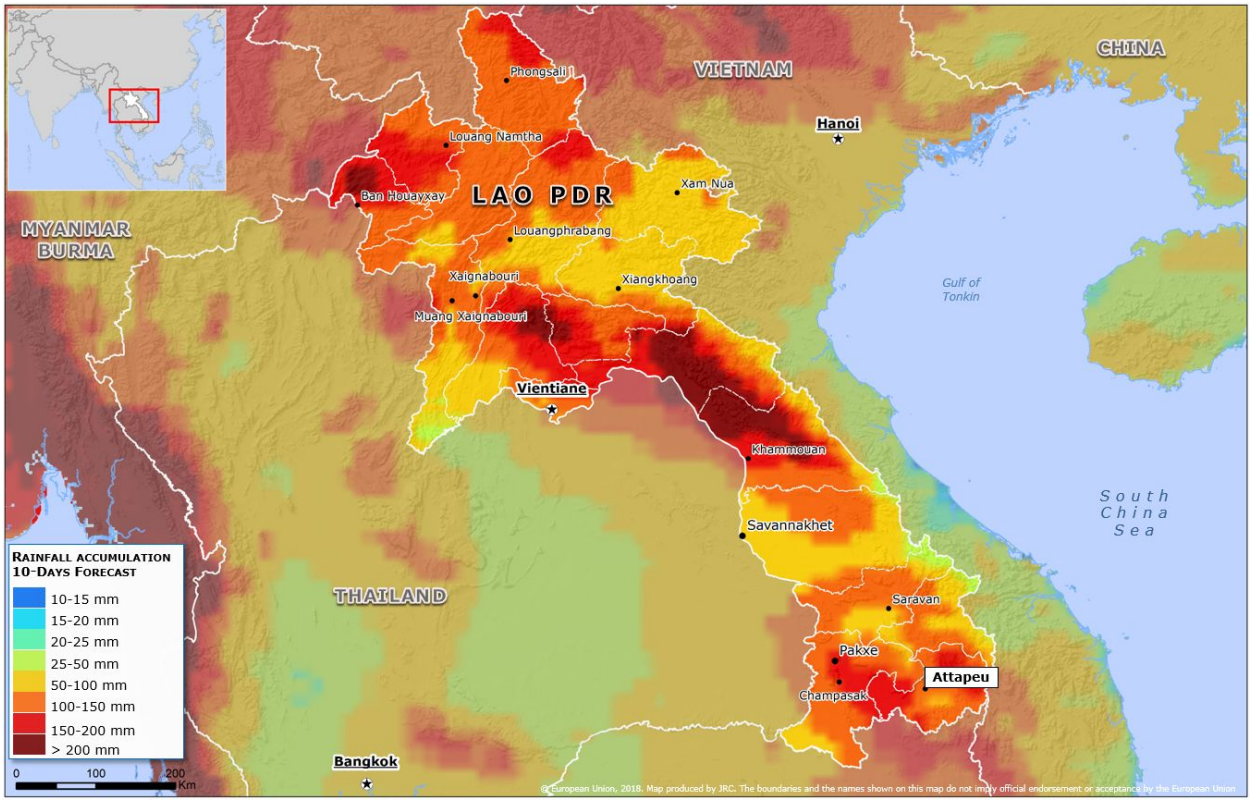


Figure 8 *- 10-Day accumulated rainfall based on the high-resolution forecast of ECMWF.*

Additional meteorological / weather analysis details and forecasts can be found in:

- Appendix A1: 10-Day (max horizon of high-resolution) based on the HIRES (high-resolution operational forecast) of ECMWF

- Appendix A2: 2-Week (max horizon of ensembles) based on the EPS (Ensemble Prediction System) of ECMWF

3. Dam Break Analysis

This chapter is dedicated to the Dam break analysis of this event. Before starting the discussion it is necessary to point out the Limitations and Uncertainties. We do not have a detailed topography of the area but are deducing it from available global datasets. Also we don't know specific details about the dams in the area although from the topography we are able to identify where the dams should located.

The objective of the analysis are:
- to identify the possible extent and height of the flooding,
- the time of arrival of the wave,
- the expected dynamic behaviour following the break of the dam.

Although the extent of the inundation is currently know by satellite images, the timeline of the wave propagation and the height reached by the water cannot be obtained by satellite images analysis.

In order to do that a numerical model was being built based on STRM-30 digital elevation model; the cell size has been increased to 50 m in order to speed up the calculation. Infact a very long and time consuming run was performed by simulating 80 h of water release from the dam. The SRTM-30 digital elevation model was developed before the construction of the dama and therefore it well represent the bottom of the lake that has been created.

We have identified that the level of the water is in the order of 780-790 m above sea level with an available jump of about 700 m. Therefore the water ejected from the dam will have a large acceleration when it will reach the downstream areas.

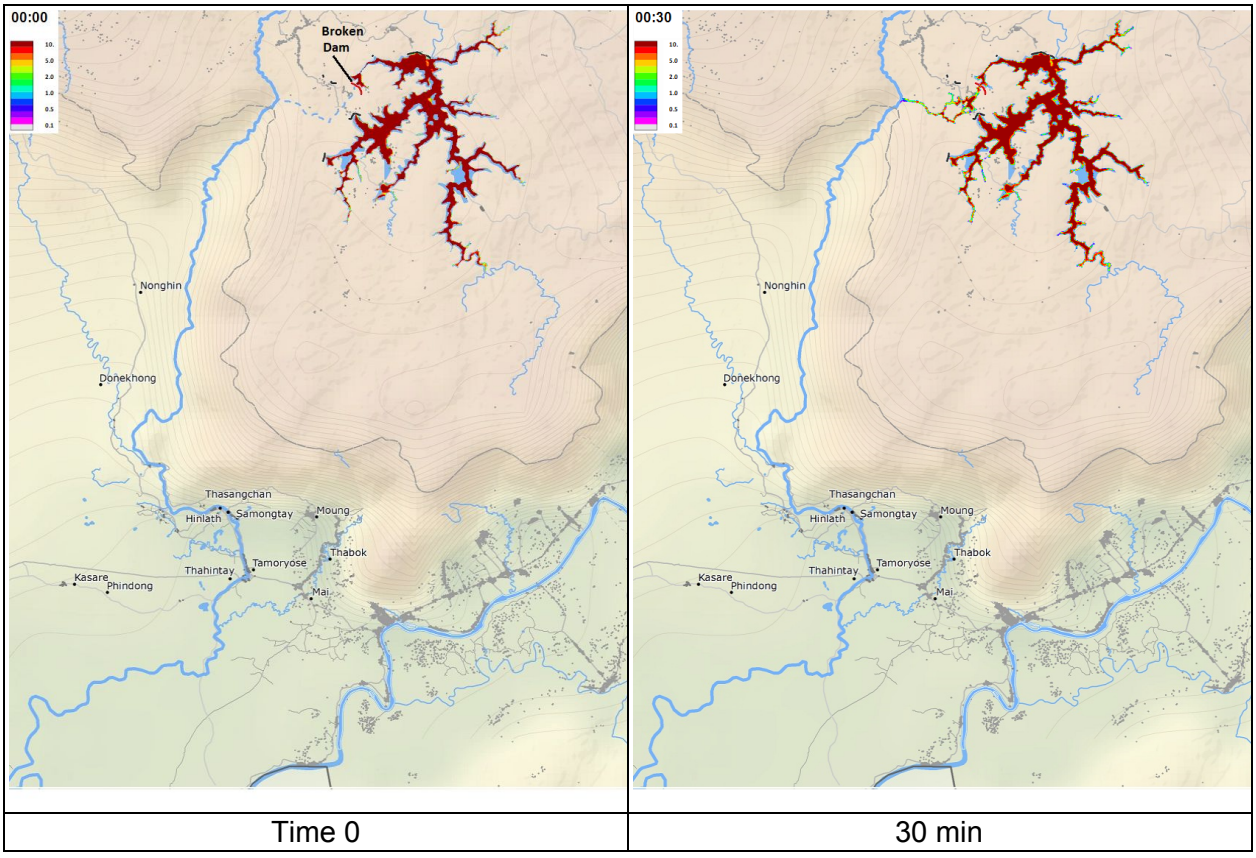
It is not know which technology was used to create the dam but we think that this was a earth filled dam type because this type of dam, in case of overspilling, may suddenly open completely (within 1-2 hours). The analysis here shown were performed by creating artificial dams where they are needed to keep the water level at 790 m and leaving completely open the dam named as **Saddle Dam D**, that is the one that disappeared.

