FRAMEWORK SERVICE CONTRACT FOR
COPERNICUS EMERGENCY MANAGEMENT SERVICE
RISK & RECOVERY MAPPING

TECHNICAL REPORT

EMSN184: Flood in Thessaly Region, Greece

Organization(s) Author	e-GEOS , ITHACA
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ACRONYMS

Acronyms	Signification
AOI	Area Of Interest
AU	Authorized User
CEMS	Copernicus Emergency Management Service
CLC	Corine Land Cover
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EFAS	European Flood Awareness System
EMSN	Emergency Management Service Normal
EO	Earth Observation
GCP	Ground Control Point
GSD	Ground Sampling Distance
JRC	Joint Research Center
LULC	Land Use Land Cover
MMU	Minimum Mapping Unit
OSM	OpenStreetMap
RRM	Risk and Recovery Mapping
SAR	Synthetic Aperture Radar
SRF	Service Request Form
SP	Service Provider
STD	Standard

1 INTRODUCTION

1.1 ACTIVATION DETAILS

COPERNICUS RISK AND RECOVERY MAPPING ACTIVATION	
ACTIVATION DETAILS	
Activation Name	EMSN184: Flood in Thessaly Region, Greece
Authorized User	General Secretariat for Civil Protection for Greece
Date and Time of Activation (UTC)	20.12.2023 15:18
EVENT DETAILS	
Event Type(s)	Flood
Location	Thessaly region (Regional units of Larissa and Magnesia), Greece
Date and Time of the Event (UTC)	September 2023

Table 1-1 Activation Details

1.2 EVENT DESCRIPTION AND CONTEXT

The CEMS Risk and Recovery Standard has been activated by the General Secretariat for Civil Protection for Greece, on behalf of the Ministry of Rural Development and Food, requesting the provision of delineation and grading products, following the flood event occurred in the Thessaly region (Regional units of Larissa and Magnesia) on the 05th September 2023.

As it was reported on the EFAS news portal[1], on the 4th September 2023, a heavy rainfall from Storm Daniel produced extensive flooding in parts of Greece, Bulgaria and Turkye. Rainfall from the storm began on 04 September and continued for several days. Climate Crisis and Civil Protection Minister mentioned that the storm dumped 645 mm of rain in a few hours on the 5th September 2023 in Zagora in Magnesia, Thessaly. From the 4th to the 7th December, 1,095.6 mm of rain were recorded in the same location.

[1] Source: https://www.efas.eu/en/news/storm-daniel-affects-greece-bulgaria-and-turkiye-september-2023#:~:text=Very%20heavy%20rainfall%20rain%20from,T%C3%BCrkiye%20in%20early%20September%202023.&text=In%20Greece%2C%20rainfall%20from%20the,continued%20for%20several%20days%20after

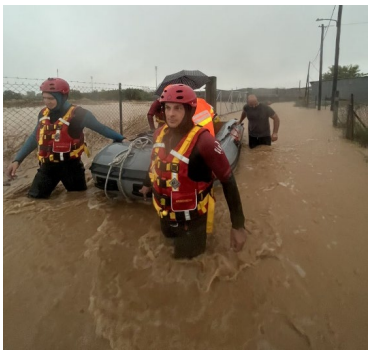


Figure 1-1 Flood rescue in Greece, September 20232 (left side) and Floodwaters submerged houses and farms in the village of Kastro, near Larissa, in Greece's Thessaly region, September 7 2023 (right side)[3]

On this event, the Copernicus EMS Rapid Mapping was activated through the EMSR692: 7 AOIs were requested with the objective of providing Delineation and related monitoring products. For the present EMSN184 activation, a single AOI was requested to be analysed, being still affected by flood. It is included within AOI01-Magnesia analysed in EMSR692, as shown in the figure below.

