European Regional Development Fund

CHAPTER 3.4: Flood risk and its territorial management in France

Monitoring, forecasting, and warning at French and Europe levels

Definitions, State of the art, Source data

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1. Definition

1.1. Definition of “risk”

A ALEA is a more or less probable phenomenon in a given territory.

The sensitivity (level of predictable effect) of this territory to this hazard is called VULNERABILITY.

RISK is the probability of damage occurring when a hazard interacts with the vulnerability of a territory. A hazard can only become a risk when there are human, economic, social, or environmental issues at stake.

The risk calculation can therefore be summarized in the following equation:

RISK = ALEA * VULNERABILITY

A risk can result from the combination of several hazards that affect the vulnerability of a territory and its society.

The risk is said to be MAJOR when it can cause a large number of victims or considerable damage, exceeding the response capacities of the authorities intervening on a territory. It is characterized by low occurrence and considerable impacts. This major risk becomes a CATASTROPHY when it permanently disrupts the natural and anthropic balance of a territory.

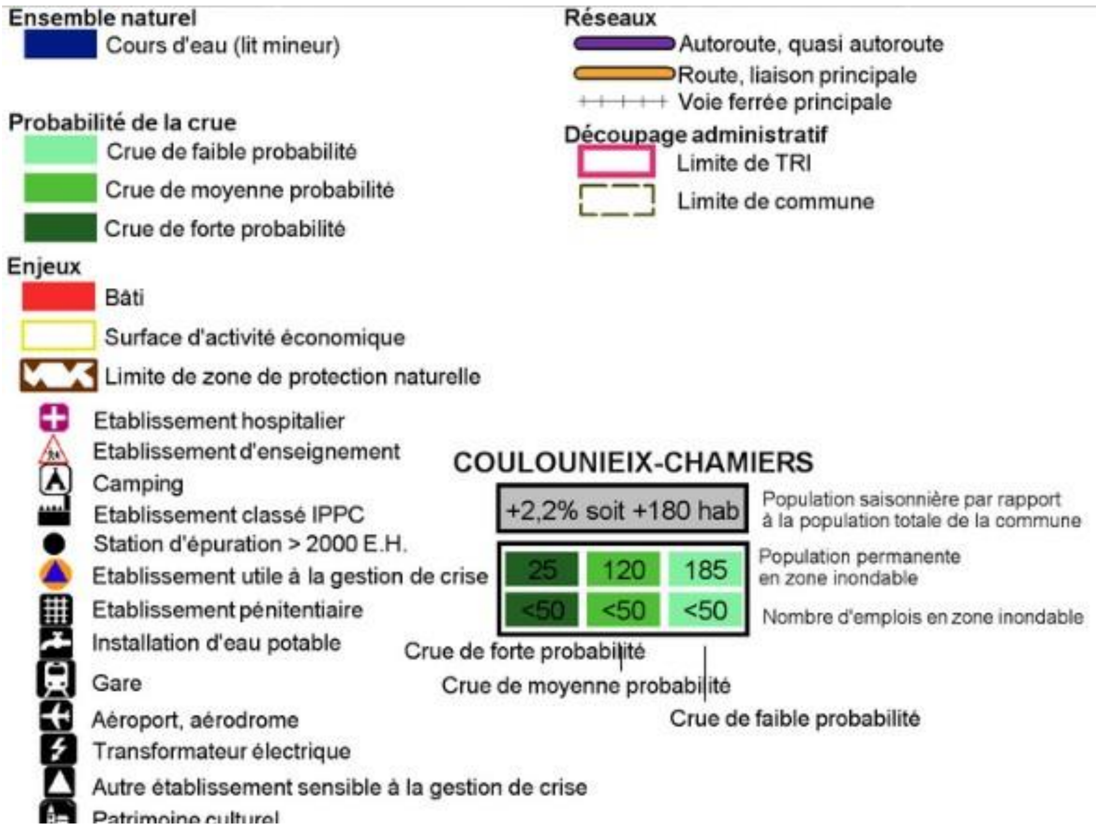


Figure 1- List of issues on the flood risk presentation map fort the Périgueux conurbation (source: DDT Dordogne)

1.2.Definition of “flood” phenomenon

Flooding is the temporary submersion by water of land that is not normally submerged, regardless of its origin: flooding of rivers, mountain torrents, intermittent streams, rising water tables, urban and agricultural runoff, marine submergence beyond the limits of the seashore. Floods account for half of the world's natural disasters in terms of frequency.

The causes of flooding have a natural, recurrent (monsoon) or weather-related (severe thunderstorms, cyclones, etc.) basis.

Flooding can result from several phenomena (e.g. high swell + high tide; storm surge and estuarine flooding).

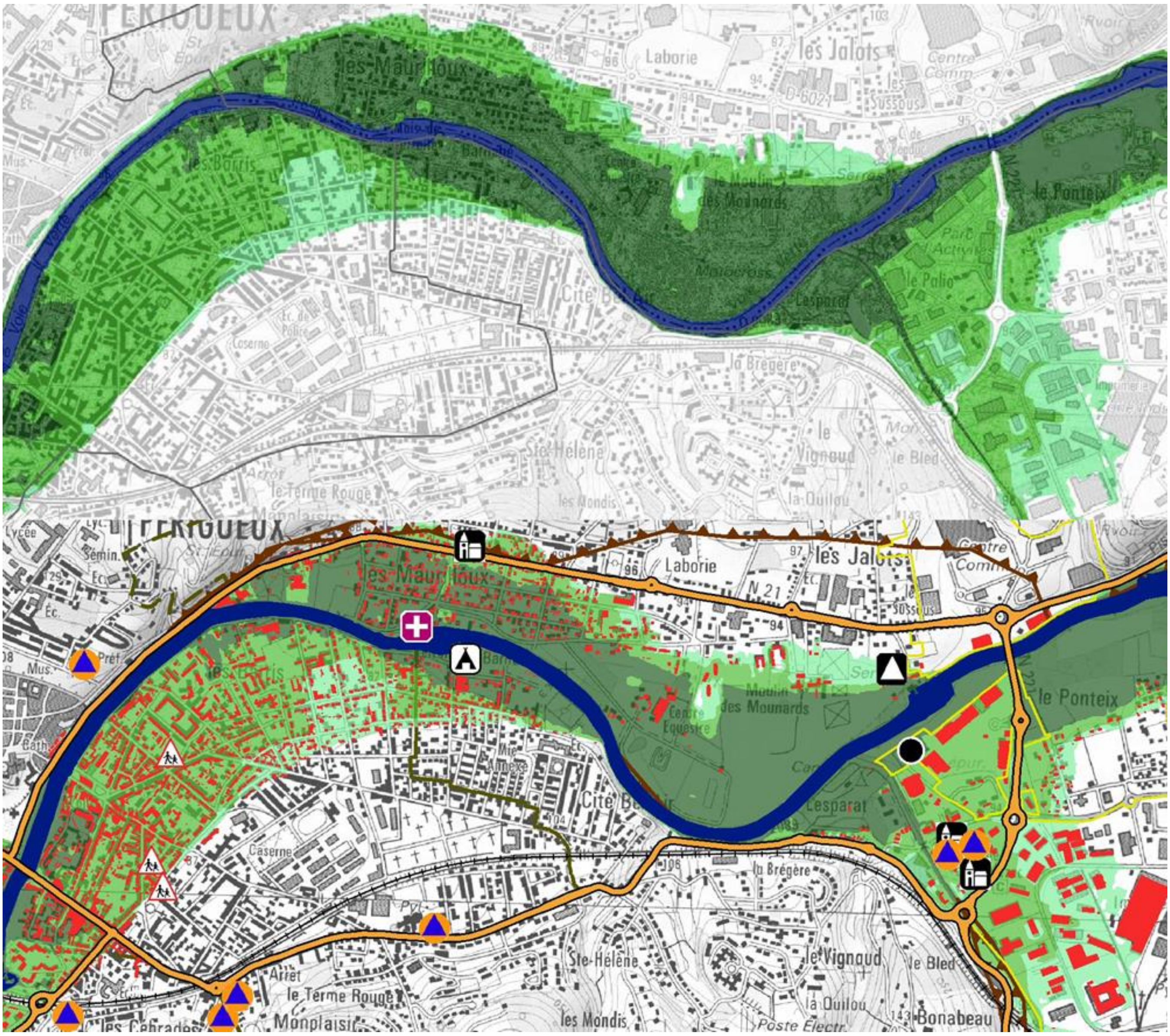


Figure 2- Example of flood hazard mapping (top) and flood risk mapping (bottom) on the agglomeration of Périgueux, Dordogne

The different types of floods are:
Slow rise of water in the plain region or in the region of a flush water table

- Flooding of the plain by rivers leaving their beds
- Rising water table flooding. As a result of several wet years. The level of the water table can cause flooding that can persist for several months. This phenomenon is very slow.

Rapid formation of torrential floods following heavy rainfall

- Floods of torrential rivers and torrents. During intense rainfall in a catchment area, water runs off and rapidly concentrates in the river, causing sudden and violent floods. Secondly, dams resulting from the accumulation of sediment and dead wood can give way suddenly and generate very large waves.
  Urban and agricultural runoff. The waterproofing of soils (artificial, bare soil and battement) limits the infiltration of rainwater and accentuates runoff. In cities, this manifests itself by the saturation and backflow of rainwater networks, on natural land this runoff erodes the soil and causes the appearance of gullies and ravines along the greatest slope.
- Diffuse runoff. Its thickness is low and its water streams bump and divide at the slightest obstacle.
- The sheet runoff, frequent on gentle slopes, they occupy the entire surface of the slope.

Marine subversions
These are coastal floods that can last from several hours to several days and occur under conditions of low atmospheric pressure, coupled with strong acting inflow winds and at high tide for tidal seas).
There are 3 modes of marine submersion

- By overflow, when the sea level is higher than the crest of the natural terrain or protective works
- By the crossing of wave-bound packets of water when, after the break-up of the swell, the packets of water exceed the crest of the structures or the natural terrain.
- By rupture of the protective structures

1.3. Definition of "flood risk"

Flooding as such is a natural phenomenon (ALEA), which can cause damage to people, property, and the environment.

Flood risk **is the probability of occurrence of damage resulting from the occurrence of the flood hazard in territories with vulnerabilities.**

Human activity is an aggravating factor in the risk of flooding, either by increasing the vulnerability of territories (occupation of flood-prone areas), or by increasing the probability of the phenomenon occurring through environmental developments (activities, roads, land consolidation, agricultural practices, deforestation) that change the flow conditions (runoff), or by its influence on the atmospheric composition and climatic characteristics.

1.4. Definition of "Early Warning System"(EWS)

Early warning is a key element of risk and disaster prevention. It results from the coordination of monitoring and warning systems. Monitoring allows the prediction of the hazard, while warning consists of disseminating messages to the communities concerned. The integration of an EWS is a guarantee of its effectiveness.