The calculations have been performed using HyFlux computer code and the duration of the calculations for 80 h on 20 cores was 16 hours elapsed time.

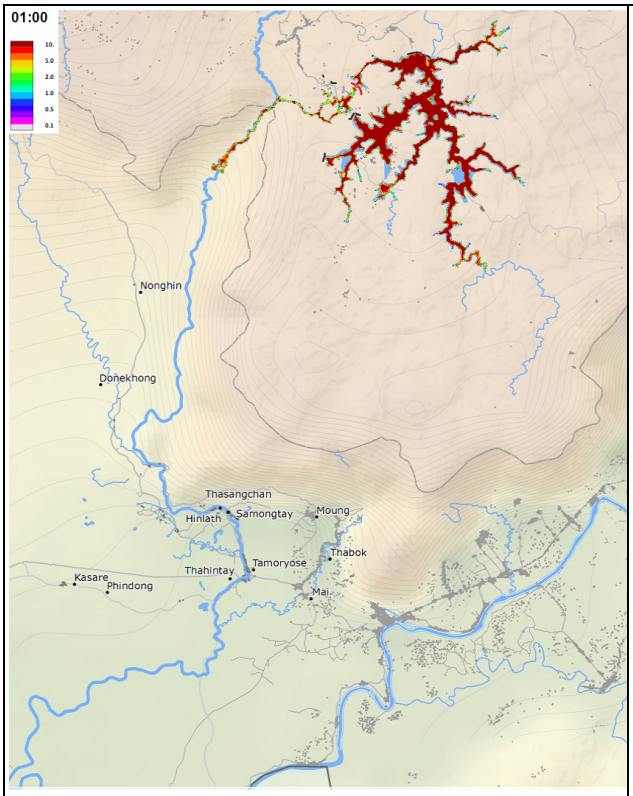
3.1 Results of the calculations

The results of the calculations are shown in the following sequence of images, that can also be visualized as an animated gif at the following URL:

http://webcritech.jrc.ec.europa.eu/modellingTsunami/damCases/Laos/50m_bat_2/depth.gif



Time 0	30 min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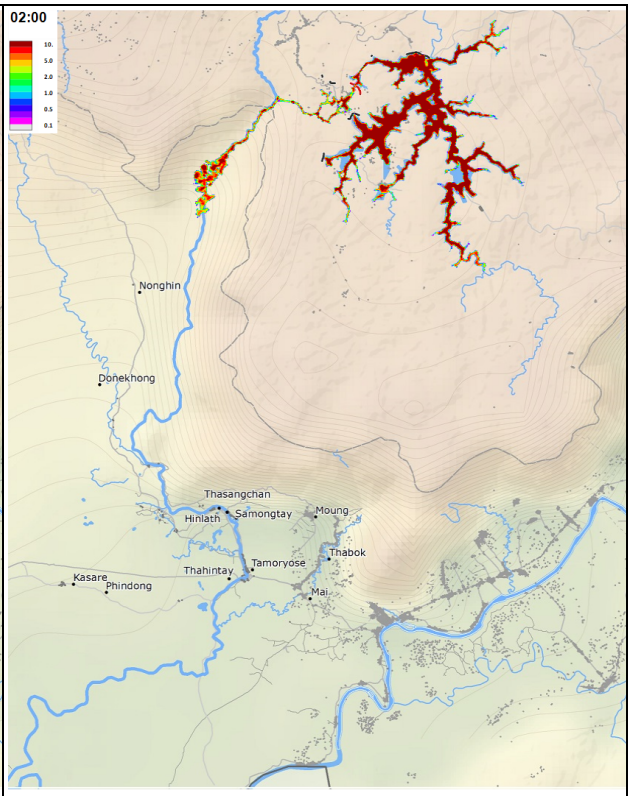
Donekhong
Thasangchan
Hinlath
Samongtay
Moung
Thabok
Tamoryose
Thahintay
Kasare
Phindong
Mai

1 h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Samongtay
Moung
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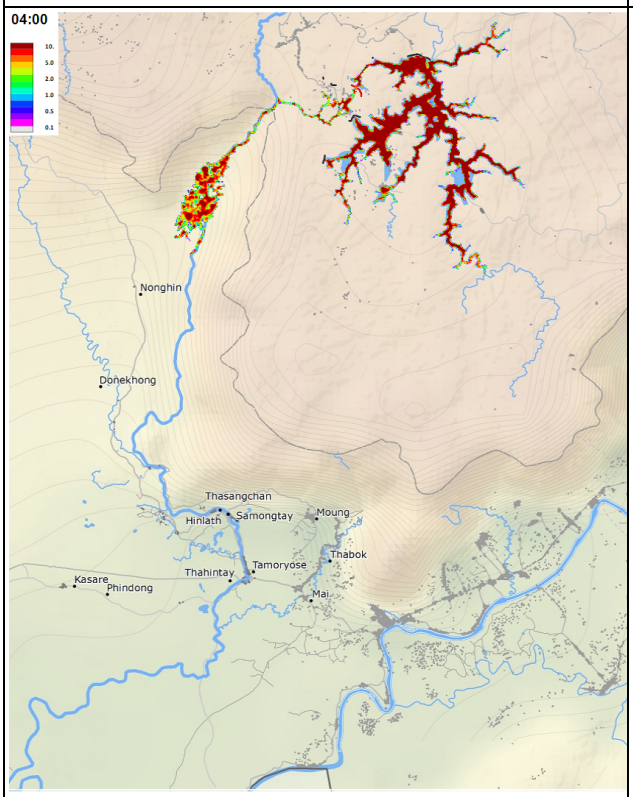
Kasare
Phindong
Mai

2h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Thasangchan
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Samongtay
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Thahintay
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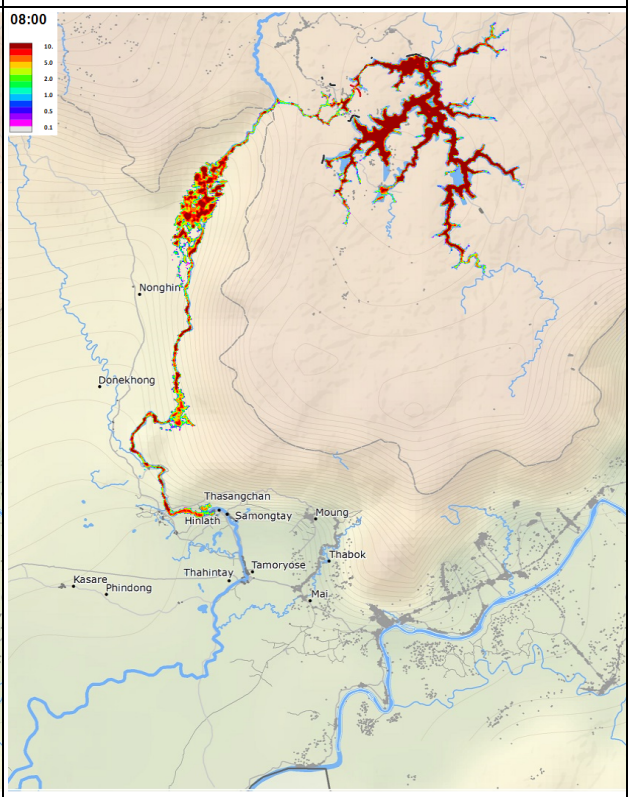
Phindong
Mai