- AOI01 – Karla Lake (500 km^2)

Figure 1-2 CEMS RM activation EMSR692 (AOI01 – Magnesia, in green) and CEMS RRM STD present activation EMSN184 (AOI01 – Karla Lake, outlined in red)

[2] Greek Fire Service

[3] Source: https://edition.cnn.com/2023/09/07/europe/greece-floods-storm-rescue-climate-intl/index.html

1.3 SERVICE REQUEST

1.3.1 OBJECTIVE

The goal of the activation is to provide the Ministry of Rural Development and Food with delineation product of the current flooded area for the planning of the necessary recovery measures.

1.3.2 FEASIBILITY STUDY

The EMSN184 activation was accepted following a feasibility analysis that was carried out to define the requirements necessary to assure the generation of the requested products (see Table 1-2).

REQUESTED PRODUCTS						
Product Code	**Product description**	**Scale**	**Image resolution class/Sensor type**	**Input Data (obligatory)**	**AOI (km^2)**	**Delivery time (days)**
P04	Flood delineation	1:25000	VHR-SAR	Image Data, DEM	25-500	5-10
P14	Impact assessment/exposure analyses on asset and population	1:25000	None	Reference dataset, Disaster Extent or predicted event extent	25-500	3

Table 1-2 Technical details for requested standard products

Following the feasibility study, the service provider committed the delivery of the following products:

- **2xP04-Flood delineation,** based on the analysis of Sentinel-1 and Sentinel-2 data for refinement satellite acquisitions
- **2xP14- Impact assessment on assets and population**, based on the evidence gathered from any flood extent product.

FEASIBILITY OF REQUESTED PRODUCTS					
PRODUCT CODE	**PRODUCT DESCRIPTION**	**SCALE**	**AOI**	**Other details**	**Feasible/Not Feasible**
P04	Flood Delineation	1:25000	AOI01 – Karla Lake (500 km^2)	**2x P04**	
P14	Impact assessment analyses on asset and population	1:25000	AOI01 – Karla Lake (500 km^2)	**2x P14**	

Table 1-3 Technical feasibility statement for the EMSN184 activation.

1.3.3 PRODUCTS DESCRIPTION

The products generated within this activation are described in Table 1-4.

	AOI	Product description
P04	AOI01	The **Flood Delineation** and the estimated water depth aims at locating the inundated areas within AOI01. From the Sentinel-1 image acquired on the 18th of December 2023, the flooded zones are extracted using a supervised classification and validated by an operator. As a result of this SAR image analysis, approximately 9815 hectares of flooded areas were detected. The refining carried out by using the Sentinel-2 image acquired on the 19th December 2023 allowed for a more accurate definition of the extent of the flood-affected areas, which increased to 10697 hectares. After validation, the water depths are computed using a 5m DTM. The results of this processing reveal the water height values in the areas submerged by the flood. These values increase, on average, from the north of the AOI to the southeast, where around Karla Lake, the maximum values obtained from the processing are recorded.
P14	AOI01	The **Impact assessment analyses on assets and population** has been performed based on the OSM dataset and EMSR692 reference layers, and the population information provided by the WorldPop dataset. The products have been delivered by reporting, in tabular form, the impacts of the flood extent provided by the two P04 products.

Table 1-4 Products description

The final delivery includes the products reported in Table 1-5.

Product Name		AOI	Description	Type	Scale	Num.
RRM OVERVIEW MAPS	1	AOI01	P04 – Flood Delineation • 18.12.2023 • 19.12.2023	Overview Map	1:65.000	2
GDB	2	-	Geodatabase with results	GDB	-	1

Product Name		AOI	Description	Type	Scale	Num.
Technical Specifications FWC	3	AOI01	.json files of: - AOI01 – Karla Lake - Intermediate results of P14 product	Vector	1:25000	14
	4	AOI01	Symbology used for all the delivered vectors and for the water depth represented in P04 RTP maps	.lyr, .sld files	-	2 .lyr 2 .sld
	5	AOI01	Water Depth (P04)	Raster data	-	2
	6	AOI01	Consequence table (P14)	.xls	-	2
	7	-	Metadata for gdb, all vector, raster and RTP items delivered	.xml files	-	19
	8	-	Flyer	Report	-	1
	9	-	Factsheet	Report	-	1
	10	-	Final Report	Report	-	1

Table 1-5 Deliverables description

2 INPUT DATA

Input data for EMSN184 mostly consist in pre-event optical data and post-event SAR and optical images (Table 2-1). In addition, ancillary datasets were used to support the analysis and to improve the readability of the cartographic products (Table 2-3).