- Knowledge and detection of disaster risks, monitoring, analysis, and forecasting of hazards and possible consequences
- Dissemination and communication
- Preparation and intervention at the level of the public

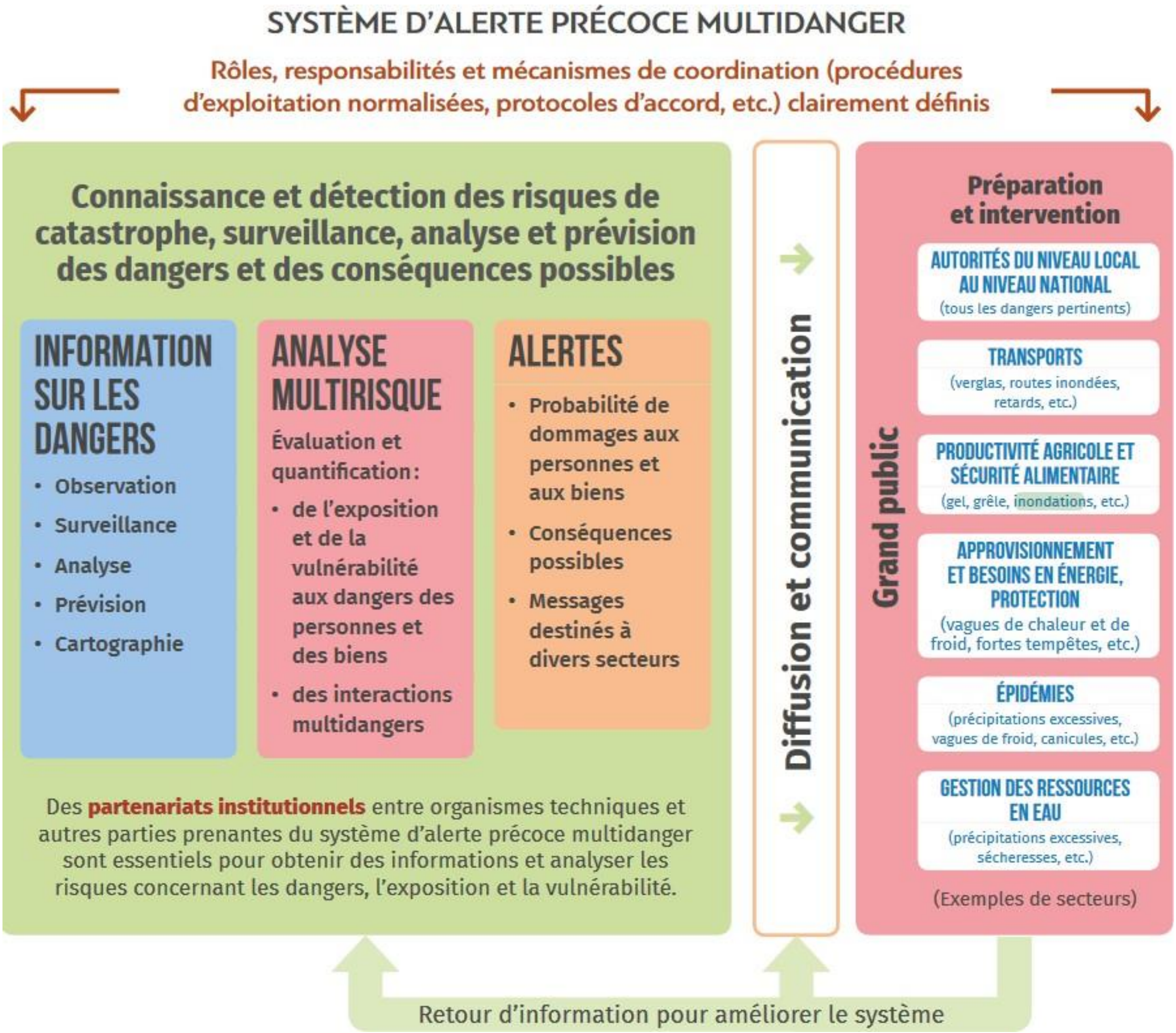


Figure 3- Schematic representation of a multi-hazard early warning system (source - report of the International Network on Multi-Hazard Early Warning Systems, May 2017)

The Paris Agreement identifies EWS as one of the important areas for action to enhance adaptive capacity, build resilience, reduce vulnerability, and minimize loss and damage from climate change impacts.

2. French and European flood management systems

2.1. Stratégie Nationale de Gestion du risque Inondation / National Flood Risk Management Strategy (SNGRI)

France has a National Flood Risk Management Strategy (SNGRI) since October 7, 2014. This strategy meets 3 objectives.

- Increase the safety of exposed populations
- To stabilize in the short term, and reduce in the medium term, the cost of flood damages
- Greatly shorten the time it takes for the affected territories to return to normal

This strategy has resulted in the production of

- A "National Flood Vulnerability Repository", intended for the bearers of local strategies, flood prevention action programmes (PAPI), and all those involved in flood prevention. It contains a method for quantifying vulnerabilities and how to build an operational action plan.
- A guide to "Taking into account agricultural activity and natural areas in the context of flood risk management". It aims in particular to encourage consultation with a view to setting up upstream- downstream solidarity, combined with exposure transfer logics.

2.2. Plan de Prévention du Risque Inondation / Flood Risk Prevention Plan (PPRI)

The State has also prescribed a PPRI (Flood Risk Prevention Plan), in order to supervise the development of urbanization.

- Control of development in flood-prone areas on the basis of a reference flood so as not to increase the risks or create new ones.
- Preservation of the flood expansion area and non-urbanised areas.

It maps the areas exposed to risk and regulates them according to hazard and land use.

2.3. Gestion des Milieux Aquatiques et Prévention des Inondations / Management of Aquatic Environments and Flood Prevention (GEMAPI)

In France, the EPCI -FP (Public Establishment for Inter-municipal Cooperation with Clean Taxation) are responsible for the Management of Aquatic Environments and Flood Prevention - GEMAPI.

2.4. Programme d'Actions de Prévention des Inondations / Flood Prevention Action Programme (PAPI)

Introduced in 2002, they aim to promote integrated flood risk management in order to reduce consequential damage. Carried out by local authorities, they are based on a diagnosis and evaluated based on a cost- benefit analysis. Quantified objective of reducing negative consequences at local level.

2.5. The Joint Flood Commission (CMI)

It is issued by the Orientation Council for the Prevention of Major Natural Risks (Orientation Council for the Prevention of Natural Risks - COPRNM) and the National Water Committee (CNE) (circular dated 5 July 2011). It is a place for dialogue and exchange between the various stakeholders concerned by flood prevention and the links with water management, town planning and regional development). The IJC is responsible for the governance of flood risk management systems.

2.6. The Flood Directive

European Directive 2007/60/EC translated into French law in 2010/11 and codified in articles L566-1 to L566- 12 and R566-1 to R566-18 of the Environmental Code. It provides a framework for Member States to reduce the negative consequences of floods on human health, economic activity, the environment, and cultural heritage.

Within the French hydrological districts, it is applied in 3 renewable stages over a 6-year cycle.

- Preliminary risk assessment (EPRI), (inventory of significant historical events and production of indicators characterizing the issues at the basin scale, especially on the population and jobs exposed. The EPRI leads to the choice of territories at significant flood risk (TRI).
- Mapping of floodable surfaces and flood risks on TRI
- Flood Risk Management Plans (PGRI), as an extension of the national strategy, based on the EPRI and the mapping carried out on the TRI. These PGRI are detailed at the local level for each TRI by a local flood risk management strategy (SLGRI). The PGRI of the first cycle (2011-2016) were decided by the basin coordinating prefects in December 2015. The great majority of the local strategies have already been developed.

The second cycle (2017-2022) follows the same timetable as the Water Development and Management Master Plan (SDAGE), resulting from the Water Framework Directive (WFD).

The IRMPs aim to integrate the consideration and management of flood risk into all policies in the territory. It thus deals with all flood management issues:

- Flood prevention about the balanced and sustainable management of water resources
- Monitoring, forecasting and information on flood phenomena
- Reduction of the vulnerability of territories to flood risks, including measures for the development of sustainable land use and the control of urbanization
- Preventive information, education, resilience, and risk awareness.

2.7. Plan de Gestion du Risque inondation / Flood Risk Management Plans (PRGI)

Ensures consistency of **SLGRI** across major basins. They clarify flood risk management at the same scale, including outside the IRRs. The ORSEC departmental provisions must be annexed to the PGRI. They also include the local variations of the actions coming under the national inter-ministerial plan for rapid submersion (PSR).

3. Data Sources for Flood Forecasting

3.1. General presentation of data that can be used for flood prevention

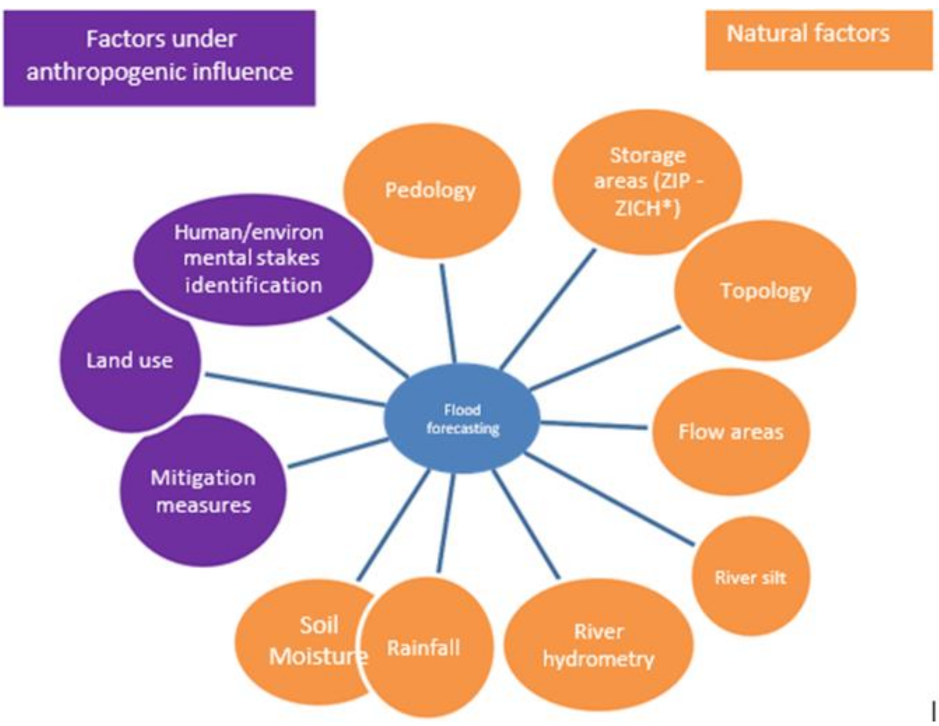


Figure 4- Information that can be used in flood risk forecasting

*SIP - ZICH - Potentially Flooded Areas - Iso Class High Zones

3.2. Existing data sources of interest

3.2.1. Human and environmental issues

- Estimation of the permanent population in the potentially affected area (method for calculating population point sowing - CETE Mediterranean on PostGIS/Postgresql) - source data
  - Population core data, INSEE
  - Land data, DGIFP
  - Legal populations, INSEE
- Estimation of jobs in the potentially affected area (SIRENE file)
- Type of economic activities in the potentially affected area
  - BDTopo IGN: Activity surface area; PAI industrial and commercial; PAIculture and leisure; PAI transport
- Sensitive establishments, infrastructures, or facilities whose flooding may aggravate or complicate crisis management, in establishments receiving the public
  - BDTopo: road network, railways and other (linear elements); administrative and military PAI, health PAI,
  - Rectorate data for educational institutions
  - Nuclear Safety Authority - Basic Nuclear Facility
  - SEVESO installation
  - Drinking water installation (BDTopo)
  - ERDF (electrical transformers between EHV and HV networks)
  - Railway stations (BDTopo)
  - Airports (BDTopo)
  - Campsites (BDTopo)
  - Other sensitive establishments (BDTopo, Regional Health Agency, SDIS)
- Cultural Heritage
  - BDTopo: PAI culture and leisure; PAI natural space; PAI religious
  - SIRTAQUI and DRAC data for libraries and media libraries.