4 h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Nonghin
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Thasangchan
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Samongtay
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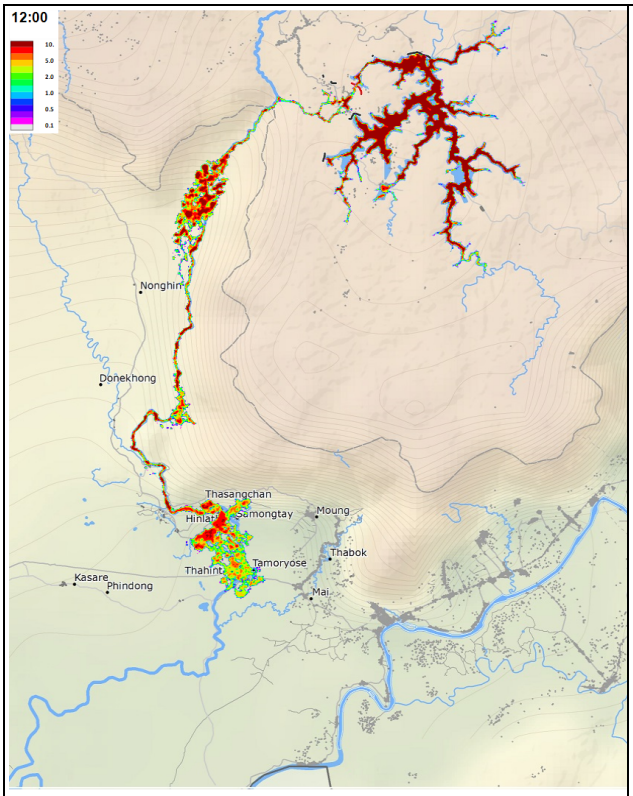
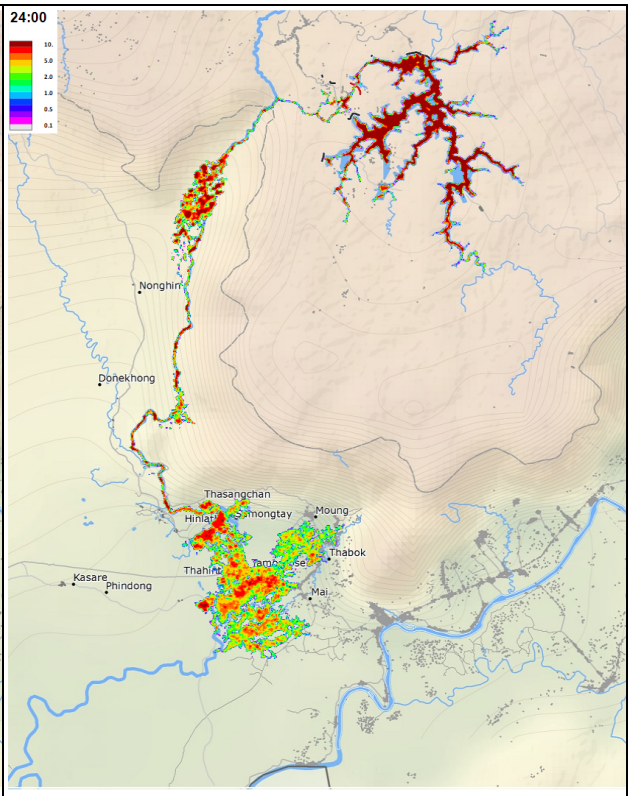
Thabok
Tamoryose
Thahintay
Kasare
Phindong
Mai

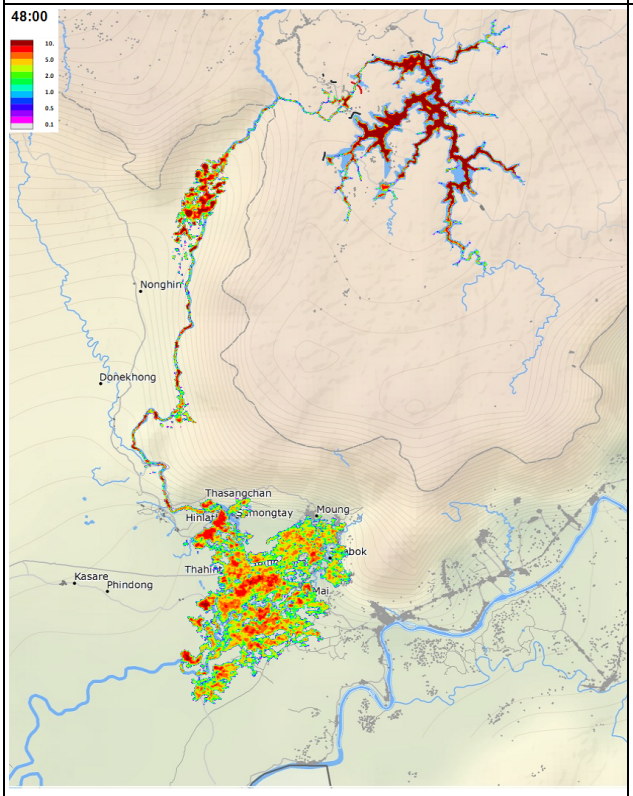
8 h



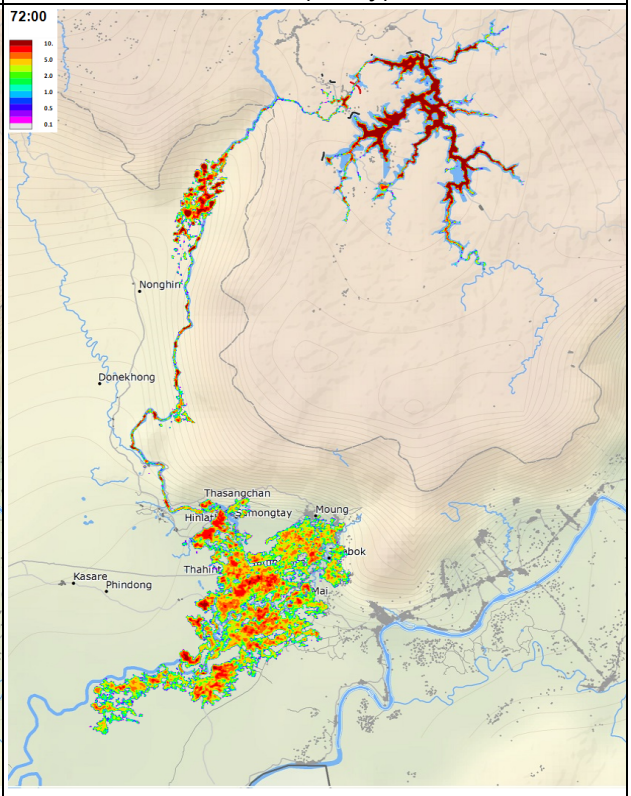
12 h



24 h (1 day)



48 h (2 days)



72 h (3 days)

The timeline of the dam break water propagation indicates that the water proceeded quite fast in the initial part of the path, where the slope was extremely high but once the water reaches the flat area the propagation speed becomes considerably reduced and the arrival time to the first important locations (i.e. Hinlath) in about **8 hours** and **12 m** water depth. Thabok was reached after **18 h** with **6.8 m** water height.

The table below indicates the maximum height and the arrival time at the locations identified as mostly affected. However in some cases, the precise location (obtained from the UN database of locations) does not show water in that cell the water. For this reason another column is included showing the maximum height and the arrival time in a 1 km radius from the nominal point. In such a way it is possible to better identify the situation in the surrounding of the selected point.

The table below reports also the daily decrease rate (m/day) at the end of the calculation, in order to have an idea of what could be the voiding time at the various locations.