2.1 EO DATA

Data type	Sensor	Acquisition date and time (UTC)	GSD (m)	Off-nadir angle (°)	Cloud cover (%)	RRM STD Products
PRE-EVENT SATELLITE IMAGERY	Sentinel-2	31.08.2023 09:15	10	0	0	P04
POST-EVENT SATELLITE IMAGERY	Sentinel-1	18.12.2023 04:31	10	-	-	P04
	Sentinel-2	19.12.2023 09:23	10	0	0	P04

Table 2-1 EO Data for EMSN144 products

Data type	Sensor	Acquisition date (or interval)	Request submission date and time (UTC)	Reception date and time (UTC)
PRE-EVENT SATELLITE IMAGERY	Sentinel-2	31.08.2023 09:15	-	22.12.2023 12:00
POST-EVENT SATELLITE IMAGERY	Sentinel-1	18.12.2023 04:31	-	22.12.2023 12:00
	Sentinel-2	19.12.2023 09:23	-	22.12.2023 12:00

Table 2-2 EMSN139 Imagery procurement details

2.2 OTHER INPUT AND ANCILLARY DATA

Data source	Provider	Format	Availability	Use
DTM (5m)	Authorised User	Raster	-	Input for water depth of flood delineation product (P04)

Data source	Provider	Format	Availability	Use
Referece dataset	OSM, EMSR692 layers	Vector	https://rapidmapping.emergency.copernicus.eu/EMSR692/download	Input to the impact assessment product (P14) and support to map production
Population	WorldPop	Raster	https://hub.worldpop.org/geodata/summary?id=26498	Input to the impact assessment product (P14)

Table 2-3 Input and ancillary data for EMSN184 products

3 METHODOLOGY

3.1 P04 – FLOOD DELINEATION

The P04 Flood delineation and water depth estimation provides a comprehensive assessment of the flood event. This product can be used both in the preparedness and recovery phase of the disaster management cycle.

3.1.1 INPUT DATA PRE-PROCESSING

The data pre-processing is essential for the preparation of the input data to be used for the extraction of the flood delineation product. The main data sources used are a pre-event optical image and two post-event images, the first SAR the second optical. The satellite data used during the P04 generation are presented in Table 3-1.

AOI01	Image
Pre-event	Sentinel-2A (2023) (acquired on 31/08/2023 at 09:15 UTC, GSD 10 m) provided under COPERNICUS by the European Union and ESA.
Post-event	Sentinel-1A (2023) (acquired on 18/12/2023 at 04:31 UTC, GSD 10 m) provided under COPERNICUS by the European Union and ESA. Sentinel-2B (2023) (acquired on 19/12/2023 at 09:23 UTC, GSD 10 m) provided under COPERNICUS by the European Union and ESA.

Table 3-1 List of HR data used for P04 product generation

All imagery needed to produce the P04 layers have been geometrically and radiometrically processed to satisfy the Risk & Recovery Mapping ITT specifications.

SAR imagery pre-processing includes the following steps (the full workflow is presented in Figure 3-1):

- Radiometric calibration: necessary to be able to compare several SAR acquisitions, it transforms the digital number of each pixel into backscattering coefficient.

- Speckle filtering: SAR imagery is subject to speckle phenomenon, giving it a very granular look. It affects the quality of the interpretation and analysis, by impacting the backscattering coefficients values. A simple local correction is conducted using a filter, in the form of a sliding window.