3.2.2. Real-time flowmetry

Hydroreel (real-time hydrometric data server) - Grand Est, Bourgogne FC, Auvergne RA, Occitanie, PACA

The frequency with which rainfall data are updated does not always allow for effective anticipation of runoff phenomena.

3.2.3. Local weather radar networks

Rhytmme (PACA region, France)

The project consisted in installing a network of 3 radars in the southern Alps to improve observations in this sector, which was poorly covered by the main Meteo France network due to the relief of the pre -Alps. A cartographic platform allows real-time monitoring of intense rainfall and associated hazards.

The strength of this mechanism is that it allows the implementation of strong actions, albeit with little anticipation (weakness).

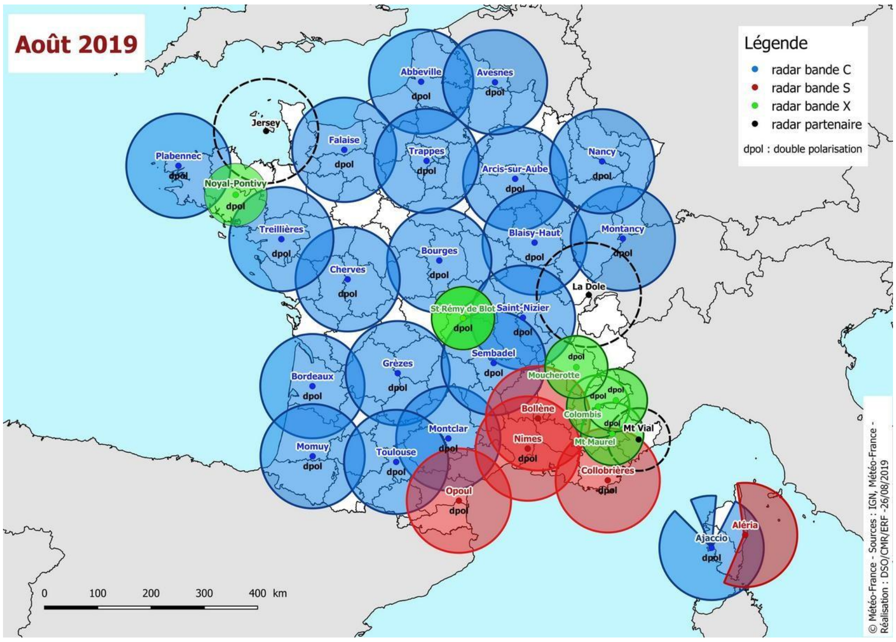


Figure 5- Network of ARAMIS radars operated by Meteo France

Radar imagery from the ARAMIS network provides essential information for flood forecasting services since it provides, after appropriate processing, an estimate of cumulative precipitation, the reliability of which increases year after year.vii
Their range enables them to measure precipitation quantities at 100 km, and to detect dangerous phenomena at 200 km. In addition to precipitation intensity, they provide information on wind. The most recent radars are capable of distinguishing between types of precipitation (rain, hail, snow).

3.2.4. Eumetsat Network

EUMETSAT – HSAF network data– support to operational hydrology and water managementviii

Data set; SSM ASCAT-A/B NRT O - Surface Soil Moisture ASCAT A/B NRT Orbit (H101 - H16 - H102 - H103)

The product of the level 2 surface soil moisture is derived from radar backscatter coefficients measured by the ASCAT (Advanced Scatterometer) on board the Metop series of satellites using a change detection method developed within the Remote Sensing Research Group of the Department of Geodesy and Geoinformation (GEO) at the Vienna University of Technology (TUWien).

This method is detailed in the product's user manual.

Spatial coverage: global

Cycle: 101 minutes per orbit, 14 orbits per day Delay of on-line publication: 2h

Delivery: dedicated FTP server for H-SAF users; via EUMET Cast for other users
Format: BUFR

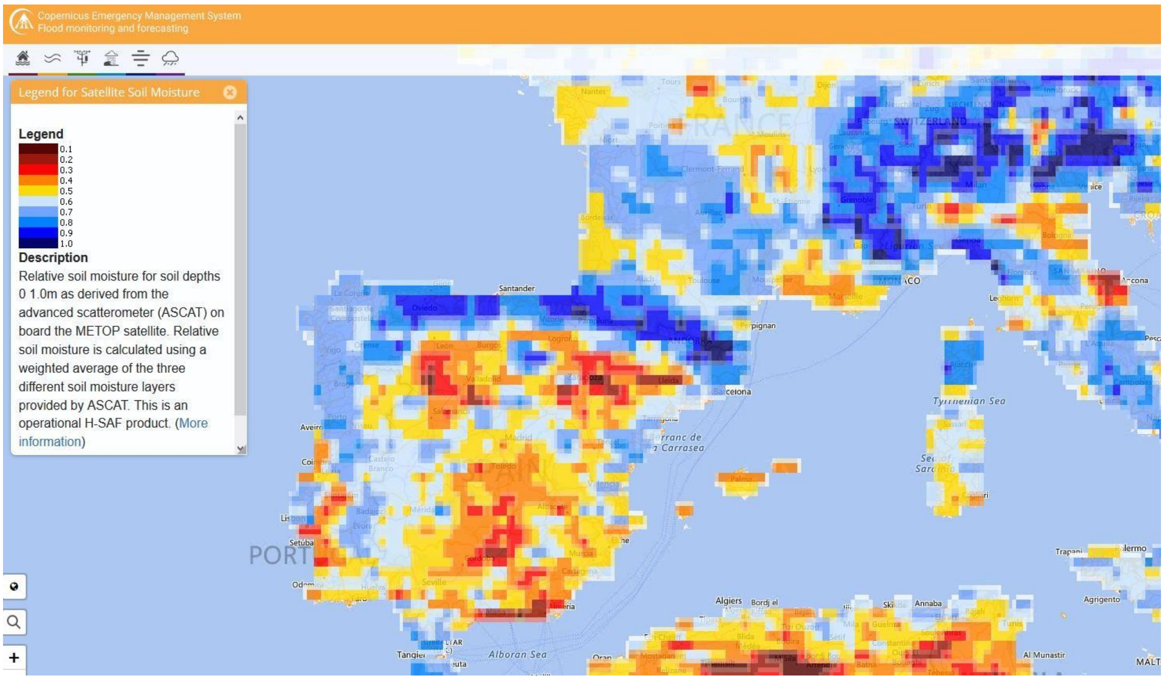


Figure 5- European Flood Awareness System (European Flood Awareness System) Map Portal Interface

This portal mobilises the information produced by the EUMETSAT network.

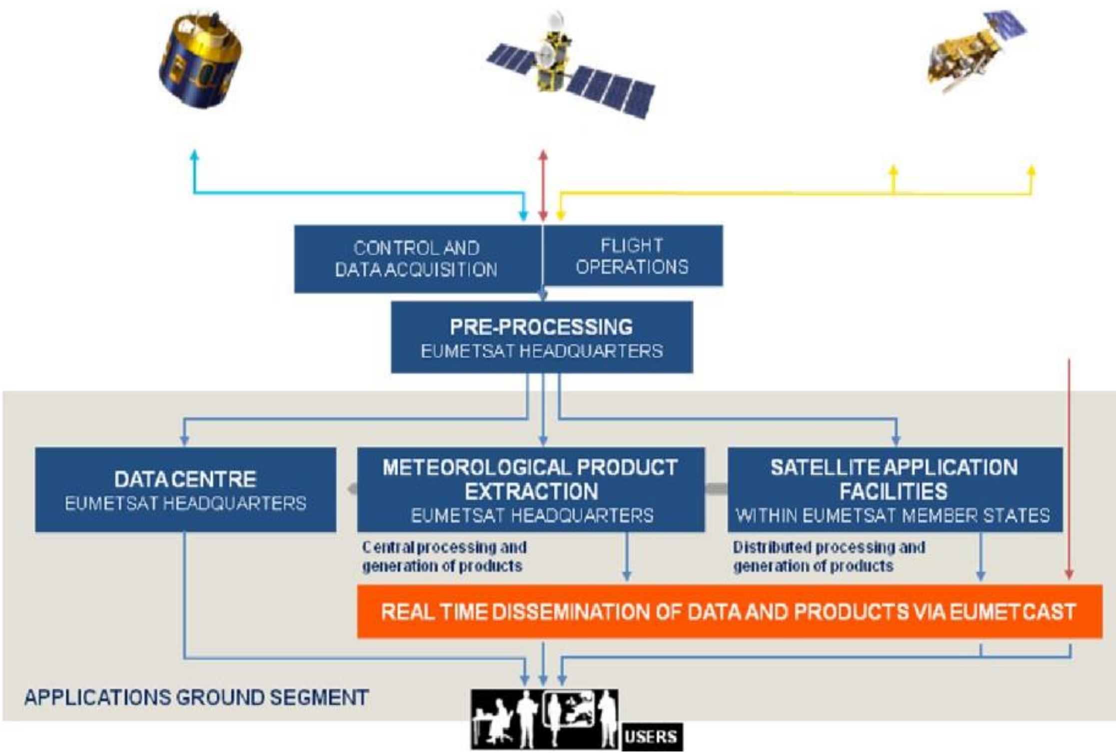


Figure 6- EUMETSAT data production scheme

A new H08 sensor, currently in the pre-operational phase, should soon produce soil moisture data with a resolution of 1km.

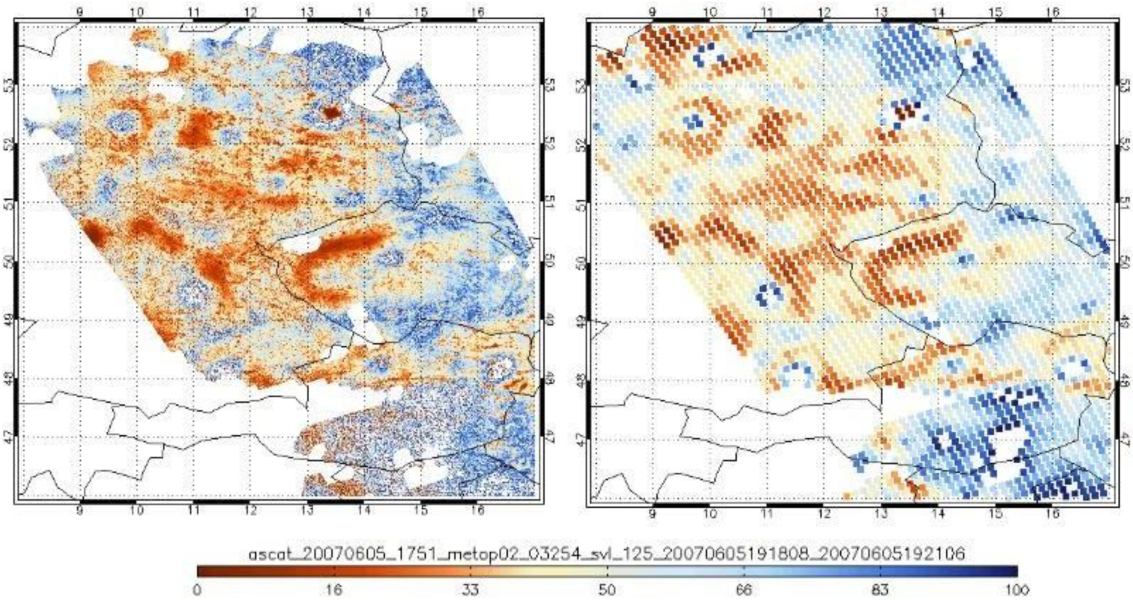


Figure 7- Comparison of soil moisture maps

These mappings are from the current sensor with a resolution of 25km (right), and from the new H08 sensor to come, with a resolution of 1km on each side.