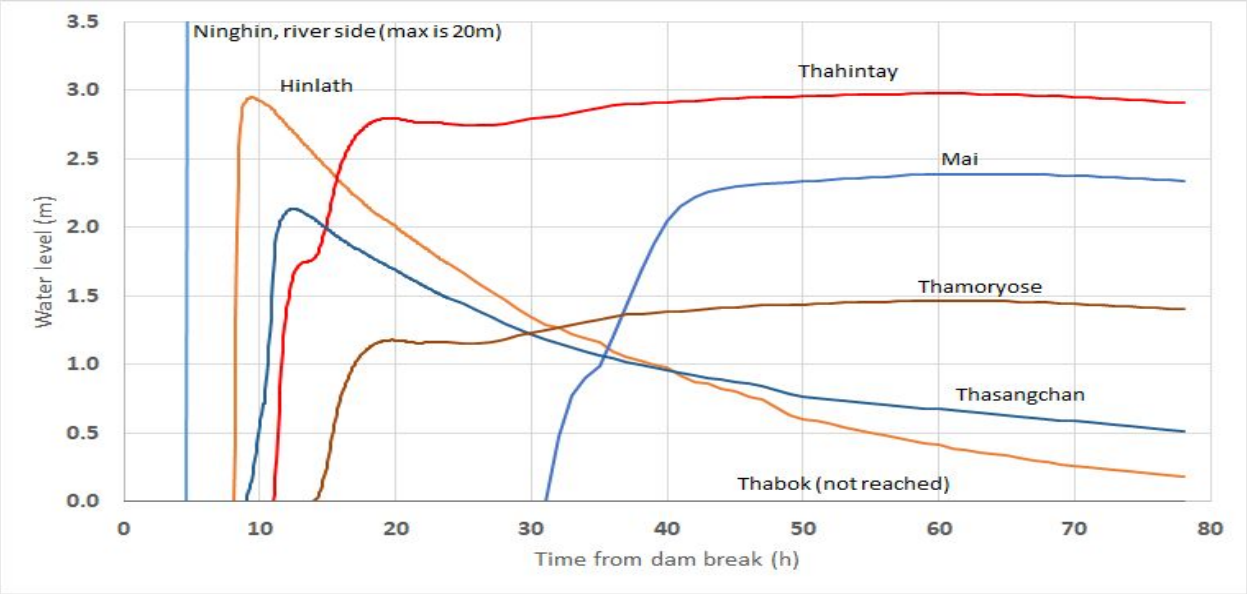
Lon	Lat	Location	Point Value Hmax	1km radius hmax	Point Value Arr time	1km min Arr time	Daily decrease (m/day)
106.4614	14.87243	Nonghin along river	20.42	**20.42**	04:37	**04:33**	0.9
106.4812	14.74976	Hinlath	2.9	**12.3**	08:07	**07:48**	0.16
106.4859	14.74725	Thasangchan	2.1	**11.3**	09:01	**07:52**	0.21
106.4916	14.74374	Samongtay	Not arrived	**11.3**	Not arrived	**08:09**	
106.5014	14.7121	Tamoryose	1.5	**12.5**	14:11	**10:30**	0.13
106.4871	14.70649	Thahintay	3.0	**8.7**	11:04	**10:31**	0.14
106.5479	14.71849	Thabok	Not arrived	**6.8**	Not arrived	**17:55**	
106.5397	14.74433	Moung	Not arrived	**5.7**	Not arrived	**19:47**	
106.5364	14.69441	Mai	2.4	**10.5**	31:28	**26:16**	0.11

Therefore, in principle, the amount of time for the evacuation was relatively long but probably the night time of the event did not allow a proper managing of the emergency.

We have no confirmation about the break time and the arrival time of the wave. Most reports indicates the break at about 20:00 of 23rd July but it is not clear when the flooding occurred. It would be interesting to check if radar images of the area are available during the discharge. As a matter of fact in the BBC web site this news was present:

- *By 24 July 01:30, a village near the subsidiary dam is flooded, and by 09:30 seven villages are flooded* (Source: BBC https://www.bbc.com/news/world-asia-44947185)

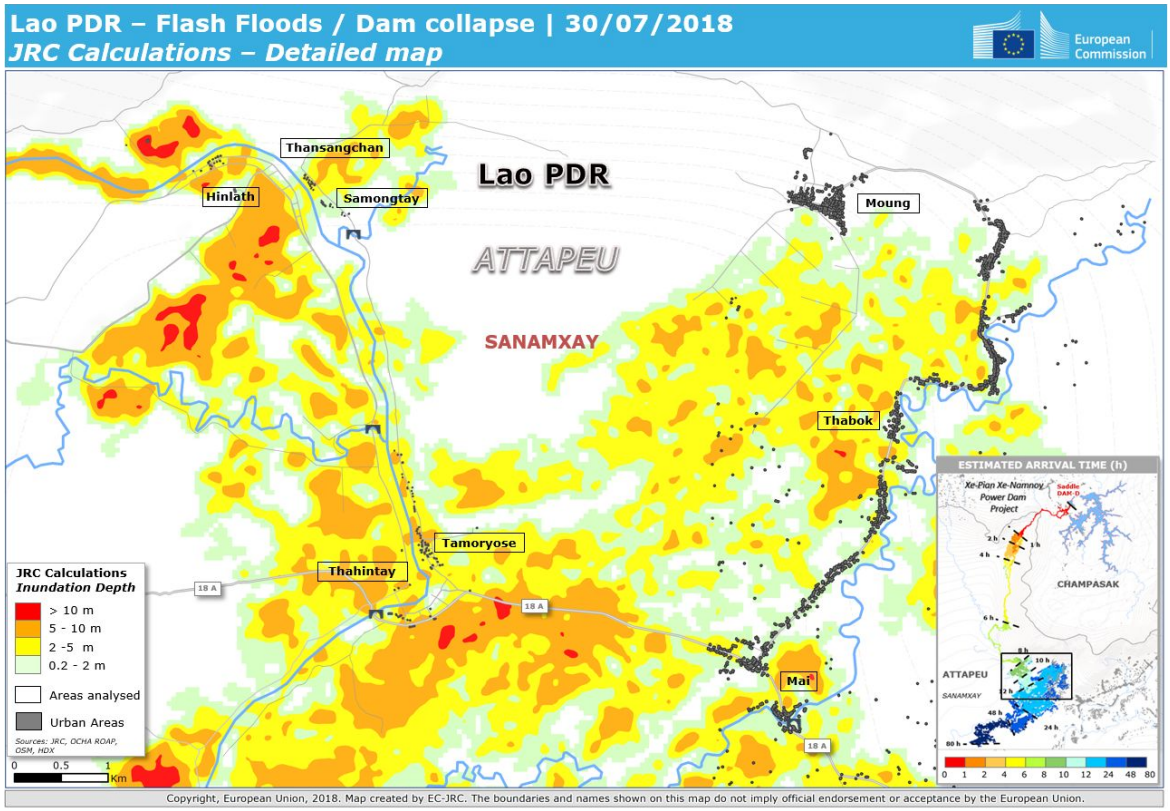
which tends to confirm that the time between a village *near (*not clear where) to the dam was flooded and the seven villages flooded (*which village?)* is about 8 h.