- Geometric correction: geocoding, georeferencing, geometric calibration and orthorectification are steps that lead to the conversion of SAR images – either slant range or ground range geometries – into a cartographic reference system. In general, it is possible to apply a direct approach using satellite orbital parameters (state vectors) and DEM data to correct topographic distortions in SAR imagery. The direct strategy determines the ground coordinates of a SAR image pixel through an

iterative resection process using the SAR Doppler equation, SAR range equation, and the Earth surface model provided through the DEM.

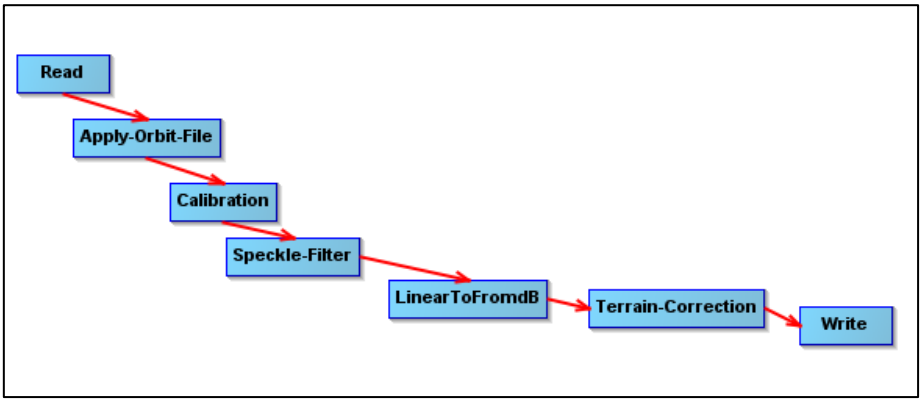

Figure 3-1 SAR data pre-processing workflow

No radiometric or geometric pre-processing steps were necessary for Sentinel-2. Only a composite of bands B2 (blue), B3 (green), B4 (red), and B8 (NIR) was performed.

To derive hydrological information useful for the estimation of the water depth, a National VHR DTM provided by the AU during EMSR692 has been used.

3.1.2 FLOOD EXTENT EXTRACTION

Flood extraction has been conducted using a supervised Random forest classification. Training samples are collected by the operator in radiometrically homogeneous areas, both inside the flooded areas and the not flooded areas. The training samples have been merged in the two homogeneous classes (water/no water) and the supervised classification has been applied. It performs a Random Forest classification on the input raster bands and creates a classified raster as output. The result has been erased by the Reference hydrology layer. The vector data has been filtered according to area filters in order to remove false alarms due to SAR shadowing and to remove/fill small patches/gaps below the MMU. The results have been checked during the final Quality Control and integrated into following products and deliverables. The process is summarized in Figure 3-2.

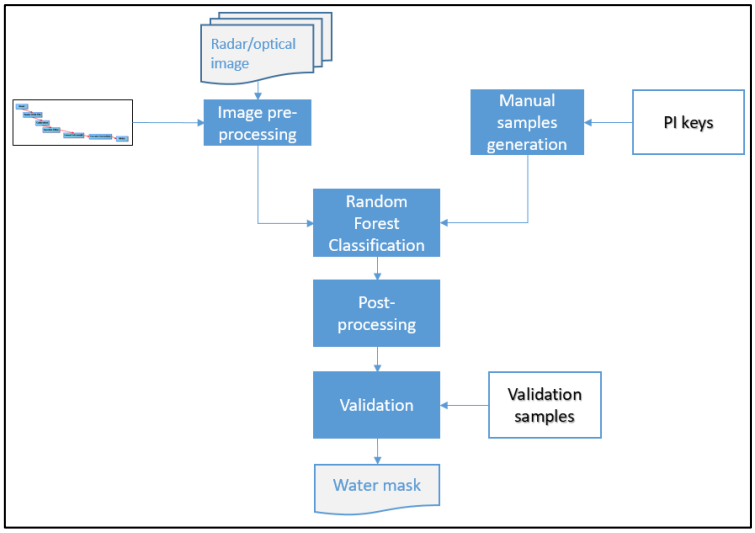

Figure 3-2 Workflow of the supervised classification for P04 production

3.1.3 WATER DEPTH ESTIMATION

The water depth has been estimated by using a direct calculation on the DTM.