3.2.5. Satellite of observation

Satellites of observation appear as the optimal solution for a large-scale monitoring. Moreover, many types of satellite images are presently available free of charge (e.g. Sentinel or Landsat constellations) at high spatial resolution (< 30 m). Low spatial resolution (e.g. MODIS at 1 km of pixel size and a swath of 2330 km, Proba-V) offers one day of revisiting while for high spatial resolution few days are necessary to acquire information (e.g. 16 days for Landsat with 30 m resolution). Since 2016 and the arrival of the Sentinel constellation the pixel size and repetitivity have been respectively reduced to 10m and 10 days (5 with Sentinel-2b). Radar images thanks to the Sentinel-1 constellation is also available. As a result of these improvements, high spatial resolution is now affordable for multi-temporal monitoring.

Notti et al., 2018 use different indexes to detect flooded areas (e.g. Modified Normalized Difference Water Index, SAR backscattering variation and map classification). These data can be coupled to digital elevation models to improve the accuracy. In this study, they characterize the areas for the pre-flood, the co-flood, and the post-flood. Radar images have the advantage to acquire images both at night and under all weather conditions, filling the gaps resulting from cloudiness optical images. However, it can only detect the co-flood for the area covered by water. It is less probable for radar to acquire images for the co-flood because of the revisit time. Medium and low spatial resolution satellites, with their daily revisit time are more able to acquire co-flood images, on the other side they cannot map small flooded areas. The optical high spatial resolution allows to recognize flooded areas several days after the event especially on cultivated crops in floodplains.

3.2.6. Runoff Hazard Mapping

ExZEco Methodx

The ExZEco model was developed by CEREMA (Centre for Study and Expertise on Risks, Environment, Mobility and Development) in the framework of an Interreg project of the Mediterranean Arc. It allows the extraction of run-off areas (of interest for dry talwegs and run-off), associated with several filling heights.

Its applications allow the realization of territorial diagnostics of flash floods over the whole of France, with a resolution of 25m, and soon of 5m over the Mediterranean arc.

This model does not consider sewerage systems and does not provide information on flows.

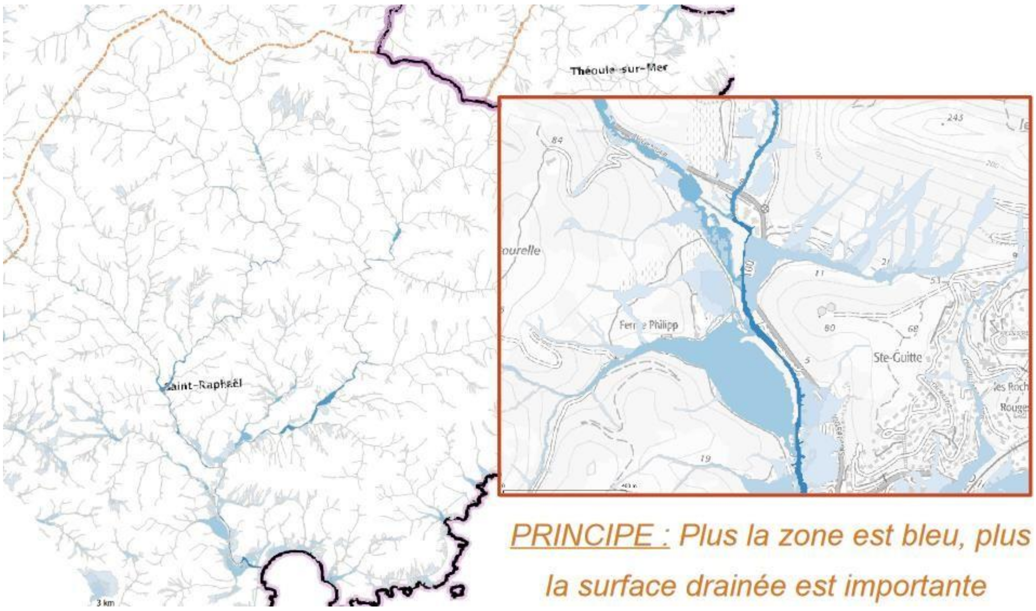


Figure 8- Presentation of a mapping rendering of the ExZEco method (source: CEREMA)

3.2.7. Flood Hazard Mapping

- Mapping of Areas at Significant Risk of Flooding (IRR) - application of the Flood Directive
- Mapping of ZIPs and ZICHs

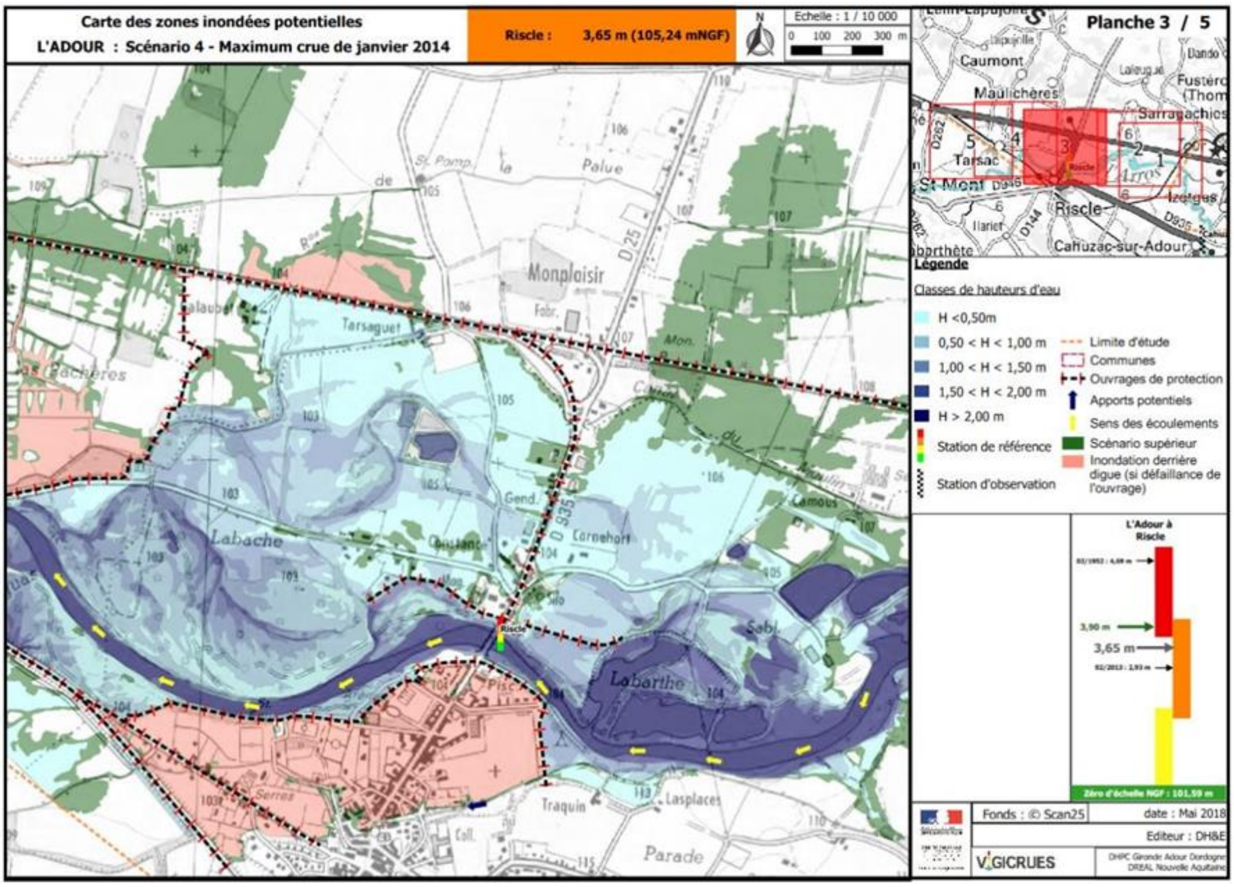


Figure 9- Mapping of a ZICH along the Adour River in the department of Landes, New- Aquitaine, France.

The risk of breakage of protective structures (zone in light red) is included in this type of document, as well as several risk zonings according to the height of water per 50 cm slice of water calibrated on one of the observation stations of the network.

3.3.Field monitoring data

The aim is to monitor the evolution of the phenomena on sites identified in advance. If monitoring of runoff phenomena is carried out at the watershed scale, upstream monitoring makes it possible to anticipate downstream monitoring. If the monitoring is done on a local scale, it only allows to follow the event.

3.3.1. Flow measurement

Predicting and managing river flows is a necessity for flood control. The measurement of flows is then necessary. Hydrometry is the discipline that seeks to measure river flows. The flow rate - the volume of water crossing a section of watercourse during a unit of time - is thus expressed in cubic metres per second (m3/s). Direct flow measurement is a complex operation that can only be carried out on an ad hoc basis. For a continuous measurement, the water level is used, and its value is related to the flow rate by means of a calibration curve.

3.3.2. Water level measurement

Over time, the process has become automated with the installation of sensors to monitor changes in height at a time step adapted to fluctuations in flow. All the devices are placed in or in contact with water with the exception of radar:

- A limnimetric scale is a graduated scale for monitoring day-to-day variations in the water level (or height of water) of a river. Most often, these scales are placed close to bridges, in easily accessible areas where there are no visual obstacles, making it easier to read the scale.
- Piezo-resistive probes measure the pressure exerted by the water column using strain gauges that capture the water column deformation of a force sensor.
- Pneumatic sensors, commonly known as bubble sensors, also measure the pressure exerted by the water column by via a pneumatic line.
- Ultrasonic sensors detect the surface of the river by measuring either an air draft if they are positioned over the flow, i.e. the draught if they are submerged. A correction related to the temperature of the medium (air or water) is necessary.
- Wells equipped with counterweight floats are the most common type of historical. They are still widely used with encoders that allows you to scan the movement of the float. The measurement of the level inside a well can be carried out with any of our of the above-mentioned sensors
- Radar appeared in the 2000s, offers the advantage of being out of the water (a guarantee of better durability, as it is not subject to the aggressions of water, sediments and floating bodies in rivers). However, the need to move the radar away from the bank (edge effects) and the wave reception spot conditioned by the waveguide may nevertheless penalise the representativeness of the measurement in relation to the reference scale **(Groupe Doppler Hydrométrie, 2017).**

3.3.3. Creation of a calibration curve

To create a calibration curve, a series of measurement campaigns at different times of the year is required, at different water heights, mainly by exploring the velocity field or diluting a tracer. To do this, the level of the scale is noted and then, in the bed of the watercourse and using the appropriate equipment, the measurements necessary to calculate the instantaneous flow are taken. The results obtained are then plotted on a graph with two axes (X = water height (cm) and Y = flow (m3/s)). Each of the measurement campaigns enables a point to be positioned on the graph. Finally, a trend curve is drawn corresponding to the smooth curve that is as representative as possible of the general trend drawn by all the points **(Groupe Doppler Hydrométrie, 2017).**

3.3.4. Data transmission

Chronicles of recorded values are transmitted at a given time step which may vary according to the risks associated with the hydrological situation.