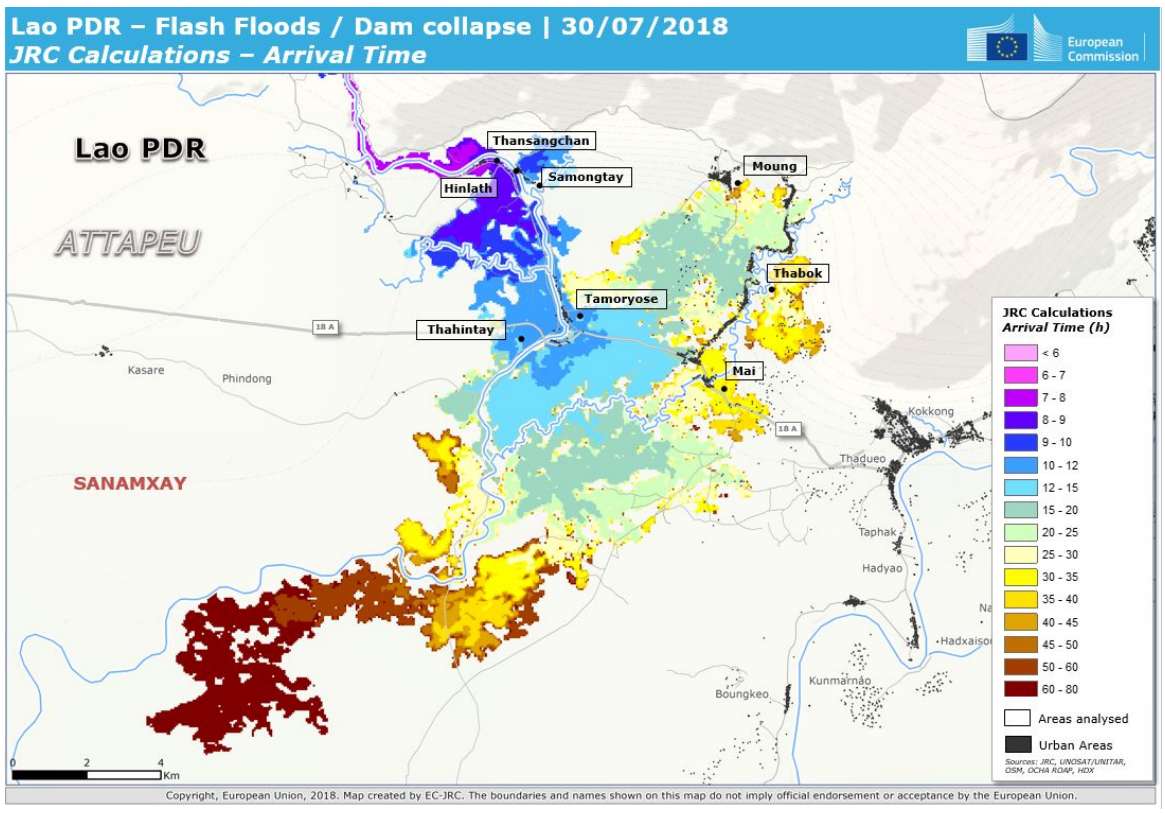


The behaviour of the level at the locations indicated above can be seen from the image here. After 24 h the water is still present in all the locations.

The timeline shows that the rise of the level, excluding the northern location, shows an almost stable level for long time. At the end of the calculation (80h), the level decrease at a rate of 0.1-0.2 m per day, which means, excluding further rains and evaporation, that between 10 and 20 days are necessary to void the various locations. Hinlath should be soon voided; the last one should be Thahintay.

The height distribution in the mostly affected section is shown in the image below that shows several areas with 5-10 m and few patches also with depth larger than 10m.

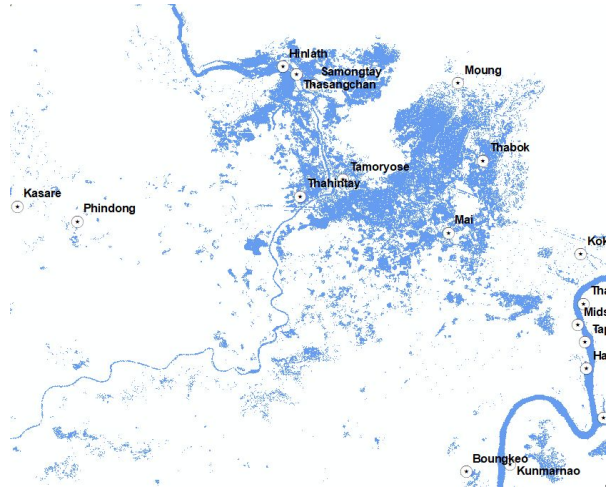
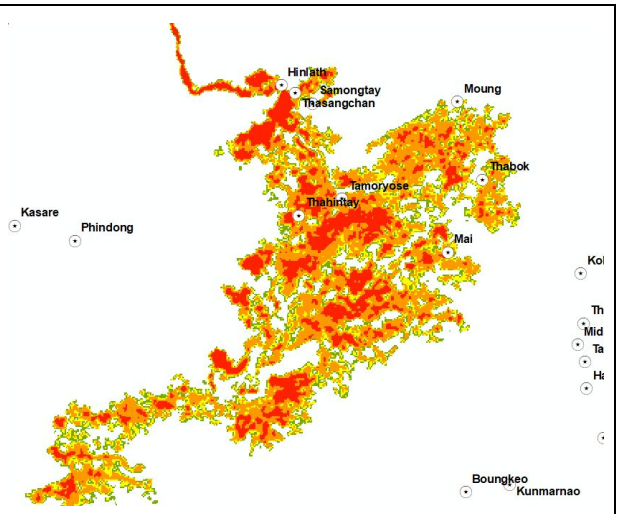

Lao PDR – Flash Floods / Dam collapse | 30/07/2018
JRC Calculations – Detailed map
European Commission
Thansangchan
Hinlath
Samongtay
Lao PDR
Moung
ATTAPEU
SANAMXAY
Thabok
Tamoryose
Thahintay
Mai
18 A
JRC Calculations
Inundation Depth
> 10 m
5 - 10 m
2 -5 m
0.2 - 2 m
Areas analysed
Urban Areas
Sources: JRC, OCHA ROAP, OSM, HDX
0 0.5 1 Km
ESTIMATED ARRIVAL TIME (h)
Xe-Pian Xe-Namnoy Power Dam Project
Saddle DAM D
CHAMPASAK
ATTAPEU
SANAMXAY
0 1 2 4 6 8 10 12 24 48 80
Copyright, European Union, 2018. Map created by EC-JRC. The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union.


Lao PDR – Flash Floods / Dam collapse | 30/07/2018
JRC Calculations – Arrival Time
European Commission
Lao PDR
Thansangchan
Hinlath
Samongtay
Moung
ATTAPEU
Thabok
Tamoryose
Thahintay
Mai
18 A
Kasare
Phindong
SANAMXAY
Kokkong
Thadueo
Taphak
Hadyao
Hadxaisone
Kunmarnao
Boungkeo
JRC Calculations
Arrival Time (h)
< 6
6 - 7
7 - 8
8 - 9
9 - 10
10 - 12
12 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 60
60 - 80
Areas analysed
Urban Areas
Sources: JRC, UNOSAT/UNITAR, OSM, OCHA ROAP, HDX
0 2 4 Km
Copyright, European Union, 2018. Map created by EC-JRC. The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union.

The arrival time shows that the first locations are reached in about 7-8 h, as shown in the table before. The area is then crossed at about 50 h so all the locations downstream this area have been reached at larger times.

3.2 Comparison with Satellite images

UNOSAT and other organizations have published the layers related to the water extent over the inundated area. It is possible therefore to perform a comparison among the calculated and the estimated water extension from RADARSAT-2 satellite radar images, with resolution 3m..

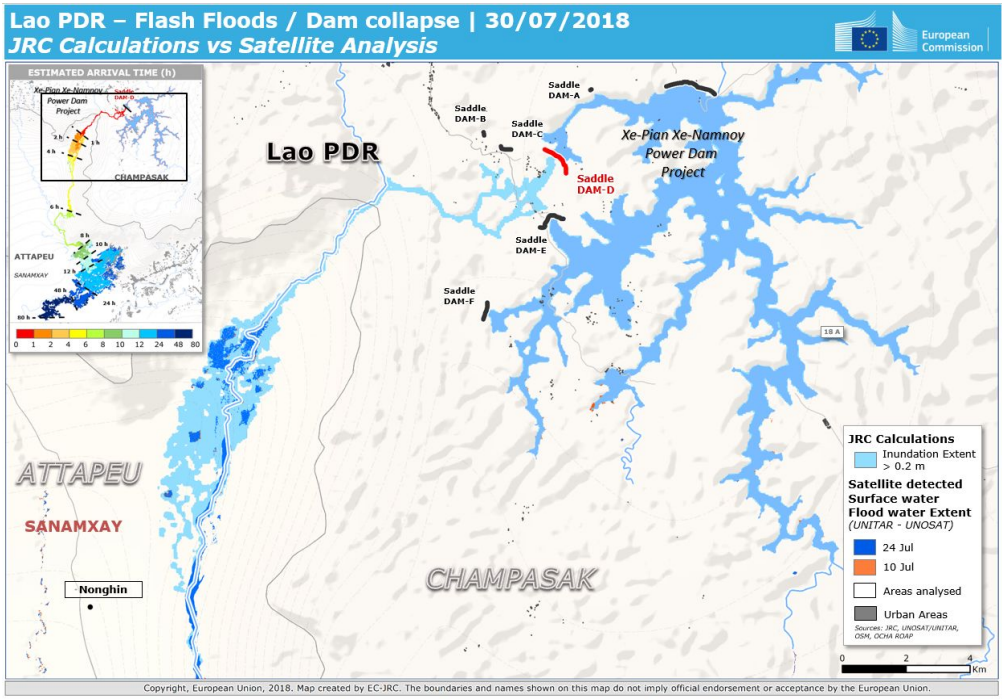
	
Analysis of radar satellite image obtained 24th July	The form of the inundation is not identical to the satellite image. However the calculation is referred to 3 days after the dam break, therefore corresponding to 26th July.