The driving thinking for this method lies on the simple fact that the water depth at limit between water and soil around a flooded area should be equal to 0. For a specific flooded area, the water depth over the area is calculated as:

$$Wd = \begin{cases} z_{ni} - z_i, & z_{ni} \geq z_i \\ 0, & z_{ni} < z_i \end{cases}$$

With zi the altitude of all pixels in the flooded area and z_{ni} the nth percentile of altitude in the ith area. The percentile is chosen in order to remove outlier values that could result from the difference in resolution between the input image and the DEM. Resulting negative values are brought to 0.

The resulting Flood Depth product consists of a single-band raster with the calculated water depth, in meters, assigned to each pixel.

3.2 P14 – IMPACT ASSESSMENT ANALYSES ON ASSETS AND POPULATION

The P14 – Impact assessment analyses on assets and population product aims at delivering statistics based on reference datasets. Results are presented in tabular form.

In this case, a P14 product has been generated by studying the impact of the flood extent as provided by the P04-Flood delineation products.

3.2.1 INPUT DATA PREPARATION

For the P14 products, the following datasets have been used:

- **DISASTER EXTENT:** The flood extent as provided by the generated P04 products.
- **POPULATION DATA:** The population distribution within the AOI01 as provided by the WorldPop Greece 100 m dataset (https://hub.worldpop.org/geodata/summary?id=26498). The dataset is available to download in Geotiff format at a resolution of 3 arc (approximately 100m at the equator). The projection is Geographic Coordinate System, WGS84. The units are number of people per pixel. "NoData" values represent areas that were mapped as unsettled based on the outputs of the Built-Settlement Growth Model (BSGM) developed by Jeremiah J.Nieves et al. 2020.
- **ASSETS:** those provided through the EMSR692 reference layers and OSM dataset. Layers that were not impacted by the event were not incorporated into the production of P14.

3.2.2 IMPACT ASSESSMENT ANALYSES

The spatial intersection of the aforementioned assets datasets with the P04-Flood delineation vector products, results in 6 intermediate spatial statistics layers, as reported in Table 3-2.

P14 Intermediate vector products	Vector description
EMSN184_STD_AOI01_P14IAAP01_intermediateresultsA1_v01.geojson EMSN184_STD_AOI01_P14IAAP02_intermediateresultsA1_v01.geojson	Affected transportation [ha]
EMSN184_STD_AOI01_P14IAAP01_intermediateresultsA2_v01.geojson EMSN184_STD_AOI01_P14IAAP02_intermediateresultsA2_v01.geojson	Affected facilities [ha]
EMSN184_STD_AOI01_P14IAAP01_intermediateresultsL_v01.geojson EMSN184_STD_AOI01_P14IAAP02_intermediateresultsL_v01.geojson	Affected transportation [km]

Table 3-2 P14 Impact assessment on assets intermediate results

The consequence tables provided as P14 inform on:

- the total flooded area (P04 flood extent), in ha;
- the estimated affected population, as well as the total estimated population within the AOI, obtained by summing up the values of the pixels of the WorldPop data covered by the flood as provided by the P04 food extent layer;
- the total affected transportation classified by typology (in km and ha), as well as the total length/area of each of these types of transportation classes within the AOI;
- the total affected facilities classified by typology (in ha), as well as the total area of each of these types of facilities classes within the AOI;

4 RESULTS

The main results and products of the activation are presented in the following sections.

4.1 P04 – FLOOD DELINEATION

4.1.1 FLOOD DELINEATION RESULTS

Due to the effects of the intense rains that began in the middle of September in the Thessaly region, two P04 were made in order to monitor the still critical situation in mid-December. The satellite data exploited to extract value-added information (see chapter 3.1 for the methodology) were acquired just over a day apart. The first product was based on a SAR (Sentinel-1) image acquired on the night of December 18 (04:31 UTC). The second product was made with an optical image (Sentinel-2) acquired on the morning of December 19 (09:23 UTC). The total flooded area observed at each date is reported in the following table.