The transmission can be carried out by PSTN telephone line (being abandoned by the suppliers), by GSM or GPRS network, by satellite or by radio for fast catchment areas (security against telephone network failures which are quite frequent during floods).

Data transmission can also be carried out in real time for stations using "high-speed" vectors and permanent connections such as ADSL for example **(Groupe Doppler Hydrométrie, 2017).**

3.3.5. Power supply of the hydrometric station

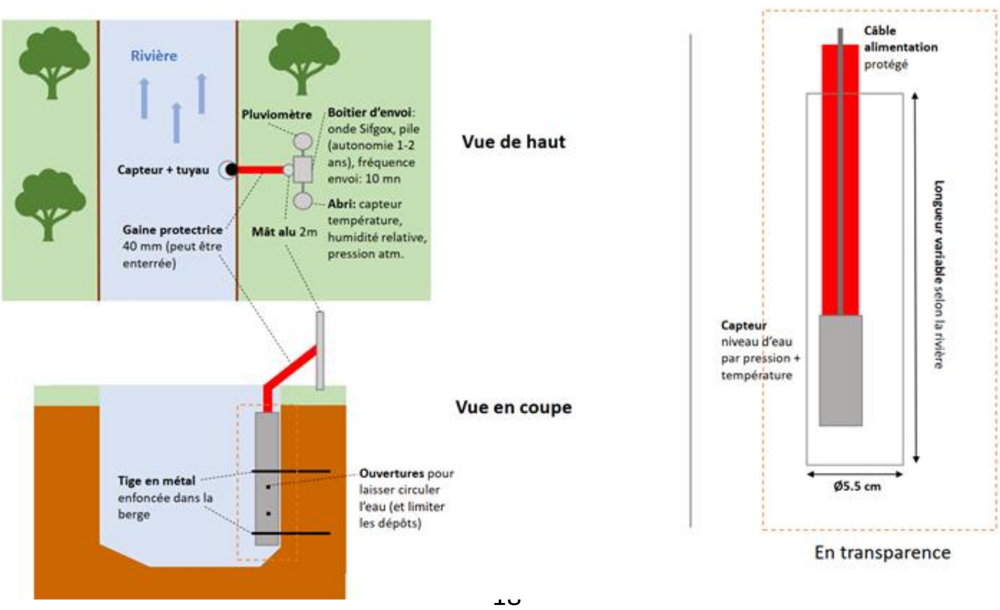
The electricity grid is used when it is available nearby. In addition, a battery installed in the box will provide several days of safety in the event of a power failure. Solar panels are a "stand-alone" solution that is tending to develop. This choice has two main disadvantages: the risk of theft is high, and the panels located in misty valley bottoms in winter are not always sufficient to recharge the battery **(Groupe Doppler Hydrométrie, 2017).**

3.3.6. Installation cost

Site conditions are an important factor that can multiply the price of a resort by 2 or 3. The "equipment" part, with ladders, a sensor, an acquisition system, cable, a cabinet connected to the network and equipped with a battery is estimated at around 20,000 euros (value 2015). A radar support bracket made by a craftsman can cost more than 1,500 euros. A technical room and its external fittings (fence, access road) can cost more than 15,000 euros. Work for networks can also be very expensive. The laying of rails to support the limnimetric ladders can cost more than 1,000 euros **(Groupe Doppler Hydrométrie, 2017).**

3.3.7. The ACMG installation

The ACMG is developing a self-contained, low-cost system for measuring water levels in small streams. The objective of this system is not to exceed a cost of 1,000 €, to be autonomous in energy, independent of the mobile network thanks to the SigFox network. The system should transmit information on the water level in 10 minutes intervals. It is connected to an alert system to warn if a pre-set threshold is exceeded. The device is equipped with a rain gauge, a sheltered temperature sensor, as well as air pressure and relative humidity sensors. The water level sensor is a pressure sensor. It is installed in the river in a reversible way, limiting the impact on the environment.



4. Flood risk monitoring, forecasting, and warning systems at the French and European levels

4.1.General organisation in France

ORSEC (Organization of the Civil Security Response) xi: A system for organising disaster relief under the authority of the prefect.

SCHAPI - Central Service of Hydrometeorology and Support to Flood Forecasting : Based in Toulouse, the SCHAPI produces and disseminates continuous flood watch information published on the website www.vigicrues.gouv.fr. It manages and pilots the State's flood forecasting and hydrometry network (Flood Forecasting Services and Hydrometry Units attached to the DREAL regional services or to the South- East inter-regional directorate of Meteo -France) - Vigicrues network. The SCHAPI expertise, validates and synthetizes the data provided by the SDPC (Flood Forecasting Service) and publishes at least twice a day, 24 hours a day and 7 days a week, the VIGILANCE CRUES via the Vigicrues flood risk information website.

Vigicrues tool (see section 4.2), a flood forecasting system provided by the State, and supplemented by **rain- flood and wave-submersion vigilance and** by the **APICs (Intense Rainfall Warning at the municipal level)** (see section4.3) implemented by Meteo France. This system also provides for the *improvement of crisis preparedness*, which involves the organisation of a joint response by all public and private stakeholders, under the coordination of the State.

The HYDRO Bank - stores water level measurements (in variable time steps) from about 5000 measuring stations (of which about 3200 are currently in service) located on French watercourses and provides access to the stations' descriptive data (purpose, precise location, quality of measurements, history, available data...).

HYDRO calculates the instantaneous, daily, monthly, etc. flow rates for a given station based on water level values and calibration curves (relationships between water levels and flow rates). These values are updated each time a height or a calibration curve is updated (addition, additional precision, correction, …).

HYDRO provides the most accurate flow values possible always based on the information it receives from station managers.

The data are provided to HYDRO by State services, Regional Directorates for the Environment, Planning and Housing (DREAL), Departmental Directorate of Territories (DDT), flood forecasting services, Departmental Directorates of Agriculture and Forestry, Water Agencies, but also by Electricity of France (EDF) or research organisations (National research institute in science and technology for the environment and agriculture (IRSTEA), universities,...), as well as development companies (Gascogne hillsides development company (CACG), National Rhône Company (CNR), Provence Canal Society, Bas-Rhône-Languedoc development company (BRL)...).

These data producers install the river measuring stations, maintain them, collect the data, check them, and feed them into the data bank. They carry out gauging at the measuring stations and establish the calibration curves, which are also included in the bank. They then validate and, if necessary, correct the data. They are responsible for them and ensure their quality.

The Central Service of Hydrometeorology and Support for Flood Forecasting (a service of the Ministry of Ecology, Sustainable Development and Energy) located in Toulouse, administers the bank, and manages the services associated with HYDRO. It also oversees the bank's development.

SDPC - Flood Forecasting Master Plan: It identifies the watercourses or segments of rivers monitored by the State. It defines the organization, monitoring, forecasting and transmission of flood information on the scale of river basins. Its operational implementation is detailed in the **Regulation on the Monitoring, Forecasting and Transmission of Flood Information (RIC) at** the level of Flood Forecasting Services (SPC).

The SDPC also identifies areas not monitored by flooding alertness where a need for LWS (Local Warning System) has been identified.

It states:

- The perimeter of State intervention with the list of communes concerned,
- Monitoring and warning systems implemented by local authorities, in the heads of basins or in unmonitored catchment areas,
- The list of information necessary for flood forecasting,
- The mechanism for informing the authorities and the population and the liaison scheme set up with the authorities in the event of vigilance.

SPC - Flood Forecasting Service: This is the state mission of monitoring the watercourses of the regulatory network. The forecasters define a level of flood risk and establish forecasts for the next 24 hours, by assessing the meteorological data transmitted by Meteo-France and the hydrometric data coming from the measuring stations or gauging carried out by the hydrometers of the VIGICRUES network.

PCS[xiv] (Municipal Safeguard Plan) - Setting up an organisation to deal with major disasters affecting the population (dead or injured people, destroyed houses...), disruptions to collective life (lasting interruption of drinking water or energy supply, bad weather, heatwave, epidemic...), more common accidents (fire, traffic...). This organization consists of training, organization methods and technical tools to avoid falling into crisis.

PSR[xv] (Rapid Submersions Plan) - above all oriented towards the safety of people - Plan for the prevention of risks related to marine submersion, flooding by runoff or flash floods and river or sea dyke breaches, through a pragmatic approach, based on specific or more global projects but on areas that are coherent with regard to the risk.

The PC&H network: This network ensures a permanent 24/24h watch on the watercourses monitored by the State.

- installs and maintains the hydrological measurement network,
- broadcasts the measured data in real time,
- ensures the production and distribution of Vigicrues.

The SDAL (Local Warning Systems): Despite the new tools developed by Meteo France and the SCHAPI, the needs of certain territories in terms of hydrogeological observation and forecasting remain imperfectly covered. On the one hand, the network of rivers monitored by the SPCs as part of the national flood vigilance should only be extended to the margin in the coming years. On the other hand, many communes are not yet eligible for the Vigicrues Flash service or the APIC. This is why, in some cases, it may prove relevant for local authorities to set up their own flood monitoring system, in the absence of coverage by existing national tools, or in addition to them.

The operation and implementation of the SDALs are well documented by the CEPRI guide on flood forecasting and anticipation published in December 2017.

Figure 10- SDAL - Schematic illustration of a watershed instrumented for measuring rainfall, water levels in rivers and streams, and sea level.