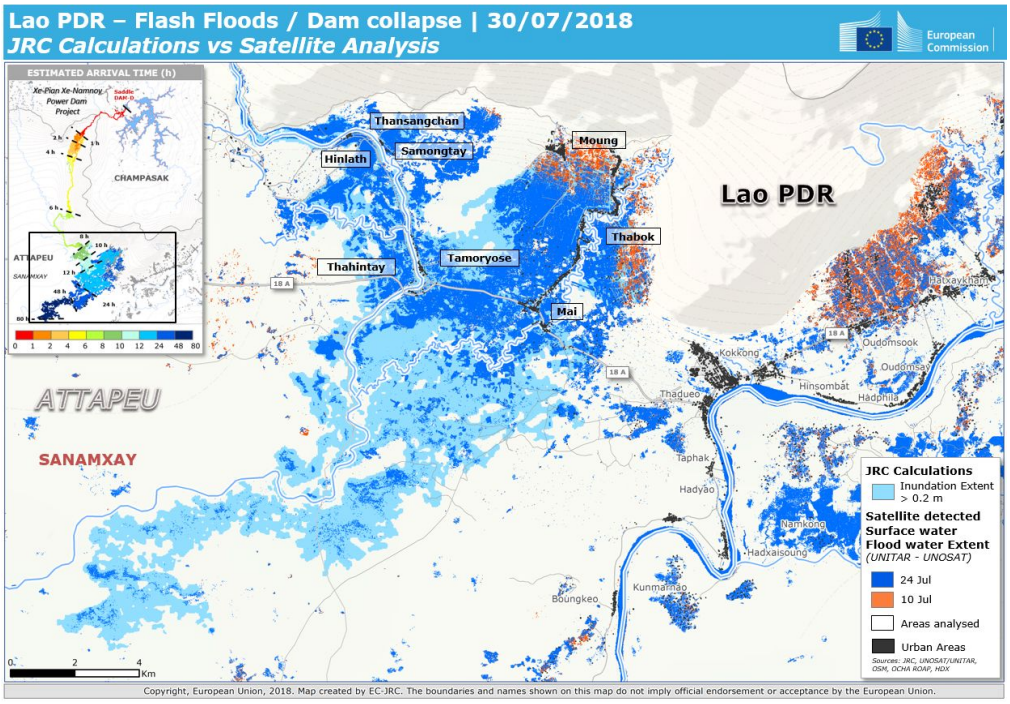
The analysis of the extent of the inundation and the comparison with Satellite images is not easy because the satellite image provides the water extent present on 24th July but a similar image of 10th July shows that water was present also on 10th July, due to rainfall. From the radar images it is not possible to distinguish if the inundation is due to the rainfall (clean water) or to the dam break (water with large mud content). Probably an optical image could help but at the moment the cloudy conditions prevents the use of this type of sensor.

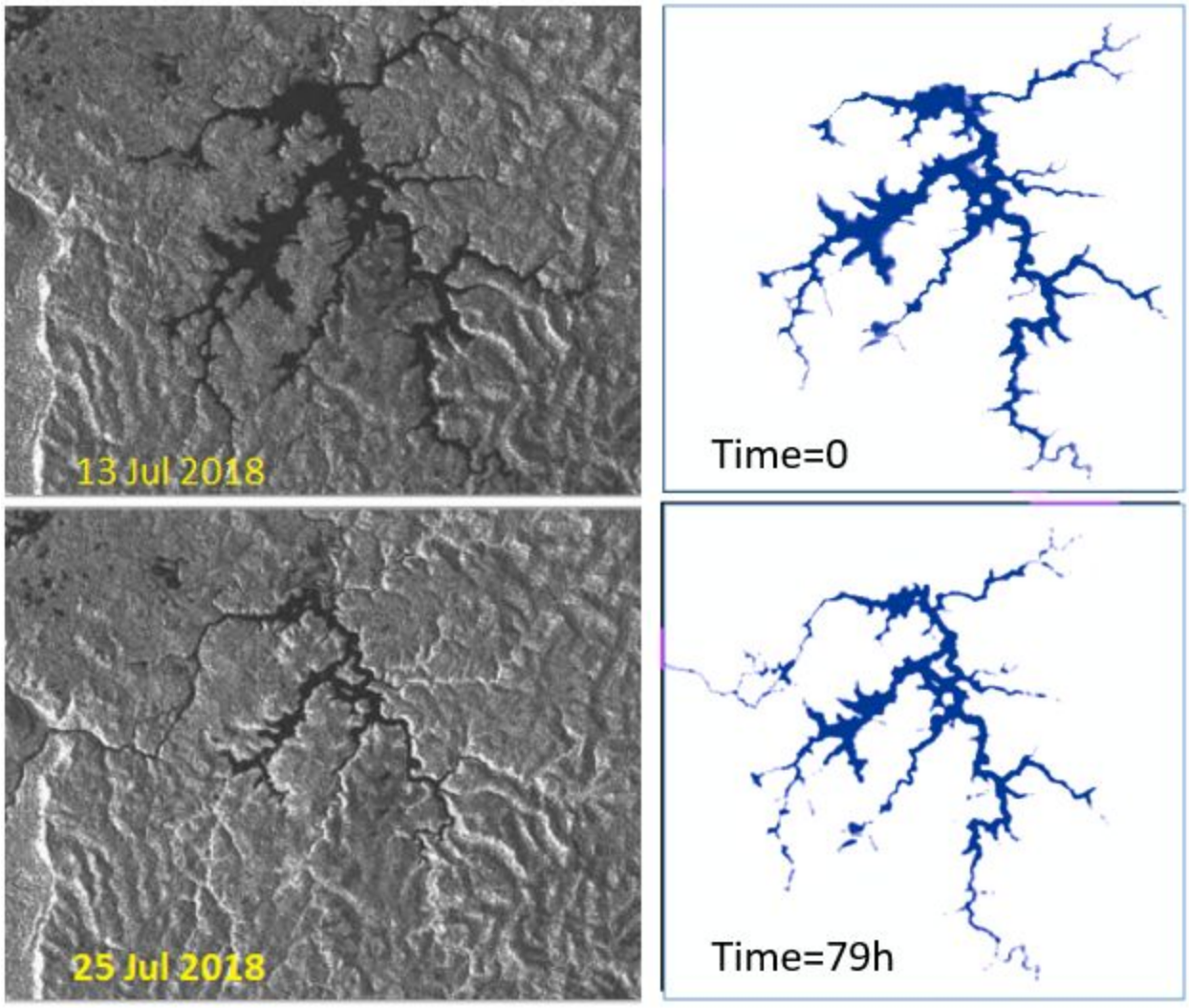
However the comparison above shows that approximately the form of the inundated area is similar. One area in the north is however under estimated (below the label Samongtay); here however water is present also on 17th July and therefore it is not sure that is due to the dam break.

Overlaying the water extent on the maximum water height, it appears evident the similarities but also some differences.

In the north section of the discharge, a difference is noticeable in the calculation with a larger inundation area. The image below represent the top part and the bottom part along the discharge path







The voiding of the lake can be seen in the image above as obtained by satellite images (before and after the break[3]) and as calculated in the dam break analysis. In both cases it is evident the strong reduction of the surface of the lake.