Date	Flood Extent [ha]
	AOI01
18.12.2023 04:31 UTC	9815.4
19.12.2023 09:23 UTC	10697.4

Table 4-1 Flood extent provided by the P04 products

Table 4-1 shows similar values of flooded areas for the two products. The larger area corresponds to the P04 of December 19th, made with an optical image that allowed a more accurate definition of the flooded areas. Indeed, it has to be stressed the fact that P04-Flood delineation product suffers the limitations of the interpretability of the SAR acquisition used. Vegetation which may characterize the cultivated fields do not allow a correct detection of flooded surfaces, since the microwave signal is backscattered from the vegetation before reaching the soil or water surface. Similarly, the spatial resolution and the complex scattering mechanisms and SAR geometric effects occurring in an urban environment, do not allow detecting any flood. As a result, the total flood extent retrieved from Sentinel-1 images is likely to have been underestimated.

4.1.2 WATER DEPTH RESULTS

The water depth product is provided as single-band GeoTiff raster files named:

- EMSN184_STD_AOI01_P04FLDEL01_WaterDepth_v01.tif (Situation as of: 18.12.2023)
- EMSN184_STD_AOI01_P04FLDEL02_WaterDepth_v01.tif (Situation as of: 19.12.2023)

The pixel values (float type) indicate the water depth in meters.

For the P04 generated with the SAR image, the average water depth value turned out to be 2.4 meters, while the maximum value of 3.8m was recorded in some areas near the lake. The P04 made with the optical image,

as expected, shows very similar results: the average value of about 2.3 meters while the maximum value of 3.8 meters is confirmed.