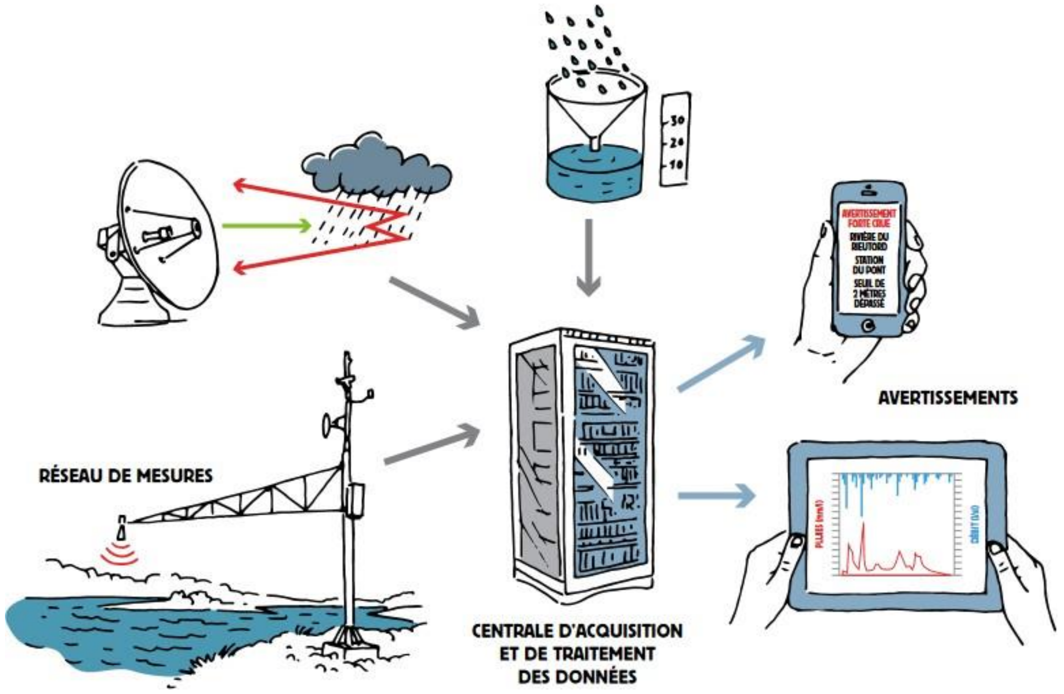


Figure 11- SDAL - Schematic representation of the possible operation of an SDAL

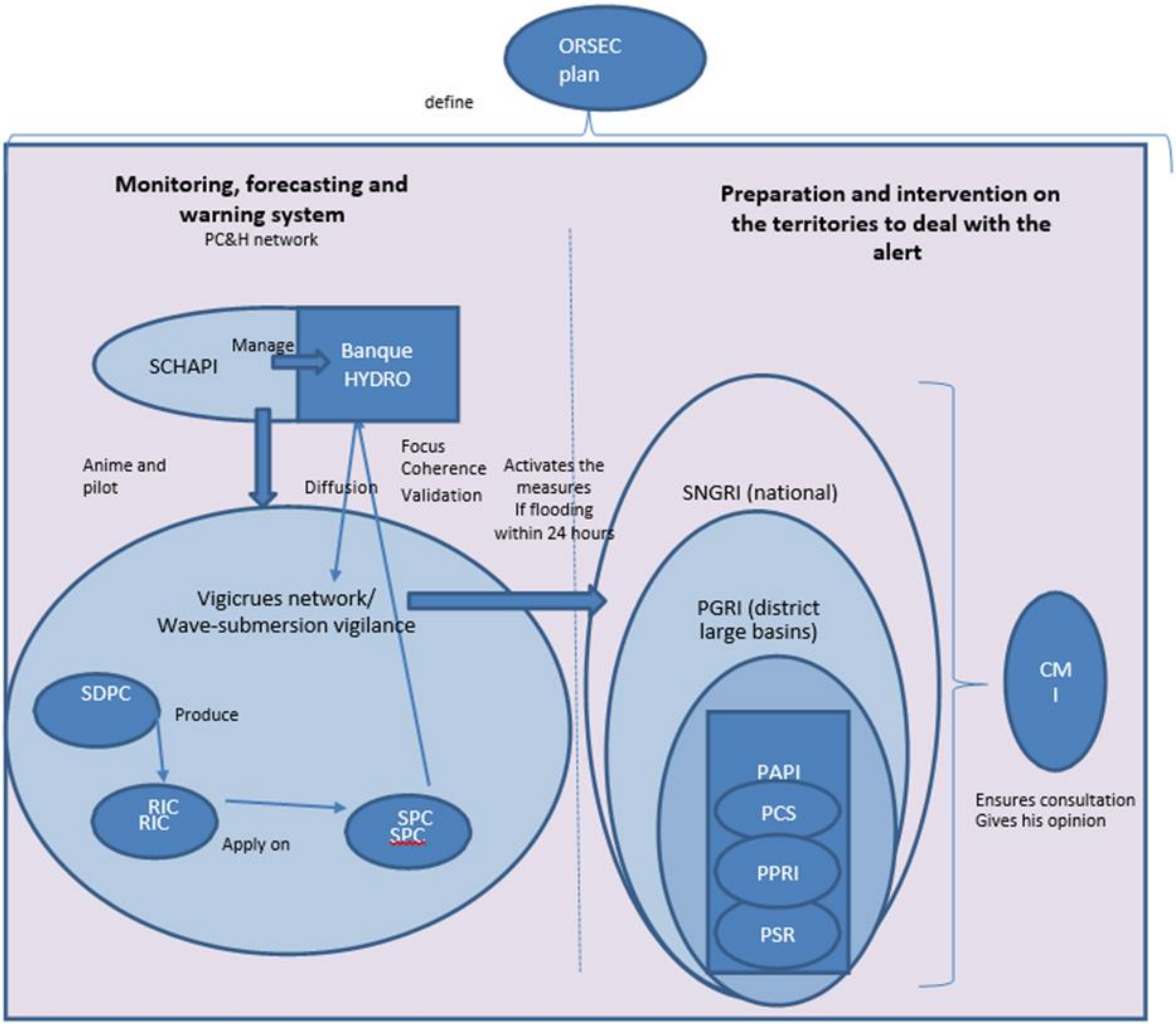


Figure 12- Functional diagram of the flood management organisation in France

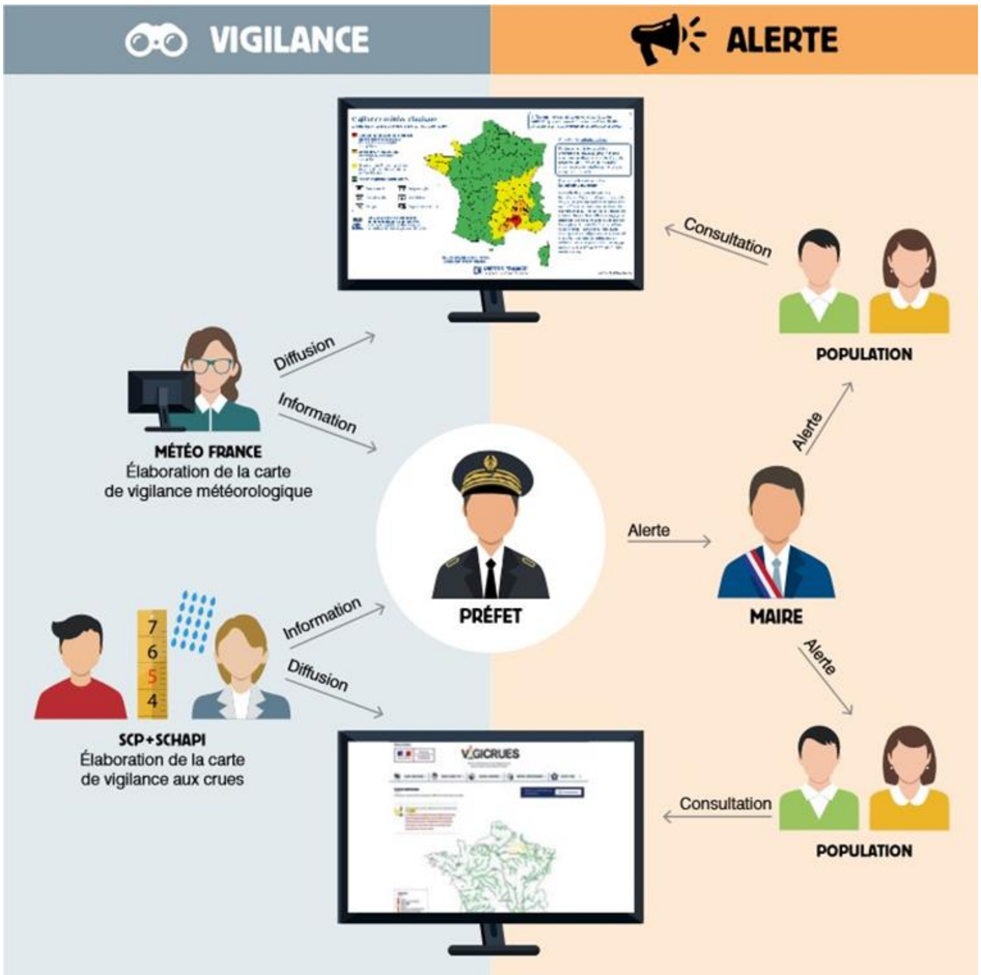


Figure 13- Actors of the warning: Implementation of the warning of the forecast to the populations, the central role of the prefect (source CPRI, 2017)

4.2. Focus on the French Vigicrues warning system

Vigicrues is based on a multi-criteria approach:

- The foreseeable water level (and/or flow) at the forecasting stations, with regard to the issues potentially at stake,
- The rate of rise of the flood, its duration, and the seasonal use of the river by users,
- The extent of the sectors affected by the flood and in particular its simultaneous impact on several issue areas located on the same vigilance section.

Flooding vigilance delivers three types of additional information:

- A flooding vigilance map, which can be consulted at national level or at the local level of each SPC's territory,
- Associated information bulletins, at the national level, to indicate the main trends, and at the level of the territory covered by each SPC to provide geographical and chronological details on current or future phenomena and

their foreseeable consequences,

- Access to real-time changes in water levels and river flows at hydrometric measurement points.

4.3. Focus on the French intense rain warning device - APIC – Vigicrues flash

https://apic.meteo.fr/

APIC (intense rainfall warning at the commune level) is a method of qualifying rainfall in terms of the return period at the commune level. The device makes it possible to warn by e-mail, SMS, or voice message that intense rainfall is observed in one or more communes. It is possible to subscribe to neighbouring communes, which makes it possible to anticipate the displacement of a major storm that has already started elsewhere.