3 http://unosat-maps.web.cern.ch/unosat-maps/LA/FL20180723LAO/UNOSAT_A3_FL20180723_Oveview_Situation_report_25July2018.pdf

4. Other information

4.1. JRC involvement

4.1.1. JRC Support to ERCC

In the period after the end of ARISTOTLE services and the beginning of the new 24h service that is being prepared, JRC supplies ERCC with a similar service during working hours.
For this emergency, JRC prepared the following products:

- 24 July (morning): JRC sent an email to the ERCC in the morning, providing a short description of the event
- 25 July:
    - (morning): JRC included more information in the JRC Draft ECHO Flash
    - (morning): ERCC requested an emergency report.
    - (afternoon): JRC prepared a daily map and was updated in the ERCC portal.
    - (afternoon): JRC sent the first emergency report, providing more detailed information on the event (dam and humanitarian situations).
      → The same map on the event and the first report prepared by JRC have been be uploaded in the Virtual OSOCC web site.
- 26, 27, 30 July (morning): JRC included more information in the JRC Draft ECHO Flash
- 25-30 July: development of dam break model and analysis
- 30 July (afternoon): JRC prepared an updated report, including the results of the dam break analysis.

4.1.2. Copernicus EMS[4] activation

Not activated.

4.2. ERCC activation of UCPM

Not activated.

4.3. Virtual OSOCC Activation

An emergency has been activated in Virtual OSOCC on 24 July afternoon. Several reports from regional organizations (i.e. AHA) and International Federation of Red Cross have been uploaded in the site.

[4] http://emergency.copernicus.eu/mapping/list-of-activations-rapid

4.4. International Charter activation

Activated on 24 July afternoon. The maps produced so far are shown below:

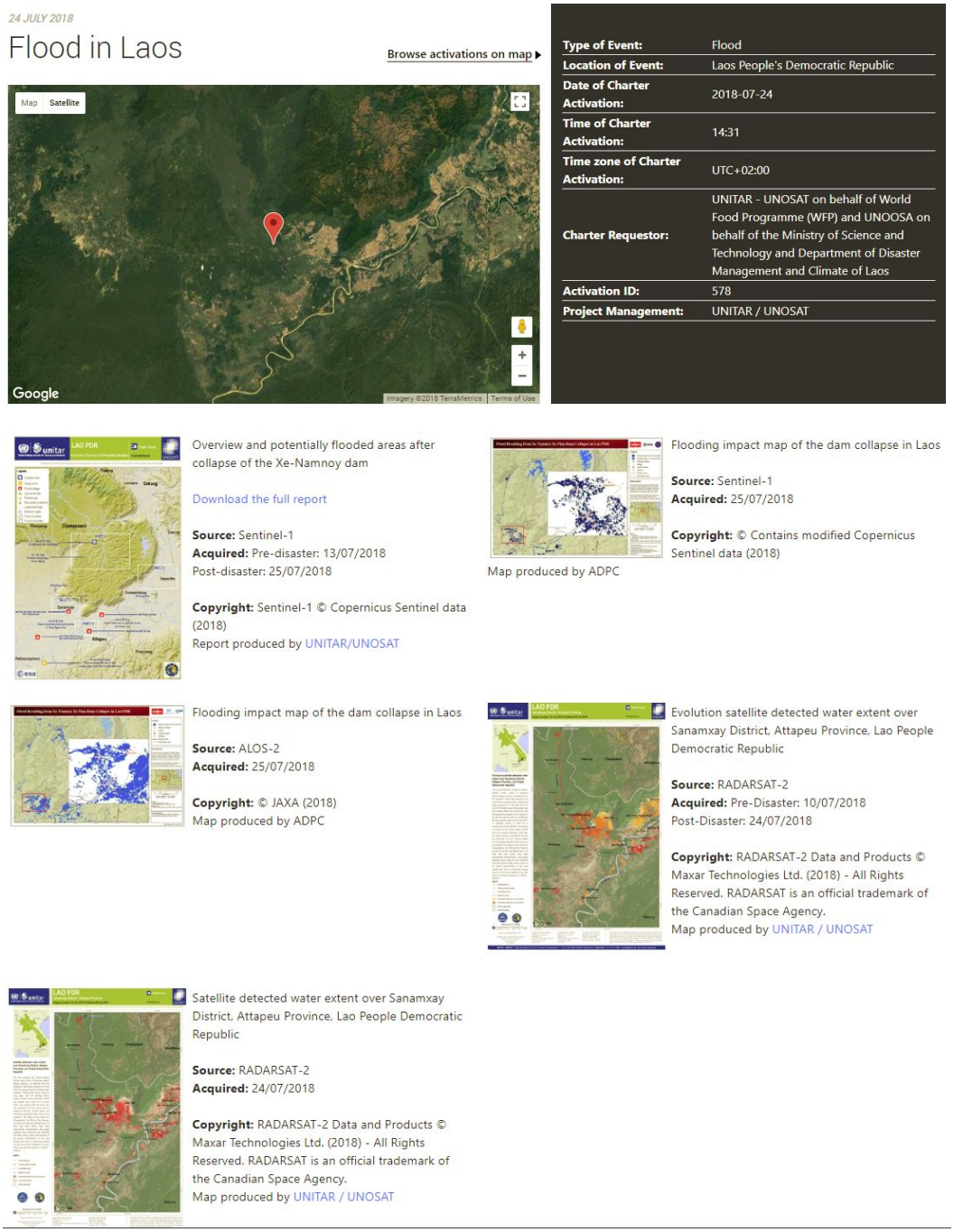


Fig. - Disaster Charter activation - Products available (https://disasterscharter.org/web/guest/activations/-/article/flood-in-lao-people-s-democratic-republic-activation-578-)

5. Expected Updates

JRC is following the situation and will produce an updated report if more information are available.

6. References and contact points within JRC

Contact points within JRC: Disaster Risk Management Unit

Technical Responsible:
- Alessandro Annunziato, alessandro.annunziato@ec.europa.eu

Analysis Team:
- Alessandro Annunziato, alessandro.annunziato@ec.europa.eu
- Pamela Probst, pamela.probst@ec.europa.eu
- Thomas Petroliagkis, thomas.pretroliagkis@ec.europa.eu

Unit Head and Deputy Unit Head:
- Ian Clark, ian.clark@ec.europa.eu
- Tom De Groeve, tom.de-groeve@ec.europa.eu

8. New Relevant Links

Only the new links have been reported below.

- JRC Dam Break Calculations: http://webcritech.jrc.ec.europa.eu/modellingTsunami/damCases/Laos/50m_bat_2/depth.gif
- GDACS:
    - Floods: http://www.gdacs.org/report.aspx?eventid=1000210&episodeid=1&eventtype=FL
    - TC SON-TINH: http://www.gdacs.org/report.aspx?eventid=1000469&episodeid=26&eventtype=TC
- ERCC portal: http://erccportal.jrc.ec.europa.eu/
- Disaster Charter Activation: https://disasterscharter.org/web/guest/activations/-/article/flood-in-lao-people-s-democratic-republic-activation-578-

- UNOSAT-UNITAR: http://unitar.org/unosat/maps/LAO

- AHA Centre: http://adinet.ahacentre.org/main
- Reliefweb: Lao PDR Floods: https://reliefweb.int/disaster/ff-2018-000118-lao
- Humanitarian Data Exchange: https://data.humdata.org/search?q=laos&ext_page_size=25:
- Lao News Agency:
    - http://kpl.gov.la/En/Detail.aspx?id=36492
    - http://kpl.gov.la/En/Detail.aspx?id=36554
    - http://vientianetimes.org.la/FreeContent/FreeConten_Attapeu.php
- Media: https://www.nytimes.com/2018/07/26/world/asia/laos-dam-collapse.html

Appendix A - Meteorological Situation: *Assessment of Precipitation*

A.1 - 10-Day Meteogram for Xepian-Xe area (max horizon of HIRES)

A pinpoint Meteogram over the next 10 days for the reference closest grid point (3 km to the south-west) to Xepian-Xe based on both the high-resolution (HIRES) operational forecast and the Ensemble Prediction System (EPS) of ECMWF has being compiled comprising main weather elements as cloudiness (in octa), precipitation (in mm/6h), wind (m/s) and temperature (deg Celsius). Based on the Meteogram of Figure A1.1, cloudy to overcast conditions are forecast for Xepian-Xe area with local heavy rains and thunder showers.