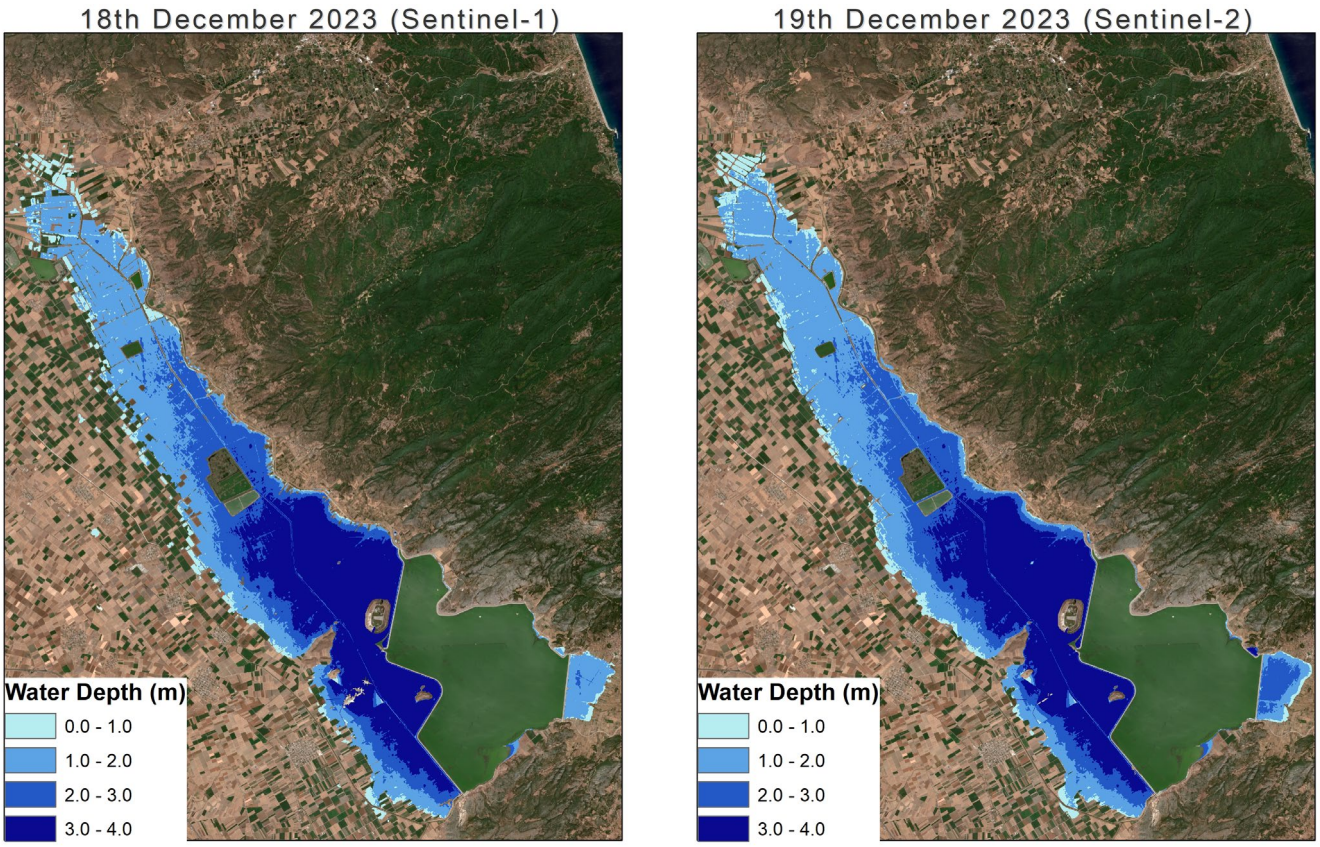

Figure 4-1 Examples of P04-Flood delineation products showing the estimated water depth on 18th December and on 19th December 2023.

4.2 P14 – IMPACT ASSESSMENT ANALYSES ON ASSETS AND POPULATION

The impact of the flood has been analysed as described in chapter 3.2. The results have been organized in the consequence tables shown in Table 4-2 and Table 4-3.

Consequences within the AOI				
	Unit of measurement		Total affected	Total in AOI
Flooded area	ha		9815,46	
Estimated population	Number of inhabitants		~650	~9800
Transportation	Roads	km	178,49	1361
	Railways	km	0,00	18
	Airfields	ha	152,90	176,20
Facilities	Sport and recreation constructions	ha	0,00	12,92
	Dams	ha	4,23	24,35
	Constructions for mining or extraction	ha	0,00	8,51
	Power plant constructions	ha	6,21	77,00

Table 4-2 Consequence table representing the impact assessment on assets and population (P14) of the flood occurred on 18 December 2023.

Consequences within the AOI				
	Unit of measurement		Total affected	Total in AOI
Flooded area	ha		10697,39	
Estimated population	Number of inhabitants		~700	~9800
Transportation	Roads	km	206,59	1361
	Railways	km	0,00	18
	Airfields	ha	173,20	176,20
Facilities	Sport and recreation constructions	ha	0,00	12,92
	Dams	ha	5,57	24,35
	Constructions for mining or extraction	ha	0,00	8,51
	Power plant constructions	ha	6,21	77,00

Table 4-3 Consequence table representing the impact assessment on assets and population (P14) of the flood occurred on 19 December 2023.

5 INTERNAL QUALITY CONTROL

5.1 P04 – FLOOD DELINEATION

5.1.1 METHODOLOGICAL OVERVIEW

Positional accuracy

The positional accuracy of P04 product is dependent on the input satellite image positional accuracies. This will not be reported due to several reasons:

- There is no ground truth to assess the geometric accuracy of the image.
- In the case of SAR images, the RMSE reported in the Terrain Correction step is relative to the DEM and precise orbits do not necessarily assess horizontal accuracy.

The only option to calculate it is to collect Ground Control Points (GCPs) where it is extremely difficult to find sufficient, stable and reliable GCPs between SAR and optical imagery.