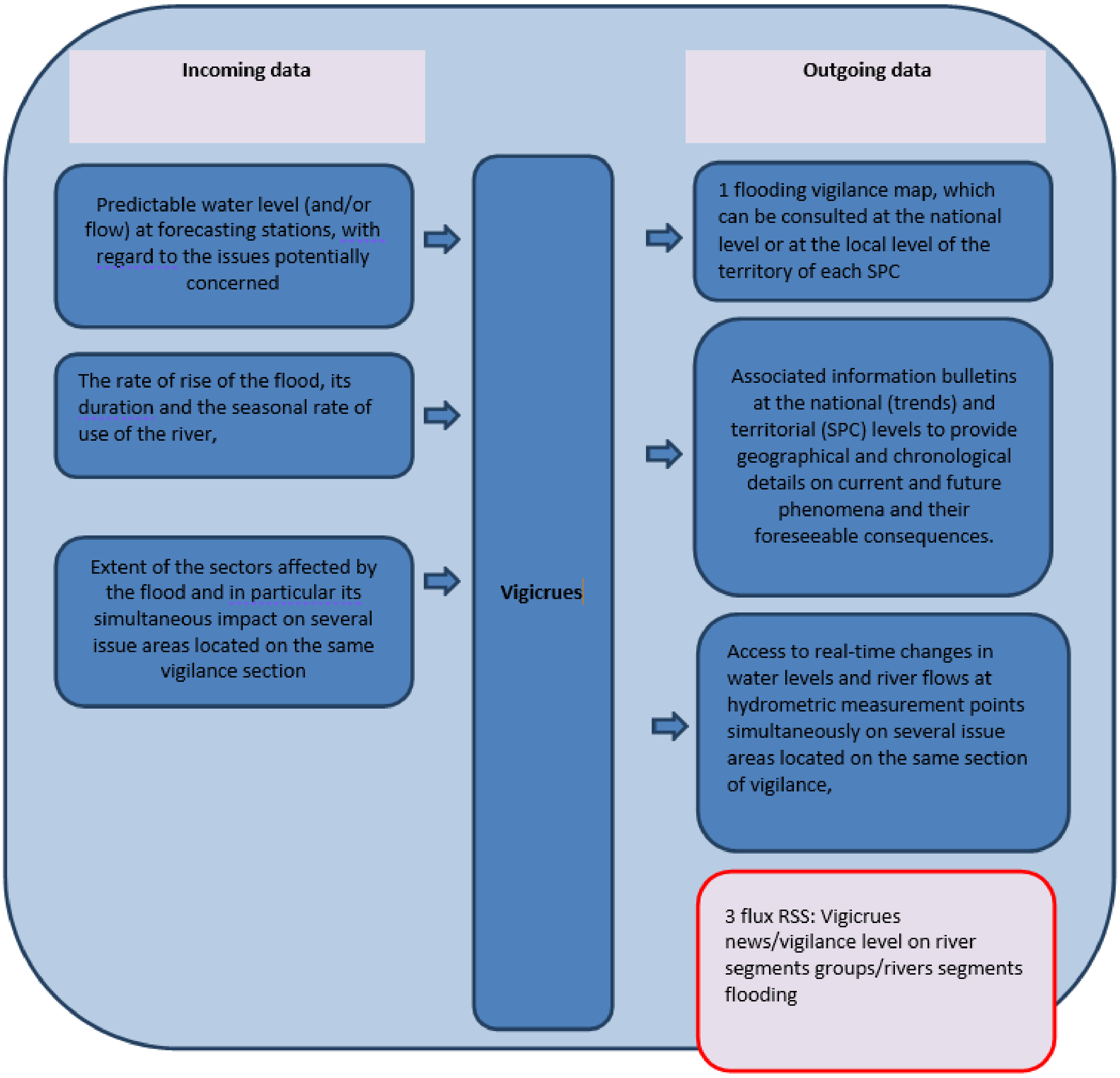


Figure 14- Information transiting through Vigicrues system

4.4. Vigilance Meteo France

Website: http://vigilance.meteofrance.com/

This service provides access to the national map and weather watch bulletins (national and local). The forecasting unit is the department. However, the bulletins specify the expected geographical extent. The classification divided into 4: from green (no particular vigilance) to red (absolute vigilance), passing through yellow and orange. As far as runoff is concerned, "thunderstorms" and "rain-flooding" are the phenomena that should be particularly monitored ("rain-flooding" means that a monitored river is on alert; it is possible that a ravine may overflow).

The strength of weather vigilance in France is to allow several hours in advance to initiate actions in anticipation of a possible event. Its weakness comes from its imprecision which does not allow the implementation of strong actions (evacuation etc...).

4.5. European cooperation on weather observations, forecasts and watches

4.5.1. EUMETNET, EUMETSAT et Meteoalarm

Cooperation in Europe in the field of weather observation and forecasting has a long history, dating back to the 1970s, within the framework of the European Meteorological Infrastructure (EMI) system.

For example, the European Meteorological Services Network (EUMETNET), which brings together the meteorological services of the Member States of the European Union, has developed, in partnership with certain services of other States (Norway, Iceland, Moldavia, etc.) a number of common tools, in particular the OPERA system consisting of 190 radars in 31 European countries. OPERA generates meteorological observations every 15 minutes on a European scale at a resolution of 2 km. This network of radars complements the meteorological satellite system managed by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

Finally, in the framework of the COPERNICUS16 program, the European Union has developed the European Flood Awareness System (EFAS), which provides national and regional meteorological and hydrological services and the European Union Emergency Response Coordination Centre (ERCC) with 10-day flood forecasts. The concept of meteorological vigilance developed in France has been judged by the World Meteorological Organization as a good practice to be followed. All European Union States have adopted this procedure. A European meteorological vigilance map "meteoalarm" (https://www.meteoalarm.eu/) is available to the general public via the website https://www.meteoalarm.eu/ on the basis of information transmitted by the national meteorological services. It is managed by the Austrian National Meteorological Service on behalf of EUMETNET members. In case of vigilance, a bulletin giving more detailed information is associated with the maps.

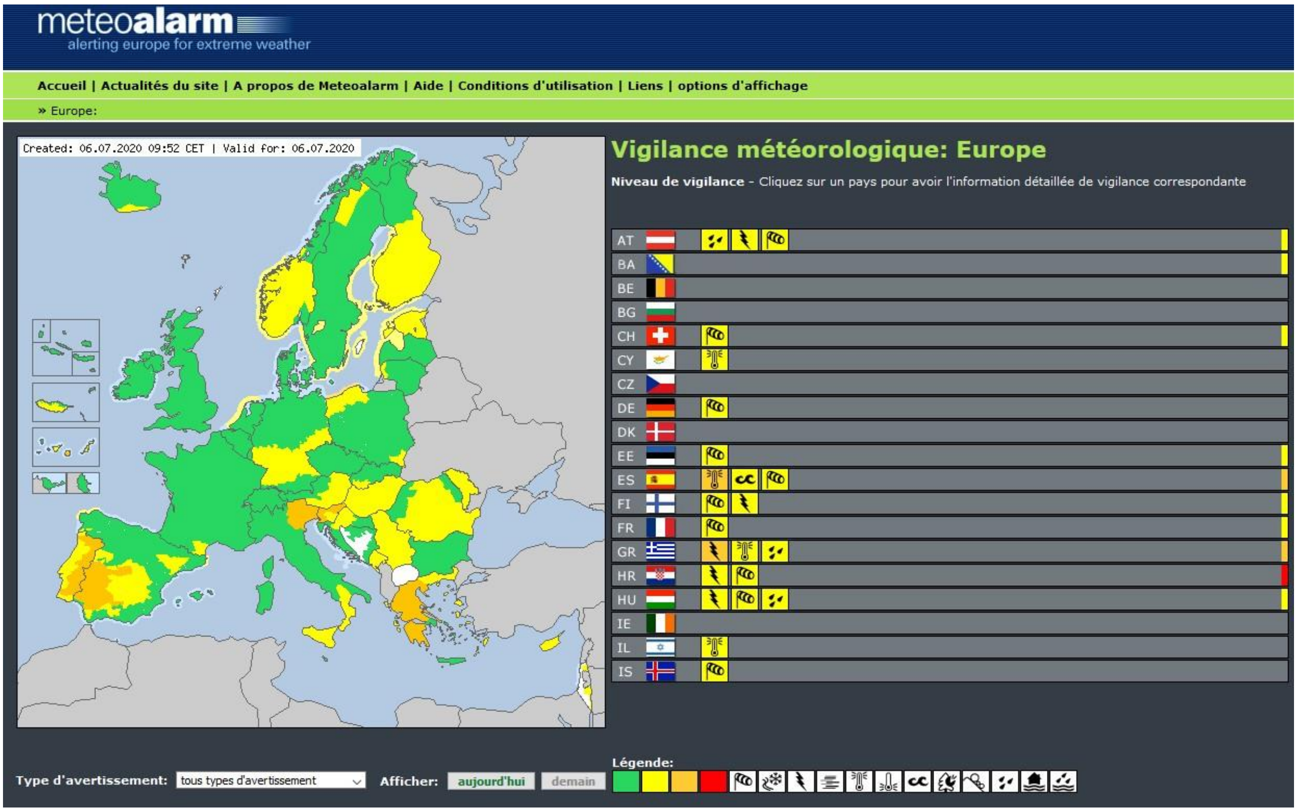


Figure 16 Extraction of the Meteolarm interface - alerting Europe for extreme weather - participating countries : Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom

4.5.2. COPERNICUS - Emergency Management Service – Mapping

The European Union also has an emergency/crisis monitoring service (floods, drought, fires, storms, epidemics, earthquakes etc.). The EMS service works on request, for a selection of crisis situations of natural or human origin.

These crisis situations are subject to a cartographic follow-up with a delay of a few hours or days in relation to the declaration of the phenomenon. In addition, the platform also carries out cartographic work on these crisis situations independently of emergencies with a view to providing data for the preparation, disaster risk reduction and recovery phases. Use of the services of this platform is subject to registration. Information is disseminated through GeoRSS feeds.

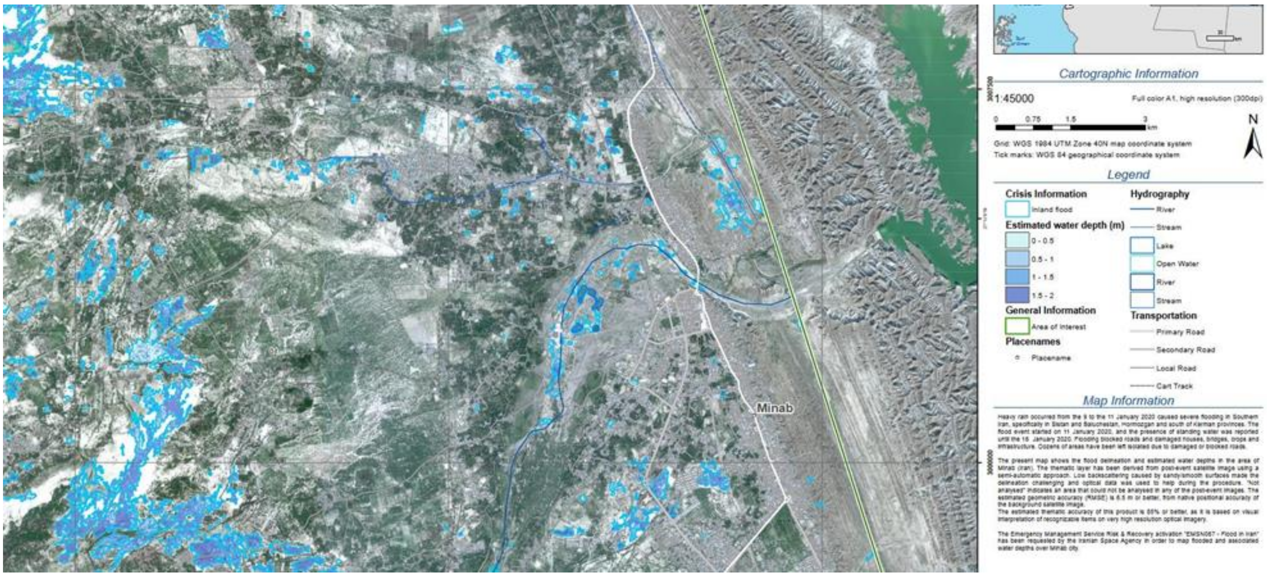


Figure 15- Mapping produced by the COPERNICUS-EMS device during floods that occurred in Iran in January 2020. The water depth of the flooded areas is carried there in 50cm increments. - source Copernicus-EMS)

4.5.3. COPERNICUS European Flood Awareness System (EFAS)

This scheme aims to support preparatory measures before major floods occur, particularly in large transnational river basins and throughout Europe in general. It provides information such as probabilistic forecasts, medium-term flood forecasts, flash flood indicators or impact predictions to the competent national and regional authorities. In addition, EFAS keeps the Emergency Response Coordination Centre (ERCC) informed about ongoing and future floods throughout Europe. EFAS has been fully operational since 2012 and is based on 4 centres run by different consortia:

- Computing Centre - European Centre for Medium-Range Forecasts (ECMWF) - It produces forecasts and hosts the information system platform
- Dissemination Centre – Swedish Meteorological and Hydrological Institute, Rijkswaterstaat and Slovak Hydro-Meteorological institute: Disseminating information to EFAS partners
- Hydrological Data Conservation Centre - Environment and Water Agency of the Regional Ministry for the Environment and Spatial Planning and Sociologic: They collect and conserve hydrological data.
- Meteorological Data Conservation Centre - KISTERS AGand Deutscher Wetterdienst - They collect and conserve meteorological data.