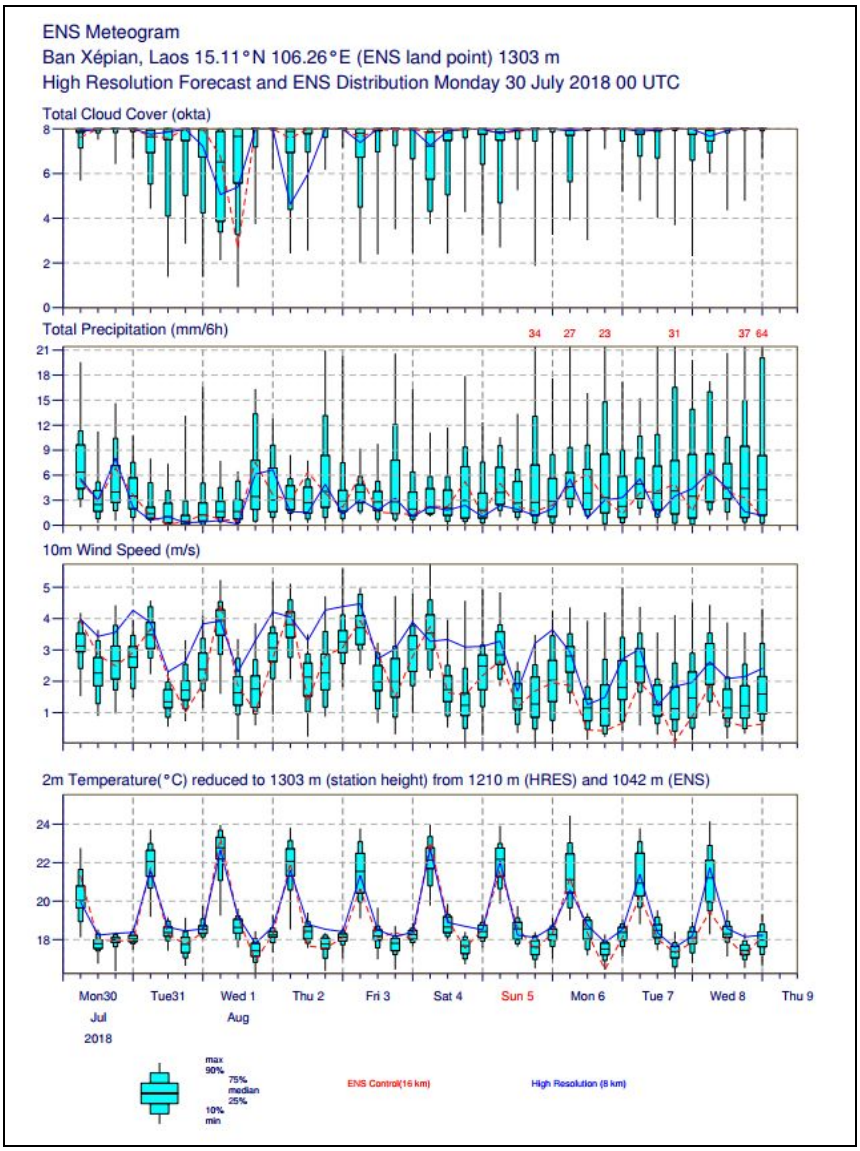


Figure A1.1 - *10-Day Meteogram for Xepian-Xe area based on 30 July 00 UTC high-resolution operational forecast and 50+1 (control) ensembles of ECMWF EPS.*

A.2 - 2-Week (15-Day) Meteogram for Xe-Pian area (max horizon of EPS)

A pinpoint Meteogram over the next 15 days for the reference closest grid point (3 km to the south-west) to Xepian-Xe based on the Ensemble Prediction System (EPS) of ECMWF has being compiled comprising main weather elements. M-Climate (model climate) values are also included for reference. Based on the Meteogram of Figure A2.1, cloudy to overcast conditions are forecast for Xepian-Xe with local intense rains and thunder showers.

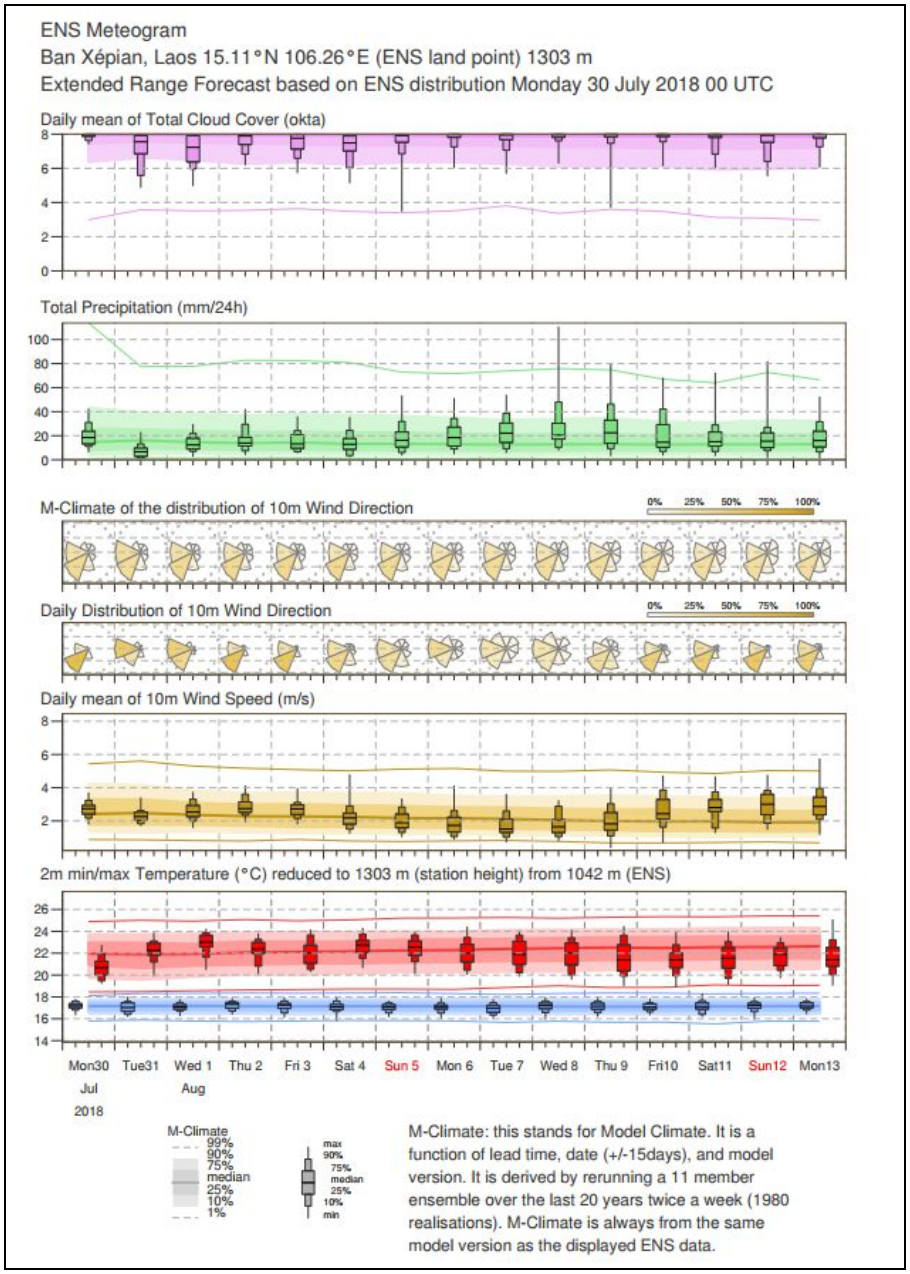


Figure A2.1 - 2-Week (15-Day) Meteogram for Xepian-Xe area based on 30 July 00 UTC EPS (Ensemble Prediction System) of ECMWF. The M-Climate (model climate) is also included.