Flood delineation thematic accuracy

A thematic validation has been performed to assess the thematic quality of P04 products. The flood delineation consists of a layer representing 2 classes: flooded and unflooded areas. Congalton, Russell G. and Kass Green (2002)[4] suggest that in the case of a change/no change map, a binomial class distribution is appropriate for assessing the sample size. An example is also presented: for a 90% accuracy and a confidence level of 95%, a sample size of 298 is required. The thematic accuracy required for P04 is 85% which can be tested with high confidence level by using 400 samples. For the validation of the P04 products, it has been chosen to test 400 samples.

The same authors proposed a method for increasing the number of samples in the areas surrounding the flooded ones. Within the P04 production, three zones, “flood”, “interface”, “not flood”, are defined, each will host at least 50 validation points. The rest of the points are spread proportionally to the zones sizes in a systematic manner according to a grid to ensure that all parts of the image are assessed. An example of point repartition is shown in Table 5-1.

Strata	Area [km^2]	Number of samples
Flooded area	20	80
Interface	30	120
Rest of the AOI	50	200

Table 5-1 Sampling strategy example for a total area of 100 km^2

The “flooded area” stratum is self-explanatory. The “direct surrounding” stratum corresponds to areas in contact with the flooded area where confusions in the flood delineation are expected to be probable. This

[4] Congalton, Russell G., and Kass Green. *Assessing the accuracy of remotely sensed data: principles and practices*. CRC press, 2002.

area is defined by a buffer around the flooded area. The "rest of the AOI" stratum corresponds to the remaining area. For each sample point, the operator will verify the correctness of the classification and enter results in a confusion matrix.

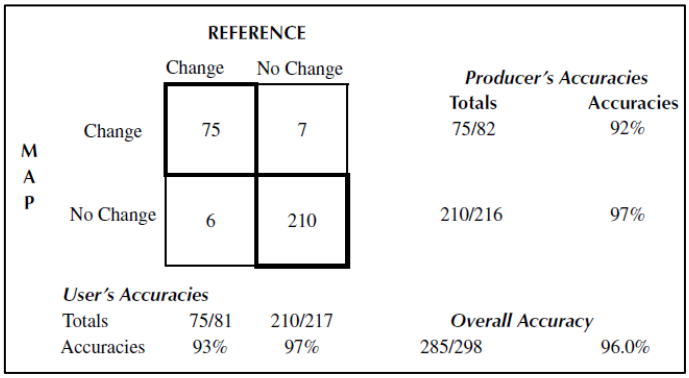

Figure 5-1 Example of confusion matrix (source: Congalton, Russell G., and Green, Kass, 2002)

The accuracy of the delineation product is assessed through Producer's, User's, and finally Overall accuracies. The Overall accuracy of the product must be over 85%. Otherwise, the delineation must be reworked and new samples must be taken to assess the accuracy again.

Water depth thematic accuracy

The water depth accuracy cannot be evaluated by photo-interpretation, and it is mainly dependent on both positional and vertical accuracies (5m) of the input DEM dataset. The only situation where a new assessment could be realized, is if field data is available for the flood event. Otherwise, press information and pictures from the event are investigated to ensure that the results are at least in the correct order of magnitude.

5.1.2 FLOOD DELINEATION THEMATIC ACCURACY

AOI01 - SENTINEL-1 18.12.2023 04:31 UTC

AOI01 Karla Lake		Reference Data			
		Flooded	Not Flooded	Total	User's Accuracy
Classified Data	Flooded	117	6	123	95,1%
	Not Flooded	4	274	278	98,6%
	Total	121	280	401	
	Producer's Accuracy	96,7%	97,9%		OA = 97,5%

Table 5-2 AOI01 P04-Flood delineation (18.12.2023) confusion matrix

AOI01 - SENTINEL-2 19.12.2023 09:23 UTC

AOI01 Karla Lake		Reference Data			
		Flooded	Not Flooded	Total	User's Accuracy
Classified Data	Flooded	144	8	152	94,7%
	Not Flooded	6	242	248	97,6%
	Total	150	250	400	
	Producer's Accuracy	96,0%	96,8%		OA = 96,5%

Table 5-3 AOI01 P04-Flood delineation (19.12.2023) confusion matrix