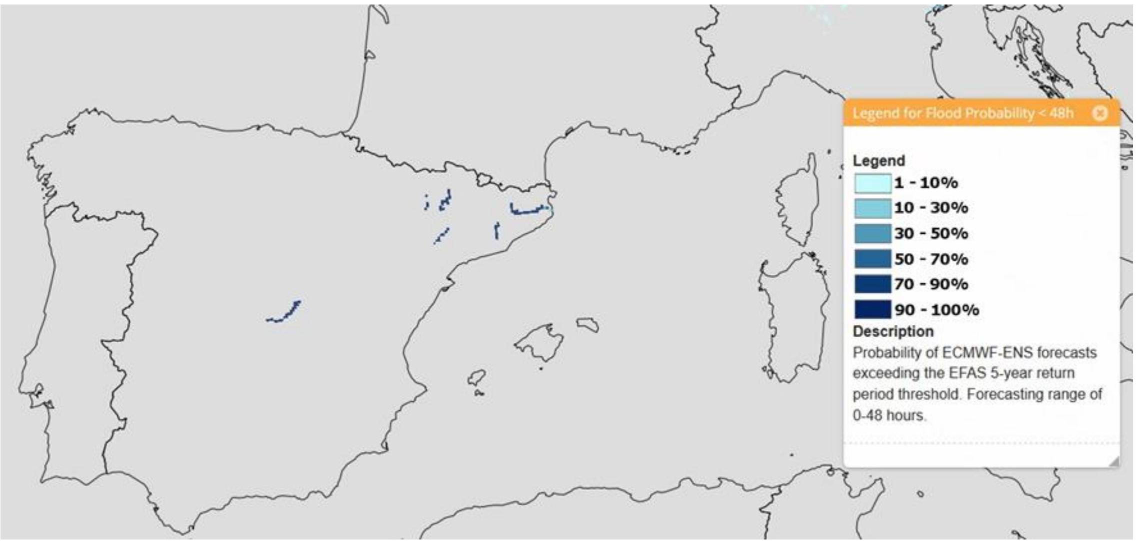


Figure 16- Extract from the EFAS mapping portal showing the probability of flooding within 48 hours in Europe on 9 June 2020

5. Multi-alert dissemination and risk monitoring portals

5.1. ORRNA Portal - Regional Observatory of Risks in Nouvelle-Aquitaine (France)

This is a multi-partner regional portal for the New Aquitaine region (France), focusing on natural, technological and health risks to increase knowledge sharing. This portal is supported by the State with the technical support of GIP ATGeRi.

It identifies and redirects to other sites of vigilance and alerts for different risks:

- Meteo France (weather)
- Vigicrues (floods)
- DFCI (forest fires)
- Atmo (air quality)
- BCSF RENASS(Seismic)
- Popluvia (water restriction)
- CATNAT also proposes
    - A space dedicated to climate change-related risks (mainly one-off publications - for example, there is a study on the impacts of climate change on the flooding of the Adour River)
    - a risk mapping observatory (regulations, exposure to hazards, claims experience)
    - a catalogue of available risk data and information
    - risk maps from the partners of the PIGMA platform and DREAL Aquitaine

- a link to risk observatory type websites

5.2.NAT DISasters portal – CATNAT

This platform presents itself as a specialized media in the field of natural risks via:

- Customized multi-format information monitoring tools (email, RSS feeds, XML)
    - Hazard warning and characterization service (hail, storm, frost, snow, lightning)
    - On-line services (weather certificates, mining, and technological natural hazard reports)

CATNAT offers an online geographic information system dedicated to natural risks in France and around the world. This system is called CATNAT Maps and is backed by a company called UBYRisk consultants.

The platform identifies several sources of alert and vigilance and appears to issue alert bulletins.

- Meteo France
- Meteo Group

6. Annexes

Les outils d'anticipation en fonction de la cinétique de l'inondation

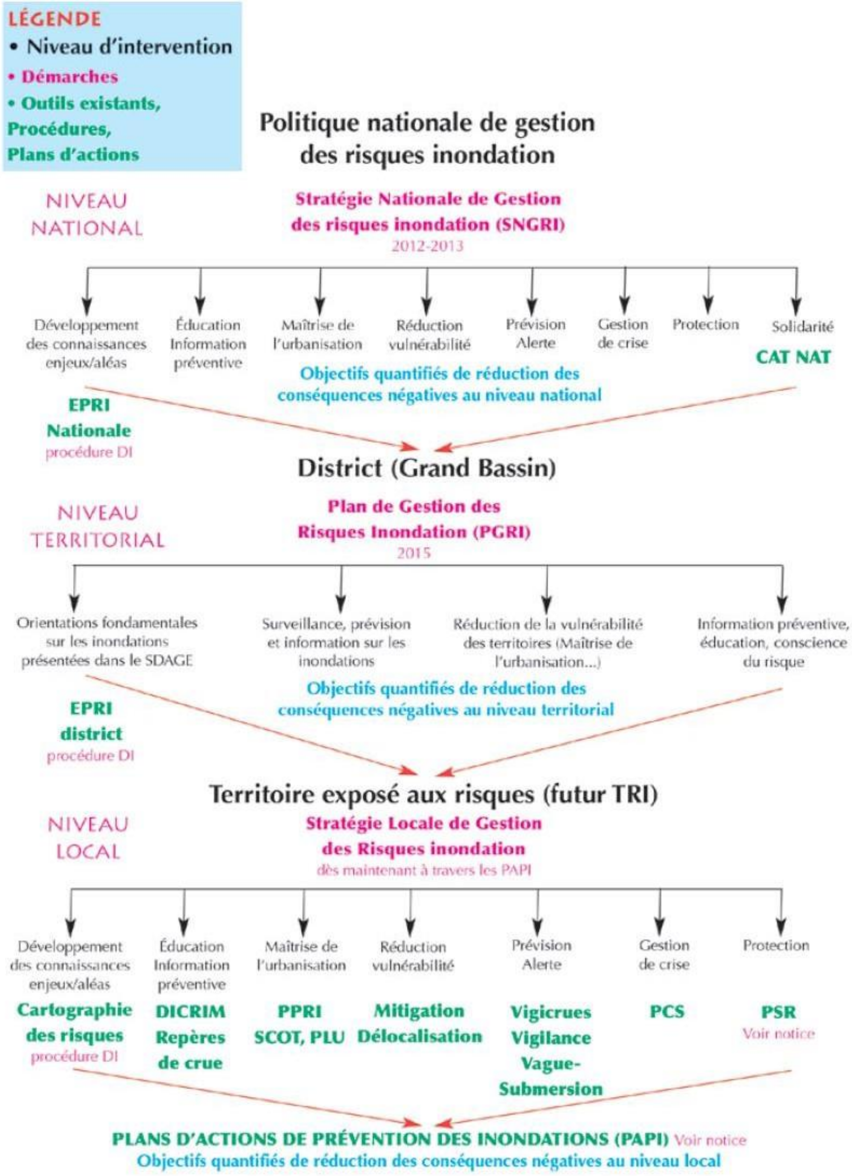
Caractéristiques	**Types de phénomène**	Objectif	Outils d'anticipation
Inondation à cinétique rapide Montée et descente des eaux : dizaines de minutes à quelques heures, Bassin versant de taille modeste avec un relief marqué, Episode de pluie d'intensité importante (plusieurs dizaines de mm/heure).	Crue rapide, torrentielle, éclaire, ruissellement	**Préserver les vies humaines**	– Vigicrues pour les cours d'eau à réaction rapide surveillés Vigilance météo pour les phénomènes orages ou pluie-inondation – Dispositif locaux de surveillance et d'alerte – Service APIC (Avertissement Pluies Intenses à l'échelle des Communes)
	Submersion marine		– Vigilance météo pour le phénomène vagues-submersion
	Rupture d'un ouvrage hydraulique (digues, barrages), d'une poche d'eau dans un glacier[1]		– Dispositif de surveillance des ouvrages
Inondation à cinétique lente Montée des eaux : de plusieurs heures à plusieurs jours, Durée de submersion : plusieurs jours à plusieurs semaines, Bassin versant de taille importante.	Plaine (ou fluviale)	**Minimiser l'impact socio-économique**	– Vigicrues pour les cours d'eau surveillés
	Remontée de nappe		Suivi du remplissage des nappes par le BRGM (bureau de recherches géologiques et minières)

Annexe n°1.Excerpt from the ORSEC S3 Guide – specific flooding provision- page 23

Tableau de définition des niveaux de vigilance et de caractérisation des conséquences potentielles

Niveau	Définition	Caractérisation - Conséquences potentielles sur le terrain
Vert	Pas de vigilance particulière requise.	Situation normale.
Jaune	Risque de crue génératrice de débordements et de dommages localisés ou de montée rapide et dangereuse des eaux, nécessitant une vigilance particulière notamment dans le cas d'activités exposées et/ou saisonnières.	Perturbation des activités liées au cours d'eau (pêche, canoë...) Premiers débordements dans les vallées. Débordements localisés, coupures ponctuelles de route secondaires, maisons isolées touchées, caves inondées. Activité agricole perturbée. Évacuations ponctuelles.
Orange	Risque de crue génératrice de débordements importants susceptibles d'avoir un impact significatif sur la vie collective et la sécurité des biens et des personnes.	Débordements généralisés. Vie humaines menacées. Quartiers inondés : nombreuses évacuations. Paralysie <u>d'une partie de</u> la vie sociale, agricole et économique : • Itinéraires structurants coupés • Hôpitaux et services publics vitaux perturbés voir inopérant. • Réseaux perturbés (électricité, transports, eau potable, assainissements, télécommunications...).
Rouge	Risque de crue majeurs. Menace directe et généralisée sur la sécurité des personnes et des biens.	Crue rare et catastrophique. Menace imminente et/ou généralisée sur les populations : nombreuses vies humaines menacées. Violence de la crue et/ou débordements généralisés. Évacuations généralisés et concomitantes (plusieurs enjeux importants impactés en même temps sur le tronçon). Paralysie <u>à grande échelle</u> du tissu urbain, agricole et industriel : • Bâti détruit • Itinéraires structurants coupés • Hôpitaux et services publics vitaux perturbés voire inopérants. • Réseaux perturbés voire inopérants (électricité, transports, eau potable, assainissements, Telecoms...).

Annexe n°2. Excerpt from the ORSEC S3 Guide – specific flooding provision - page 106



Schématisation de la politique générale de gestion des inondations
Source : Infographie extraite du PSR.

Annexe n°3.Except from the ORSEC S3 Guide – specific flooding provision- page 19

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